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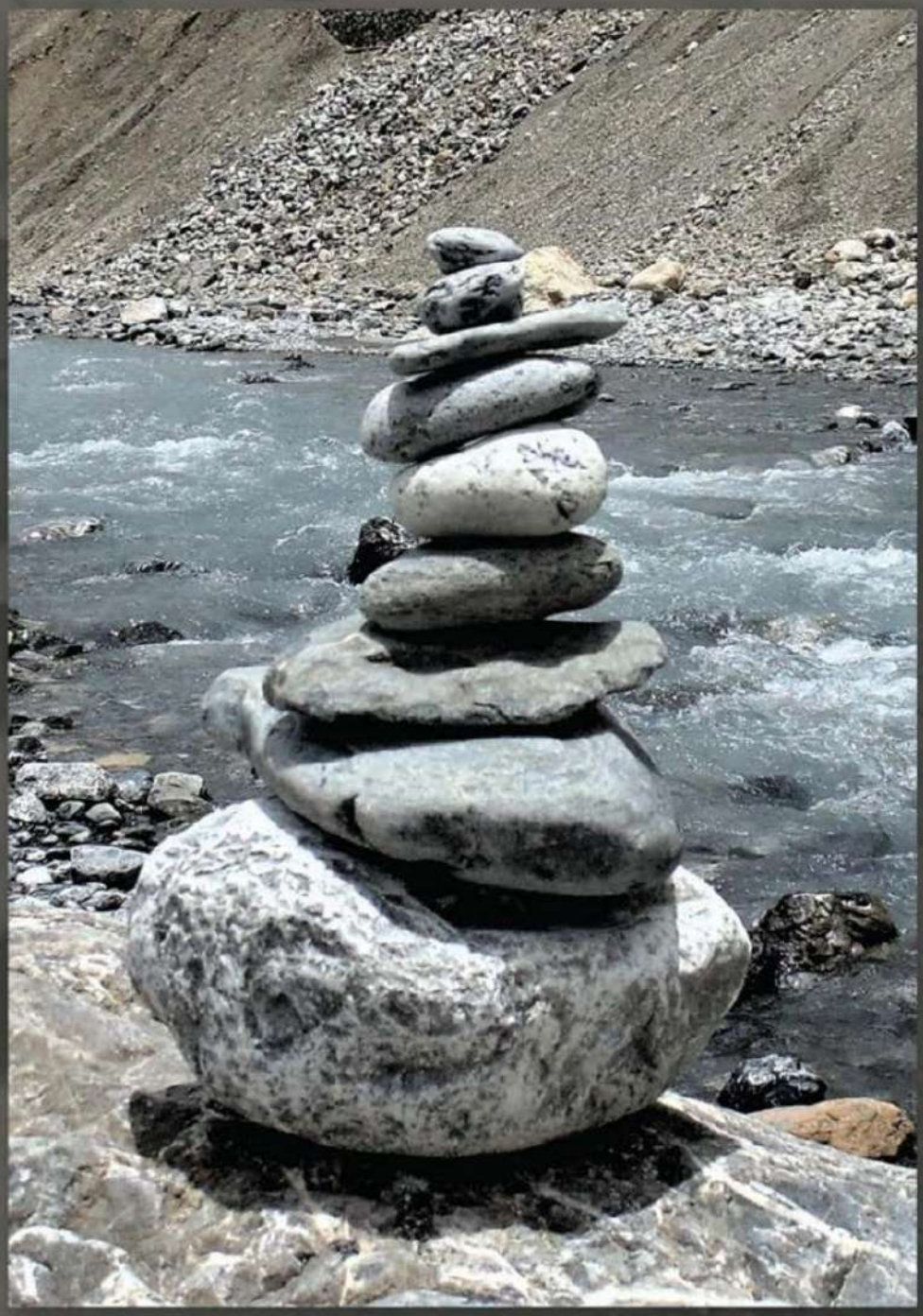

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Theory and Applications

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FOREWORD

Current trends in computer science and engineering are driven mostly by data science, machine learning, the Internet of Things, cryptography, and other practical uses. Therefore, a complete book on advanced data structures that will work as a backbone in explaining these modern subjects is much sought after.

However, writing such a book is challenging because it must meet two goals: allowing students to understand the fundamentals of advanced data structures and enabling them to apply in-depth knowledge in their chosen areas. This book is one of the first efforts in this direction and it will play an indispensable role for students in computer science and related disciplines to enhance their expertise in advanced data structures and applications.

The authors are members of the faculty at Jaypee University of Information Technology. They have more than ten years of teaching experience and have published a wide range of peer-reviewed articles in many areas of information technology. They possess unique skills in analyzing and explaining difficult algorithms and data structures simply and elegantly. Their expertise in all areas of computer science equips them to be suitable authors of a comprehensive book about data structures.

The book chapters are well organized. Part I covers theoretical advancements in basic data structures. Part II discusses evolving paradigms of data structures, and Part III details recent applications. All the material is organized logically and both students and researchers can benefit from reading this book and applying its concepts.

I hope this book will serve as a useful tool for all inquisitive students who plan to apply recent developments in data structures to their work.



Dr. Amit Chattopadhyay
International Institute of Information Technology
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It has been almost two years since we started writing a book about advanced data structures. This book was kept on track and seen to completion with the support and encouragement of numerous family members, friends, colleagues, teachers, and students. It is a pleasure to express our thanks to all those who contributed in so many ways to our publication success.

We are very thankful to Dr. Amit Chattopadhyay of the International Institute of Information Technology in Bangalore for reviewing our work and writing a favorable foreword message. Our heartfelt thanks also extend to our friends and colleagues for their help and encouragement.

We express our sincere thanks to the students and colleagues of Jaypee University of Information Technology, Solan, Himachal. We also appreciate the excellent work of the editorial and production teams of CRC Press and Taylor & Francis. Thanks are also due to all the reviewers who evaluated this book and provided suggestions and advice.

Readers' constructive feedback and suggestions for improvement may be emailed to suman.saha@juit.ac.in or shailendra.shukla@juit.ac.in.

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PREFACE

Advanced data structures are usually covered in core courses included in most graduate programs in computer science, engineering, and allied disciplines, during the first year or first semester of the curriculum. The objective of the course is to provide students with a much-needed foundation for advancing their technical skills and sharpening their problem-solving abilities in their respective disciplines.

Although many technical universities have offered advanced data structure courses for decades, major technology advances triggered a recent paradigm shift that focuses on huge databases and Internet-based technologies. Most technical universities have redefined their course contents to meet current needs and rely heavily on research papers because of the lack of comprehensive texts on advanced data structures.

To the best of our knowledge, existing textbooks on advanced data structures provide only partial coverage of the subject. This book evolved from materials the authors developed over several years while teaching advanced data structures at Jaypee University of Information Technology. The course was designed for advanced graduate students, although it has become accessible to advanced undergraduates and beginner researchers in the areas of computer science and bio-informatics.

This book emphasizes recent evolutions of data structures to fit new paradigms of computation and applications to various domains of computer science. We included illustrative problems, review questions, and programming projects to enable students to comprehend, implement, and appreciate advanced data structures.

The book is divided into three parts. Part I details basic data structure advancements such as cuckoo hashing, skiplists, tango trees, Fibonacci heaps, and index files. As an introduction, the first chapter discusses the need for advanced data structures and some basic concepts pertaining to amortized analysis of algorithms.

Part II covers data structures of evolving data domains and dedicates chapters to spatial and temporal data structures, external memory data structures, and distributed and streaming data structures.

Part III elucidates the applications of data structures to various areas of computer science—for example, cryptography, the Internet, networking, the Internet of Things, and images and graphics.

The concepts and techniques behind the data structures and their applications are explained. Every chapter includes a variety of illustrative problems

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pertaining to technical content, a summary of the concepts, and review questions to reinforce comprehension of the material.

This book may be used as an introductory or advanced-level text for undergraduates, graduate students, and participants in research programs that offer advanced data structures as a core or elective course. While the book is primarily intended for classroom use, it could also serve as a starting point for researchers working in specialized computer science areas.

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Dr. Suman Saha spent the last 14 years performing research in the areas of data and information science, specifically working on information retrieval, web mining, decision theory, social network analysis, and big data technologies. He started his research in the field of web mining by working as a senior research scientist at the Center for Soft Computing Research of the Indian Statistical Institute in Kolkata for almost five years. After that, he joined the Department of Computer Science at Jaypee University of Information Technology, Himachal, India as an assistant professor. For the past eight years, he has continued his research, taught classes, and handled other departmental responsibilities.

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Chapter 1
Advances in Carbon Capture and Utilization



Deepak Pant, Ashok Kumar Nadda, Kamal Kant Pant, and Avinash Kumar Agarwal

1.1 Introduction

A combination of enzyme and material which jointly capture and convert the CO_2 into methanol plausibly energizes the CO_2 utilization (Sharma et al. 2020a). The CO_2 to methanol conversion utilizes carbon better than the conventional syngas and the reaction yields fewer by-products, and the methanol produced can further be used as a clean-burning fuel, in pharmaceuticals, as a general solvent, etc. The various aspects of circular economy with present scenario of environment crisis will also be considered for large-scale sustainable biorefinery of CO_2. In this book, thirteen chapters have been included which represent the natural, conventional, and artificial systems for carbon management. The contents of the book have been divided into four sections.

The natural systems of carbon sequestration have been discussed in detail in the first section of this book. Since ancient times, fossil fuels are used in huge amount to meet the energy demands across the world. In India, the emanations from fossils fuels have developed a lot, but alternative sources are not enough to fulfil the demand.

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The emissions from fossil fuels are considered as one of the major factors leading to climate change (Kumar et al. 2019). To limit the pace of emissions of these harmful gases, various methods and approaches like reduction of energy consumption, switching to alternative fuels, have been reported. This section emphasized on the carbon capture and storage (CCS) using geological and soil-based methods. The recent advancement in CCS technology is progressively concerned with ideal design and functioning of the CCS infrastructure collectively maintaining every strategy of CCS system throughout a certain range. The attainable quality of CCS technology would reduce the reliance on sustainable power sources. CCS system also implies transfer of atmospheric CO_2 into other long-lived global pools including pedologic, oceanic, geological and biotic strata to reduce the net rate of atmospheric CO_2 increase. Since industrialization in the nineteenth century, the CO_2 concentration in the atmosphere has increased and an accord is there where a visible impact on world's climate due to mankind is forming. The CO_2 emissions from man-made sources have also been increasing in the same time frames which are known to produce greenhouse effect. CO_2 holds 82% of all the greenhouse gases present in the atmosphere. There are various techniques where CO_2 is injected into geological strata, oil wells, deep ocean, old coal mines, and saline aquifers. Furthermore, the soil is the biggest terrestrial sink of carbon (C) and store nearly three times of the atmospheric carbon pool and 4.5 times of the biotic carbon pool, and thus, maintains the global carbon cycle. Therefore, any change in the atmospheric carbon could be the result in modification of soil carbon. However, the carbon stabilization as well as subsequent sequestration in soil is greatly affected by different climatic and soil factors, such as soil type, nature of organics presents in soil, management practices, diversity of soil microorganism, rainfall, and temperature, etc. The sequestration of carbon in soil is very crucial to mitigate the effect of climate change by reducing the greenhouse gases emission and also to improve the soil quality for better crop productivity in sustainable manner (Roudi et al. 2020).

Among different developed methods, biomineralization and bioinspired storage systems are not only cost-effective but also efficient in controlling global warming and CO_2 emission. A microbial-enzymatic CCSU system can act as a green source of energy in form of electricity along with the utilization of wastewater by bacterial and algal biomass (Sharma and Kumar 2021). Instead of the whole-cell capturing systems, enzyme-based CO_2 capturing systems have also been proved efficient for various industrial applications.

Researchers are been joining their hands for the improvisation of several carbon capture materials. In the second section, superior performance of organic blended physical–chemical solvents is drawing much attention in recent times. Even some blends attained the optimal performances, advancements in the materials have not come to an end. Various types of nano-materials, nano-textured surface, and microwave regeneration techniques are being introduced to bring down the energy consumption of the setup. Amine technology for the capture of carbon dioxide has certain drawbacks including cost, energy consumption and by-products formation. Other methods such as membrane, cryogenic, biologicals are also of interest but not technically or economically feasible at large or industrial scales. In view of this,

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ionic liquids (ILs) are the one of the alternatives for the conventional and other technologies.

Some other methods of simultaneous wastewater treatment and carbon capture have also been explored in the third section of this book. Conventional wastewater treatment systems are not environmentally friendly as they significantly contribute to the CO_2 emission, directly as well as indirectly. It has been realized that there is an urgent need to not only reduce the emission of CO_2 but also capture it to counter the negative impacts of climate change. Microbial fuel cell (MFC) has the potential of carbon capture while treating the wastewater with an additional advantage of direct electricity production (Verma et al. 2020). On the other hand, algal technology has the potential to capture and utilize CO_2 for the production of algal oil, which can be utilized for bioenergy production (Kamyab et al. 2019a).

Furthermore, the climate smart agriculture is one of the key tools for carbon capture which ensures the efficiency in income generation, productivity and food security; adaptation to climate change and resilience. Although sequestration of carbon and depletion in emissions of greenhouse gases can happen with various smart agricultural practices, perhaps there are numerous challenges while making these pillars of climate smart agriculture into reality. The change in soil carbon pool can directly influence the climatic conditions of any area due to its capability to store carbon twice as much of the atmosphere. The soil is one of the principle components for capturing terrestrial carbon, so the spatial distribution map developed along with the major nutrients from the study will provide an input for agricultural land evaluation for selecting appropriate land use plans for healthy carbon budgeting in the area (Kamyab et al. 2019b).

The biological carbon cycles are not sufficient enough to switch the billions of metric tons of CO_2 emission while the biochar (a recalcitrant organic charcoal material produced from pyrolysis of biomass under limited oxygen conditions) emerging as a considerable tool for long-term sink of carbon. Biochar has many other advantages of increasing the water absorption and water holding capacity of the soil which aids to increase the fertility. The charcoal produced by incomplete burning due to the limitation of oxygen in this system captures much more natural carbon from the biomaterial. Along with the ability to lock up additional carbon, biochar can also store CO_2 in sink for thousands of years, displaces the fossil fuel use and also reduces the release of nitrous oxide (N_2O) and methane, thereby reduces the greenhouse gas emission from the atmosphere and helps in mitigating the impacts of climate change. The Western Himalayan regions are characterized by marked climatic conditions, variations in topography, soil-texture, and land-use practices. In the present scenario, the fragile landscapes of the Himalayan region are facing an ongoing concern about current and potential climate change impacts. Carbon stocks in vegetation types of western Himalayas have immense ecological significance, vital for the regional and global carbon reserves. Among the vegetation types, forests, pasture, agricultural fields, and orchards dominate in this region. The increasing human interventions, land management practices and natural ecosystem processes are the potential sources of GHGs emission in the atmosphere. Deforestation and other changes in land use cause significant exchanges of CO_2 between the land and the atmosphere. The carbon

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stock storage and climate change mitigation cannot be easily achieved in the high-altitude Himalayan regions, because of the type of land use available, cold climate, and the land holding capacity of the people (Sharma et al. 2020b). The sustainable management regimes for these land uses can increase their potential to act as a sink for long-term carbon storage along with providing livelihood opportunities and vulnerability of natural resources to climate change can be reduced through adoption of these management practices. Anthropogenic CO_2 discharges are viewed as the significant patron of ozone-depleting substance outflows around the world. Conversion of CO_2 into fuels or energy-rich compounds is very beneficial as it is cheaper to produce, less inflammable, can be produced from biomass and is discussed in the last section. Also, it is advantageous to many automobiles, power plants, and other industries like pharmaceuticals, fine chemical, and food production units. Methanol is gaining popularity as an alternative to petroleum-based fuels and is beneficial for a safer and cleaner environment. The enzymatic method for CO_2 conversion has attracted much attention due to its improved selectivity and yields under mild reaction conditions. CO_2 can be reduced through different methods like physical, chemical, electrochemical, photochemical and biological or enzymatic methods. Among these potential approaches, biological or enzymatic methods offer viable, effective, green and potent alternative of CO_2 conversion into value-added products because of high stereo specificity and region/chemo-selectivity of enzyme.

The development in global carbon management strategies becomes the mandate of all educational and research bodies. In fact, the public awareness and inclusion of climate change topics at elementary education is also equally important. We should focus on the techniques and methods to minimize the emission of excessive greenhouse gases. Alternatively, more green and sustainable methods should be developed to generate the energy for transport and industrial applications. The protection and conservation of natural ecosystem forest, lakes, rivers, wild fauna and flora should be increased to elevate the biotic carbon level and minimize the atmospheric release. Thus, in this monograph various developmental strategies for carbon management in our ecosystem have been highlighted in respective chapters. Specific topics covered in the monograph include:

- Carbon capture: Innovation for a green environment
- Geological carbon capture and storage as a climate-change mitigation technology
- Soil carbon sequestration for soil quality improvement and climate change mitigation
- Post-combustion of carbon capture technologies: Advancements in absorbents and nano-particles
- Carbon biocapturing system for environment conservation
- Simultaneous wastewater treatment and carbon capture for energy production
- Carbon dioxide capture by ionic liquids
- The climate smart agriculture for carbon capture and carbon sequestration: The challenges, risks and opportunities
- Quantification of the soil organic carbon and major nutrients using geostatistical approach for Lahaul valley, cold arid region of Trans-Himalaya

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- Biochar: A carbon negative technology for combating climate change
- Carbon sequestration potential of different land use sectors of Western Himalaya
- Progresses in bioenergy generation from CO_2: Mitigating the climate change
- Recent advances in enzymatic conversion of carbon dioxide into value-added product.

The topics are organized in four different sections: (i) carbon capture as natural phenomenon; (ii) advance carbon management techniques; (iii) miscellaneous techniques, and; (iv) value addition techniques.

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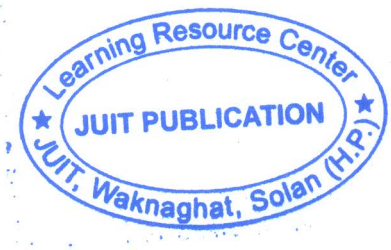

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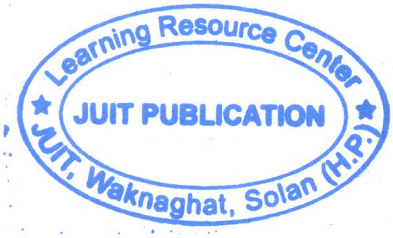

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Ashok Kumar Gupta · Sanjay Kumar Shukla · Hazi Azamathulla *Editors*

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Edited by
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Preface

Assistive technology (AT) in healthcare and rehabilitation has had consistent applications in the treatment of and intervention in several conditions. AT is nothing but a type of product, system or equipment used to improve the functional capabilities of different-aged people, from children to older people. It may improve the quality of life and ease dependence on family members or caregivers for the person with disabilities. Nowadays, many types of AT are commercially available on the market, such as hearing aids, wheelchairs, augmented communication, and so on. Internet of Things (IoT)-enabled devices have made remote monitoring possible in the healthcare sector by unleashing the potential to keep patients safe and healthy and enabling medical professionals to provide superlative care.

Adolescent idiopathic scoliosis, commonly known as AIS, is a major severe orthopedic anomaly observed in a significant part of the human population. The disease arises during adolescence and may become fatal if untreated. Detection of the region of interest (RoI) based on histogram analysis, localization of vertebrae segments and edges with the help of advanced image processing methods and deep-learning algorithms has the potential for better treatment strategies. The IoT has revealed a paradigm shift in health, introducing benefits like availability, accessibility and cost-effective delivery of individualized care. Enabling such a shift requires that hardware and software work together to enable widespread technical innovations. Electronic health records (EHRs) are becoming popular among radiologists, clinicians, pharmacists, healthcare providers and researchers for effective treatment and diagnosis, as they contain confidential and critical information about patients.

Reversible logic (RL) has received immense consideration in recent years due to its ability to lower power dissipation. There are six different types of reversible gates, based on simulation and evaluation of different parameters using Verilog and SPICE; the Toffoli gate shows remarkable results. Using a Toffoli gate, different combinational and sequential circuits are designed and simulated using both reversible and irreversible logic. It has been observed that results using reversible logic are exceptional.

COVID-19 has bought about disruptive and transformative digital automation in the health sector worldwide with multifold investments in upgrades. The situation has led to many developing cost-effective digital health technologies by using existing smartphones and integrating smart watches. Epilepsy disease management systems can also be made affordable. Among these, the technique known as segmented microaneurysm using the measures of entropy, skewness and kurtosis gives high performance regardless of image contrast. Augmented continuous particle swarm optimization successfully detects microaneurysms and helps to diagnose diabetic retinopathy in the early stages in an efficient way. In the same way, another technique known as computational fluid dynamics (CFD) has been an effective tool for obtaining insight into the circulatory system's physical

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functioning. Similarly, gait analysis has become a significant way to gauge movement debilities and provide therapeutic interventions in the early phases of neurological diseases.

Biosensors are analytical devices used for identifying alterations in biological processes or biological elements such as tissues, cells, acids, enzymes or microorganisms, converting them to electrical signals. A biosensor is a combination of transducer and biological sensing elements used for modifying data into electric signals. Autism spectrum disorder (ASD) is a neurodevelopmental disability that impairs the social interaction and communication skills of an individual and can include repetitive behavior. The behavioral features of ASD emerge during the later part of the first and second years of life. The early detection of abnormalities in an EEG may be used as a biomarker for developmental cognitive disorders and is emphasized in this book.

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- **University Question Papers** **1**

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Fundamentals and Applications

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Chemo-Biological Systems for CO_2 Utilization



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Ashok Kumar and Swati Sharma

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Preface

This book will describe the various advanced tools and techniques developed in the past decade for carbon dioxide capture and its utilization. In the ecosystem, CO_2 is primarily absorbed by plants, oceans, algae, and soil contents. But in the 21st century, increased industrialization and urbanization result in a tremendous production of CO_2, which is considered as one of the challenging factors of global warming and a dreadful pollutant that affects the human health. Researchers attempted to develop various techniques using chemical, microbiological, enzymatic, and biomolecular systems in order to absorb the increased concentration of CO_2 in the environment and produce some value-added compounds using CO_2. In this context, various biopolymers, nanomaterials, bioinspired surfaces, polysaccharides, organic solvents, chemicals, enzymes, and metal–organic frameworks (MOFs) were developed and utilized for the sequestration of CO_2 into various carbonates. The biomolecular system has its own importance in the conversion of the atmospheric CO_2 into carbonates. Carbonic anhydrase is one of the fastest enzymes and most studied for the conversion of CO_2. Microflora on the Earth present various classes of methanogens, thermophilic bacteria, phosphate-solubilizing bacteria, and acetogens, which play important roles in CO_2 absorption. Amine-based chemical compounds, porphyrins, ionic liquids, eutectic solvents, ceramics, biochar, and organic solvents have also great potential to convert CO_2 into other fine chemicals or useful products. The major advantages such as stability and efficiency of the systems will be discussed in the various sections of this book.

Nowadays, climate change is considered as one of the major issues, and the massive generation of greenhouse gases from automobiles, industries, and carbonaceous fuels have tremendously promoted the alteration in temperature from its normal cycle. This book will emphasize on the energy generation in the form of biofuels, bioelectricity, or biogas from CO_2 using chemicals; nanomaterials; and microbial, enzymatic, and chemo-enzymatic-integrated systems. This book has been divided into four sections. The chapters 1–4 described the importance and utilization of CO_2 in the living system, and various fundamental methods, policies, and techniques involved in CO_2 conversion. The chapters 5–8 focused on the adsorption and fixation of CO_2 using various ionic liquids, organic solvents, amine-based solutions, electrocatalytic reduction, nanomaterials, porphyrins, ceramics, MOFs, and activated carbons (in particular, biological materials). This section draws the insight of various chemical engineers and researchers working across the globe for CO_2 conversion. The chapters 9 and 10 give the emphasis on the production of value-added products using CO_2 and will mainly focus on the production of biomethanol, industrial carbonates, lime, liquid and gaseous fuels, industrially useful precursors, etc. The chapters 11–13 discuss the potential of the microbial system, enzymes involved in the sequestration of CO_2, and CO_2 utilization. The chemo-enzymatic system

developed for the utilization of CO_2 will be discussed in the respective chapters of this book. This reliable information from various active researchers and groups will be helpful to find out the alternative methods for clean energy and mitigating the climate change. This book will help the researchers and industrialists to better understand the correlation between microbial, biological, and chemical products and their roles in the conversion of CO_2 into useable energy and related products.

Editors



Dr. Ashok Kumar is working as an assistant professor in the Department of Biotechnology and Bioinformatics, Jaypee University of Information Technology, Waknaghat, India. He holds an extensive 'research and reaching' experience of more than 10 years in the field of microbial biotechnology, with research expertise focusing on various issues pertaining to 'nanobiocatalysis, biomass, and bioenergy', and 'climate change'. He holds International work experiences in South Korea, India, Malaysia, and Republic of China. He worked as a post-doctoral fellow in the State Key Laboratory of Agricultural Microbiology, Huazhong Agricultural University, Wuhan, China. He also worked as a brain pool researcher at Konkuk University, Seoul, South Korea. Dr. Ashok has a keen interest in microbial enzymes, biocatalysis, CO_2 conversion, climate change issues, nanobiotechnology, waste management, biomass degradation, biofuel synthesis, and bioremediation. His work has been published in various internationally reputed journals, namely *Chemical Engineering Journal*, *Bioresource Technology*, *Scientific Reports*, *Energy*, *International Journal of Biological Macromolecules*, *Science of Total Environment*, and *Journal of Cleaner Production*. He has published 60 research articles, 25 book chapters, and 5 books. He is also a member of the editorial board and reviewer committee of the various journal of international repute.



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Measurement of Human Bioelectricity and Pranic Energy of Different Organs: A Sensor and CPS-Based Approach



Rohit Rastogi, Mamta Saxena, Devendra Kumar Chaturvedi, Mayank Gupta, Neha Gupta, Umang Agrawal, Yashi Srivastava, and Vansh Gau

Abstract The Kirlian photography is one of the most spectacular ways to shoot different subjects. It is a technique based on electrical coronal discharge. It may be quite a mystery for the beginners in the art of photography. It shows the auras of different subjects. In this technique, the photographic plate made of metal is charged with a high-voltage source. It may seem hard to master this, but let me tell you it is still easier to shoot objects using Kirlian photography. The process is also quite simple. All an individual needs is to ready all equipment. It is recommended to use transparent electrodes instead of the discharge plate. It is a very interesting method to capture the coronal discharge of certain subjects. It will surprise you every time! The present manuscript is an effort by the researcher team to discuss the human bioelectricity and measure the different biophysical factors and reasons of different ill symptoms. We have tried to investigate the energy balances, head, and immune and musculoskeletal systems of subjects under study.

Keywords Kirlian photography · Bioelectricity · Covid-19 · Happiness · Radiation · Head · Immune · Musculoskeletal systems

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1 Introduction

1.1 Human Bioelectricity

The electric current continuously flows in the human body (termed as bioelectricity) that plays a vital role in physiological conditions. The human body consists of millions of nerves which transfer information and are responsible for the whole functioning of the body through electrical impulse which is actually bioelectric signals. So we can term bioelectricity as the electric current which is present inside the living body or produced within it. The number of biological processes occurs every second in the human body which leads to formation of bioelectric currents. Bioelectric currents and potential of human cells and tissues are recorded by machines like ECG, EEG, etc., which can be used in making medicines for various organs of human. Consciousness simply means awareness of both internal and external existence of self. Till now, despite of analyses, explanation, and researches, consciousness is still a topic of debate among scientists. Opinions of every philosopher and scientist vary from one to another. In recent days, consciousness is now a significant topic in cognitive science. Even we can measure the degree of consciousness by behavior observation scales. The famous scientist Locke defined consciousness as "the perception of what passes in a man's own mind." Ned Block suggested that there are two types of consciousness named as phenomenal (P-consciousness) and access (A-consciousness).

1.2 Global Understanding on Consciousness

Consciousness can be seen as a role of energy in our brain. Any type of activities requiring energy done by the body involves physical processes leading to biological behavior. This product of energetic activities in our brain is termed as consciousness. The consciousness and functioning of the brain is related to each other in some or other way.

Brain operates on some principles of energy processing, and this presence of energy in the brain with some additional techniques, the presence of consciousness, can be predicted. Thus, the consciousness can be termed as not only presence of mind but presence of some kind of energy that drives various activities taking place in our brain [32].

Meditation refers to a family of techniques which have in common a conscious attempt to focus attention in a non analytical way and an attempt not to dwell on discursive, ruminating thought. The term "discursive thought" has long been used in Western Philosophy and is often viewed as a synonym to logical thought.

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1.3 Kirlian Photography

Kirlian photography is contact print photography which is connected with high voltage. In 1939, Semyon Kirlian found that if an object on photographic plate is exposed to strong electric field, an image of object will be created. He claimed that this discovery gives the proof of supernatural auras. These photographs are considered to be mysterious and controversial over the years. Although Kirlian discovered this method in 1939, he didn't make it public till 1958. The machine that was used in this process was a spark generator which works at around 75 kHz. As Kirlian claimed that the images, so produced, showed aura of living entities, his machine trends among the professional scientists [7]. After the success of this experiment, Kirlian became very popular. All magazines and newspaper were flooded with the success story of Kirlian; even a short educational film was produced on this experiment. The physiologist Gordon Stein wrote that Kirlian photography is only a hoax and it had nothing to do with vitality and auras of living being. In order to verify that claims of Kirlian were true, a typical experiment was done on a leaf which is popularly known as torn leaf experiment.

Photography is one of the most visual medium to capture something. There are a wide variety of techniques and aspects used in photography. The right use of these aspects can lead to unexpected results.

A similar technique was accidentally discovered in 1939 by Semyon Kirlian and his wife Valentina and thus given the name Kirlian photography. Once during their visit to a hospital, they noticed a patient receiving high-frequency generator treatment and that sparked in them an idea to conduct an experiment [30].

The Kirlian photography is also known to be as aura photography as it contains different auras/subjects. Their inventors claimed that it can be used to shoot different aura of living beings. The photographs resulted from this experiment also depicted force that surrounds every single being on this planet (Ref.: https://www.pixsy.com/kirlian-photography-image-protection/).

1.4 Energy Measurement

In physics, we define energy as the physical quantity which can only be transferred from one form to other. Energy can neither be created nor be destroyed. The SI unit of energy is joule. There are also other forms of energy such as kinetic energy (moving body), potential energy (position of body), and gravitational energy (gravitational force of earth). The most famous scientist of all time Albert Einstein said that energy and mass are correlated to each other, and he proposed his statement by eq. $E = MC^2$.

Every living organism needs energy to survive, and most of their energy they get from food they eat. James Prescott Joule was the scientist in honor of which SI unit of energy was named as joule. The units of measurement of energy is numerous,

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among them well-known are tons used for coal, barrel for crude oil, cubic meter for gases, and liters for petrol and diesel. Besides joule, there are many other units of energy measurement such as kilowatt hour (which is widely used to calculate bill of electricity). The most common units measuring heat include the BTU (British thermal unit) and the kilogram calorie (kg-cal) [5].

There are two types of energy, where one is energy in rest and other is energy in motion. Energy is measured in various units. Some of them can be seen as:

- Joule (J)
- Watt which is joule/second
- Their definitions are the following:
- 1 Joule (J) is the MKS unit of energy which is equivalent to force of 1 Newton
- 1 Watt is the power of a Joule of energy per second

1.5 Bioelectricity

The electric current continuously flows in the human body (termed as bioelectricity) that plays a vital role in physiological conditions. The human body consists of millions of nerves which transfer information and are responsible for the whole functioning of the body through electrical impulse which is actually bioelectric signals. So we can term bioelectricity as the electric current which is present inside the living body or produced within it [9]. The number of biological processes occurs every second in the human body which leads to formation of bioelectric currents. Bioelectric currents and potential of human cells and tissues are recorded by machines like ECG, EEG, etc., which can be used in making medicines for various organs of human. All the bioelectric activities associated with the skin and tissue are used to make biomedicines. Till the eighteenth century, European physicians and philosophers believed that nerves transfer the information to the brain through some organic fluid, but later on two Italian scientists demonstrated the concept of bioelectricity. Emil du Bois-Reymond, a very famous scientist of that time, discovered that during any tissue injury a unique electric potential is generated, and he named bioelectric current as "the current of injury" [8].

1.6 Pranik Urja

The life energy which keeps us alive and strong is called prana or ki. The word prana is derived from Sanskrit word and is recognized by most of our ancient culture. It also means the breath of life. The more life energy that one person has, the more energetic and excited that person is. Pranayama is the nutrition of life. It is essential to keep the body healthy and happy. Sun, wind and ground are the major sources of Pranik Urja. The solar prana (or energy) can be obtained by sitting in the

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sunlight for 5–10 minutes or by drinking water kept under the sun. The air prana is absorbed directly by our energy centers. It is obtained by slow and rhythmic breathing. Color prana or life energy is mostly of six types: red prana, orange prana, green prana, yellow prana, blue prana, and violet prana. And the pranic energy is mainly defined into two types: electric violet pranic energy and golden pranic energy [29]."By remembering you are in an ocean of life energy, your life energy level will automatically increase."

Pranik Urja means pranic energy (feel divinity all around you).

The main sources of these kinds of energy are solar, air, and the ground.

1.7 The Human Body and Seven Chakras

The human body is one of the most complex structures of living beings. It has millions and billions of cells, tissues, RBC, WBC, nerves cells, etc. The human body is the most developed and advanced structure, as it has brain (organ to think, very memory), heart (for blood circulation), lungs (for breathing), kidneys (to filter out toxics from body), etc. The study of the human body involves anatomy, and physiology. The main component of the human body is hydrogen, oxygen, calcium, carbon, and phosphorus. The human body contains several systems like circulatory system, digestive system, immune system, and many more. The human body is like a machine which runs only when energy is provided to it. It is said that there are seven chakras in the human body [15].

First one is root chakra (Muladhara); it represents the foundation of human and is located around spine base. Second is sacral chakra (Swadhisthana) which helps in dealing our emotions with others and located in the lower abdomen. Third is solar plexus chakra (Manipura) which represents our confidence and located around the upper abdomen. Fourth is heart chakra (Anahata); it is located in the chest center. Fifth is throat chakra (Vishuddha) which controls our communication and is located in the throat. Sixth is third-eye chakra (Ajna) and located between the eyes. Last is crown chakra (Sahasrara) which is found on top of our head [1].

Ours mental health depends on our outlook and our attitude toward everything. The way we think and the way we develop rapid thoughts are the reason we grow in life. Hence, there are some energy centers in our soul which give us energy to do anything. They are the following:

- Muladhara chakra – root chakra
- Swadhisthana chakra – sacral chakra
- Manipura chakra – solar plexus chakra
- Anahata chakra – heart chakra
- Vishuddha chakra – throat chakra
- Ajna chakra – third eye chakra
- Sahasrara chakra – crown chakra

All the above chakras lead us to live life and have their own significance [6].

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1.8 Aura of the Human Body

The word "aura" means wind or breeze. It is believed that there exists an aura or human energy field. Since ancient times we see many pictures and paintings in which the human body is surrounded by a visible energy field known as aura energy field. The aura represents the mental, physical, and spiritual energy of being, and it also contains a mixture of different color frequencies in which each color has its own significance and characteristics. By scientific researches, scientists came across a conclusion that this aura actually is electromagnetic field of energy which comes out from a body of men and is 4–5 feet tall in the case of healthy person, but its strength reduces in the case of unhealthy person. Studies show that aura is associated with the human health. If a person is healthy in terms of physical vitality, mental clarity, and emotional well-being, then obviously that person will emit a positive spiritual energy. Today all scientists come across a result that the matter which appears to be solid is not real solid. These solids actually are made up of energy which is emitting frequencies; it is also confirmed that whenever there is an electric field, there develops magnetic field around it. So aura is an electromagnetic field of the body [11].

The human aura means energy field of the human body which acts as shield to the human body.

It is directly connected to energy centers of the body, the seven chakras discussed above. It creates an egg-shaped field aura surrounding the human body originating from the chakras. Actually, the truth is we all are interconnected. Still it's our thoughts which make us believe we're different. Actually this interconnectedness can be observed through the term human aura. Some examples of above arguments are feeling of love, anxiety, sadness, and fear [2].

1.9 Yin and Yang Energy

Yin and Yang is related to Chinese philosophy. Actually Yin and Yang is a concept of duality, i.e., the opposite poles. It is related to negative-positive, dark-bright, meaning things that are contrary to each other. Yin is receptive and Yang is active principle, and it is seen in every form such as annual cycle (winter-summer), sexual couples (men-women), etc. In Chinese cosmology, yin and yang are material energy from which the universe has created. Yin and yang are opposite of each other, and both are interdependent on each other. Both of them are necessity of life as they counterbalance each other, but they can't inter-transform each other. It seems that every human has yin and yang energy or good or bad side, and it depends on human to which side they prefer and what they become. Yin and yang is also present in symbol form in which yin represents white area and Yang represents black area. Yang energy is considered to be masculine, very expanding, active, energetic, and light. Some properties of Yang are heaven, sun, light, time, etc. [10].

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It is a concept of dualism, meaning that even the forces which seem opposite or contrary can also be complimentary, interconnected, or interdependent in the natural world. These all actually give rise to each other. According to the Chinese cosmology, the reason of this universe is primary material energy which forms all kinds of objects and lives. In the concept of Yin and Yang, Yin is the passive, i.e., receptive, and Yang is the active principle. They can be seen in all forms of change. Some of them are annual cycle, sociopolitical history, sexual coupling, the landscape, and all other different laws of nature [14].

1.10 Quantum Consciousness

It was a failure of classical mechanics which was not able to explain consciousness and derived a group of hypothesis known as quantum consciousness. They proposed quantum-mechanical phenomenon like superposition that plays vital role in brain functioning of human and can easily explain consciousness. Also, it is believed that quantum idea is necessary for the brain to even exist.

There exists a strange link between the human mind and quantum physics. Nobody understands quantum and consciousness. It's because both are somehow related to each other. The classical mechanics cannot explain the human consciousness [16].

The consciousness emerges from complex computation among brain neurons which is similar to digital computing in quantum physics. Same as quantum can be used to understand the two various things at a time, the human mind can contain two mutually exclusive ideas at a time. Just as quantum is mysterious, same as consciousness.

Thus, consciousness is a manifestation of quantum processes in the brain.

Some still thinks consciousness is a mere illusion. Yet, the real origin of this is still unknown.

The famous "double-slit experiment" simply introduces the quantum mechanics in a more fashionable way.

The concept behind the term is that quantum theory may actually explain how the brain really works. Same as quantum objects can be apparently present at two places at a time; similarly, the quantum brain can hold onto two mutually exclusive ideas at the same time [17].

1.11 Science of Meditation and Its Effect on the Human Body

Now discussing about medication, studies show that medication can affect both physical and mental well-being of a person. The main purpose of doing medication is to know what is going on in one's mind. Medication can be useful in many ways, but side by side its harmful too. By taking medication, we get relief from pain,

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depression, and anxiety. In ancient time many people die as we don't have any cure for it, but now we have medication for almost all the diseases that surround us. From cancer to simple cold, we have medication for everything; from headache to stomachache, all can be cured. Consuming a lot of medicines can have many side effects; it may harm the antibodies, produce many hormones, and/or reduce fertility in both male and females. According to a research by Harvard, there have been a number of key areas like depression, anxiety, etc. where mindful meditation has shown benefits for the patients. Meditation has shown many benefits. Eight weeks of meditation can reduce aging. It can improve memory [18].

Our health has two aspects: physical and mental. When the body is fit physically, it doesn't mean he/she is fit mentally and emotionally. The highest level is spiritual level which is even far higher than soul. It means understanding the real self and the reason for your existence. All these can be achieved by performing meditation which can be said as an exercise for the better mind.

Different types of meditation practices followed are concentration, mindfulness, etc.

The benefits are the following:

- Lower blood pressure
- Less perspiration
- Less stress and anxiety
- Deeper relaxation
- Feeling of well-being [19]

Our mental health is as much important as the body. Meditation helps the mental health in following ways:

- Reduce stress
- Controls anxiety
- Promotes emotional health
- Enhances self-awareness
- Increases concentration
- Reduces memory loss due to aging
- Also reduces bad addictions
- Builds honesty and kindness
- Helps in quick healing
- Improves bad sleeping habits
- Improves blood pressure problems

1.12 Science of Mantra and Its Effect on the Human Body

Yajna means sacrifice, devotion, and offerings. It is the holy work that we do to make our god happy; we offer mantras, japs. It has been seen that in our scriptures, we are doing Yagya for welfare of humanity. Whenever we face a gigantic difficulty,

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a solution is to make gods happy by doing Yagyas. Its effect is very positive on humanity. The chanting sound of Gayatri mantra and heat from the fire of Yajna is a powerful combination and produces some important effects. We chant the Sanskrit mantras while performing the Yagyas; these send vibrations which ensure proper functioning of our body parts. The cosmic energy associated with the Gayatri Mantra is of the sun. These mantras sooth our mind and calm us. Performing Yagya also helps in removal of insects and bacteria in our environment. The environment becomes light and pleasurable. Not only it makes us happy, but it provides positivity to people who participate in them [12, 13].

This is believed to be another gift of Indian sciences which is for the betterment of us.

In the course of doing this holy Yagya, the two main energies, heat and sound, are released. This, along with the sound of the mantras such as Gayatri Mantra or other Vedic mantras, helps to achieve what we are wishing for. This is mainly done to get some physical, psychological, or spiritual benefits [20].

Yajna literally means devotion, worship, and offering. It is a process of cleaning oneself by invoking fire.

1.13 Science of Yajna (Yagya) and Its Effect on the Human Body

Yagya is a type of Holy Fire Ritual performed by Hindus to destroy the demons (the Asuras).

It is a ritual followed since the Vedic times with fact that it destroys negative energy.

The head and sound are two basic types of energies.

In performing Yajna, these two energies, namely, the heat from Yagya fire and the sound of the chanting of the Gayatri and other Vedic Mantras, are blended together to achieve the desired physical, psychological, and spiritual benefits [21].

The science behind using Ghee in Yagya is that Ghee helps in combustion of wood and keeping fire on. So, it is an important reason to recommend to perform rituals of Yajna in sunlight.

This reason is taken from (https://www.speakingtree.in/allslides/scientific-aspects-of-yagya-the-holy-fire-ritual).

1.14 Artificial Intelligence for Health Informatics

In modern world, which is full of new fresh ideas which are capable of generating innovative technology which has a potential to surprise everyone in this world? This modernization we can see in our medical sciences. Healthcare organizations have

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adopted new development. Today, machines can act, sense, and behave similar to the brain of the human being which is made possible only because of artificial technologies.

Due to AI, our medical system handles large set of data sets (information overload issue faced by health official is solved), solve complex problems using its analytical skills, and also able to handle administrative functions.

AI is able to handle large data and work efficiently because of machine learning technology which acts as its backbone [33].

1.15 Health Sensor Data Management

With its regular increase in market size, smart devices such as smart watch, smartphone, fit-bit like devices have created its popularity and unique identity.

With their useful features and extra ordinary applications of sensor based gadgets, people love to use these products so that they can keep an eye on data of patients without affecting their personal lives in a convenient way. Smartphone contains many embedded sensors such as microphones, cameras, gyroscopes, accelerometers, compasses, proximity sensors, GPS, and ambient light. Easily wearable and tear-off medical sensors can easily connect with the smartphones and transfer the sensing results directly. This helps a lot in maintaining blood pressure and calories in the body using fit-bit-type smart device.

Newly arising technology like artificial intelligence, internet of things, and data analytics gives an edge in easy and fast approach of data collection and performs certain action on it [22].

1.16 Multimodal Data Fusion for Healthcare

Data Classification is one of the most important area of work for understanding the features and conditions of different objects and data mining is a popular tool regarding this. The medical and healthcare sector handles big data which is available in unstructured form and it generates many difficulties like complexity of characteristics, functional diversity and redundant informations. These problems generated by multimodal unstructured data cannot be directly utilized by traditional machine learning methods. Therefore, some researchers have tried to implement multimodal data fusion using deep learning techniques [23].

Multimodal data fusion-based data processing method has high flexibility. This data processing method has a potential to work upon traditional data processing methods and respond to dynamic data. This method is able to reduce the load of data calculation by combining different fusion methods, but it requires significant effort to fuse data in the right way.

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1.17 Heterogeneous Data Fusion and Context-Aware Systems for the Internet of Things Health

The number of internet-connected devices present in our day-to-day life is currently increasing in an exponential way. We use these devices at every place like home, workplace, etc. Even people like to interact with each other using these embedded devices [24].

A quite high number of researches are done on data fusion process using complex algorithms. In this, data is acquired and processed from heterogeneous sources and always centralized on a powerful computing node. We have a method which is based on lightweight service composition model to implement a distributed data fusion acquisition, which is able to ensure the correctness of collaborations without a cyclic behavior. Due to this method, we can work on decentralized and distributed manner and allow developers to use the concept of service and the interaction among services to design the high level of abstraction in IoT scenario [25].

The distributed approach for data fusion makes the service model very scalable and a really important aspect in the development of future applications, which can be deployed in embedded devices.

2 Literature Survey

Paper-1 Starting with some analysis, what we did was, we compared 61 healthy-state people with 256 patient people who had bronchial asthma. The study of the so-called bioelectrograms of those patients had been studied for the same. A widely used technique gas discharge visualization, i.e., GDV, had been employed for all the analysis. It is a type of bioelectrograph technique. Let's have a brief discussion on this technique as how this originated and from where. The GDV-gram taken from the fingertips of the hands of the person being the victim and the method of same is given further.

The main instrument and technology used hereby the team of authors is GDV camera and GDV processor which helps in maintenance of GDI processing and records. The main factors that we have taken into account was organization of data; other than this, the focus was on factors which interfered with our analysis. The main condition was to do registration of subjects to be done on GDV camera to see the Kirlian effects. Also, the mandatory coefficients like integral area, form, and emission are also required as methods of the GDV-gram being taken. Moving further, before giving out the conclusion and result of analysis, an experimental data has been studied. Its application is mentioned herewith.

As mentioned and reported before, GDV-gram of fingertips of both hands are taken separately to be able to differentiate the value of indices of both hands. Then, basically, the average is taken as a final observation. Both fingers' study taken as an

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individual study is thus obtained by us. Now, moving more further, based on the obtained value, the final evaluation of result is thus done, and the final lines are obtained as a conclusion.

While expanding the discussion a little for clear understanding, GDV (Gas Discharge Visualization) has been accepted and it is a type of bio electro graph technique.

All the data and info is collected in a group of three people, the elaborated types of the three are as follows. First type consisted healthy people, the second including BA victim, and the last one included ulcer and stomach patients. This was done basically to study the results more widely and clearly differentiate them. The main parameters we focused on was on the coefficients like farcicality (FC) , emission (EC), and the integral area as already being mentioned above. Using the calculated values, the results are drawn.

This was just an upgrade of the previous derived techniques, now also known as gas discharge (GDV) bioelectrograph. In this one we added a more wider medical practice, beyond the previous one. Now, it is capable of monitoring clinical trials by clinical acumen and diagnostics. It was thus able to upgrade the previously used practices and tools. Formally, the collection and monitoring of multi-morbid patients can be now more organized with the help of the impact created by medications in comparison with the properties related to energy information. This also made selecting the right therapy simpler and accurate.

For our second-category people comprised of BA victims, this technique can be more widely employed. The biological functions of their body are made more in the course of the treatment process. This can also help in other ways too. Let's talk about them. The indications which are more relevant for medicinal as well as non-medicinal mergers of treatment are drawn now from the GDV-gram.

There can be one disadvantage here in this process. The patients with acute myocardial infarction is not accurate and not allowed as well as it can have side effects on them.

Now conning on the main section of the literature survey, the conclusions are ready to be mentioned. The patterns obtained from those samples of the GDV-gram can be simply and accurately related now with all three different groups of people. The main correlation was obtained by the BE technology with all collected pathogenic information. The result can be categorized into two sections. First, the traditional medical solution and homeopathy which is a collection of strategies, some of which are optional. We are now introduced to a newer technology, GDV-BE, which can study different medicinal solutions and problems such as diseases and infections and allergies by fluid commonly called as auras in vitro which is clearly biological. Also, the more elaborated organism can be studied in the similar way by simple comparison. At last, this can be more used in the fields of sports, business, professions, and other well-known works.

Paper-2 In these series of analysis and studies, the contributors have categorized the conditions into three subsets. First one is orthostatic test followed by deep

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breathing, second is 10 minutes of serious exercise, and the last one is intake of chocolate, being the most important as it is performed to reduce stress and fear.

Different correlations can be observed in these tests such as the correlation of the sympathetic component of HRV and GDV. As a result of these, the GDV measures can be used as well-being in different physiological conditions.

These physiological conditions are affected by different negative thoughts and emotions such as anger and fear, whereas the positive thoughts will leave a positive and productive effect on the body. This investigation examines as if such correlation between HRV and GDV can measure a well-being. All the cardiovascular activities are regulated by the nervous system; hence, the activities of both branches of the nervous system can be observed or judged by the heart rate variability (HRV) [3].

The methodology used in this paper is the amplifier with time constant (T) = 2.5 and (T) = 10 s. The rheostat and a variable capacitance are connected in parallel in the Wein bridge.

A sinusoidal wave of 1000 cps is used as an alternating current in the process.

For observing galvanization effect, DC is used [31].

Instruments and Data set used were related to traditional electrocardiogram which was equipped with four electrodes which as connected to left and right hands and left and right ankles to measure the HRV (Heart Rate Variability). GDV Compact Device and GDV Processor Software were used for the analysis of those images.

In supine position, the patient was asked to take a deep breath. This was done for a time period of 5 minutes. Also, the subject was asked to resume regular tidal breathing. Then after that, the readings were obtained. Before the GDV and HRV parameters are calculated, a 10-minute exercise was involved. Then, the third condition involved consumption of dark chocolate 3 hours after GDV and HRV parameters were measured [3].

Application of Work

Impedance change during response: On comparing the obtained GRS's, the impedance is observed to vary gradually with lapse of time.

The effect of removal of the epidermis: Two records (lower and upper) are recorded using small and large electrode, respectively. It is performed on the left little finger and right little finger [31].

A comparison of endosomatic and exosomatic method is made, and the changes in the wave form are observed using small electrodes.

Impedance change observed by negative process and sweat gland activities is judged by positive process.

The impedance change is independent of secretary activities. The response always followed a monophasic fashion [31].

Paper-3 In the absence of the epidermis, the galvanic skin reflex can be observed. It can be recorded by impedance change in the presence of current flow. Two processes called as negative and positive can be observed simultaneously using this. Two parts of the body are in connection using a galvanometer in Tarchanoff's galvanic skin response.

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Tarchanoff also suggested the involvement of a sweat gland in this reflex. The indication of physiological event is confirmed using the abovementioned methods. It will also help to clarify the quantitative treatment of this galvanic skin reflex [31].

Gas discharge visualization (GSV) and heart rate variability (HRV) are mainly two methods used. The two were used as follows:

- GSV – Image analysis, registering both static and dynamic GDV images, and all the GDV parameters are described using this method.
- HRV – Using R-R time interval variability, the parameters are measured, and peaks in the very-low-frequency range are revealed by the spectral analysis of those time domain parameters [3].

Instruments and data set used: (A) Wein bridge is used as an instrument in the above process. (B) Variable resistance and capacitance are connected to form a parallel circuit. (C) GSR is used to check the balancing of the bridge. (D) The endosomatic and exosomatic methods are used for comparing the GRS [31].

Application of work is that, as discussed above, the cardiovascular activities are centrally controlled by our nervous system; it involves fluctuations in HRV. Hence, these fluctuations provide us a tool to measure the relativeness of both its branches. Also, the correlation between spectral analysis and fetal well-being is allowed by high sensitivity to hypoxia [3].

Future scope and limitations of this paper state that mostly positive deflection is observed in the removal of the epidermis. The negative one can be recorded after a slight regeneration of the same. The positive deflection was less observed with small electrode.

Conclusions of this paper says that the main purpose to establish the correlation was successful. Using those parameters of GDV and HRV, the main conclusions drawn are as follows:

- The study clearly observes a statistical correlation exists between brightness parameters of GDV and HRV (VLF component).

The range of frequency (VLF) is seen as 0.003–0.04 Hz, whereas the upper region can be seen as 0.01–0.04 Hz [3]. Therefore, on seeing the correlation, it can be concluded that "well-being can be measured as resilience to psychophysical stimuli."

3 The Methodology and Protocols Followed

The methodology which was followed during this experiment were based on capturing photos by Kirlian camera. The volunteers had to chant and meditate for 15 minutes daily. Then they also had to perform Yagya. This turned out to be very beneficial for cancer patients. Even the European platform of Cancer and European Organization for Research and Treatment of Cancer supported this research work. It also shows a positive growth toward people's happiness index and quality of life.

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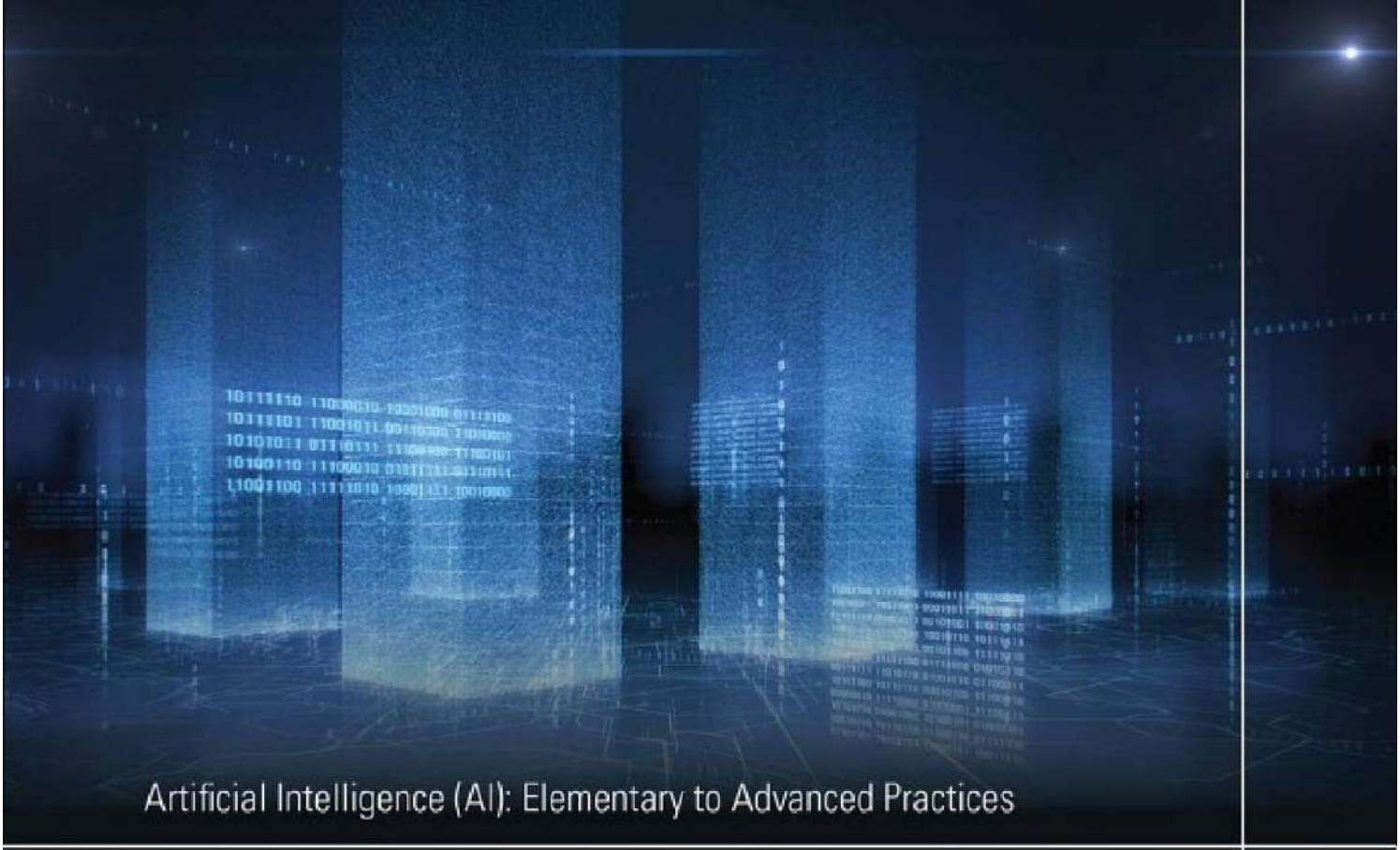

Artificial Intelligence (AI): Elementary to Advanced Practices

CYBERSECURITY

Ambient Technologies, IoT, and Industry 4.0 Implications

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Preface

Humankind has ventured into the time of the Industrial Revolution 4.0. Industry 4.0 could be a standard term to portray the fourth-generation Industrial Revolution that we are encountering these days. With each passing day, innovations such as cloud computing, the IoT, and mechanical technology are disturbing the conventional manufacturing process. With computerization, the IoT, and data analytics making production methods more and more intelligent, smart, and productive, the Industrial Revolution 4.0 has been evidently apparent. To all intents and purposes, this transitional move to digitization and robotization is known as "Industry 4.0."

However, this stage of the industrial revolution has introduced challenges, especially in terms of cybersecurity threats. Around the world, cybersecurity specialists have been concerned around the suggestions of Industry 4.0. In an age where everything is hyper-connected, industries have recently become more defenseless than ever. In other words, digitally connected industries are more vulnerable to assailants who are looking to abuse assets and information. As a result, the need for compelling cybersecurity measures inside an IIoT-enabled generation environment is posing a genuine threat to new-age industrial revolution systems and methods.

Nowadays, smart manufacturing plants and supply chains are consistently associated by means of an Industrial Internet of Things (IIoT) that makes use of IP addresses to associate and communicate inside and outside the production line. These internet-connected gadgets are always vulnerable to unauthorized access without legitimate cybersecurity measures.

Therefore, we attempt to provide a significant effort to identify and combat these risks, in the form of present book, *Cybersecurity: Ambient Technologies, IoT & Industry 4.0 Implications*. The book contains 12 chapters.

Chapter 1 covers the general security services and modeling aspects associated with any system. It also looks at the latest research done on such services and security models. The chapter explores the risks associated with a system and how, for a specific use-case of virtual reality implementation, we help the reader to see what risks can be mapped out and tackled. This chapter acts as a baseline for an individual to understand security services, the risks associated with a system, and the security models available, which can be used while designing a system.

Chapter 2 discuses the IDS approach, and methodology and different types of computer and network attacks. The latest trends, issues, and future research issues regarding intrusion detection systems are also presented. The chapter addresses the emerging research issues in designing reliable and accurate ID systems.

Chapter 3 defines the ethics and techno-ethics concepts, along with the main challenges and issues for ethics in technology. The chapter explains the main applications of cybersecurity, considering two main types: secure web applications and secure mobile applications. Finally, it explores the ethics for cybersecurity applications. This includes user privacy, freedom of speech, intellectual property rights, legal protections, and responsibility for crimes.

Chapter 4 presents the dependency on the technology that defines cloud computing and the IoT. Consumers face challenges from the risk of security flaws surrounding data

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privacy, loss, theft of intellectual property, insecure APIs, etc. These can become huge risks for any organization, as described in the chapter.

Chapter 5 discusses the software's Internet of Things, hardware, telecommunication network, and related technology issues required for these projects. Smart mobility applications and data are integral parts of the system, and therefore, problems related to data and their privacy may arise. The chapter deals with the security concerns of the public, legal issues, etc. Finally, the chapter discusses various levels of regulatory requirement and their roles.

Chapter 6 discusses various models of digital forensics, underlying principles, the concept of cryptography, and its impact on the domain of digital forensics. The chapter also addresses the impact of related technologies on human life, as Industry 4.0 has had a tremendous impact on these areas, enabling them, as well as enforcing the acceptance of such smart technologies in various aspects of our lives.

Chapter 7 proposes a mathematical model for malware attacks through the IoT, considering proper vaccination. The existence and uniqueness of the model have been proven. The infection-free and endemic equilibrium points have been found successfully. This model explains how the basic reproduction number determines the local and global stability of the system in IoT devices. It adapts the vaccination-based IoT devices in the network for protecting against malware attacks. The numerical simulations are critically analyzed and performed to validate the developed model.

Chapter 8 endeavors to build up a mechanized framework on rice plant disease detection using the IoT, which recognizes the presence of infection in the leaves and soil. There are various factors that determine pH, temperature, moisture, DHT 11, and TCS 3200 to detect the current position of the soil and plant. Those sensor values are sent, using an Ethernet shield, to be stored on an IoT server. Here, we have created a framework to detect the current condition of the plants' environment. We then analyze the current situation of the environment by comparing it with the healthy plant's actual values and show it on our constructed platform.

Chapter 9 focuses on the security issues of e-health care systems and provides the methodology to assure security. Various security protocols have been proposed, including an energy-efficient routing protocol, a secure protocol for user authentication and key agreement, a node-to-node authentication protocol, eliminating the man-in-middle attack, a lightweight anonymous authentication protocol for network security, and a trust key management protocol for biomedical smart devices. Finally, the chapter also discusses security protocols for biomedical smart devices.

Chapter 10 discusses different access control mechanisms associated with the health care system. In today's world, data has become the most important thing. Therefore, data privacy and security are crucial. In any information system, the satisfactory security of data, as well as access control by the owner of the data, are the primary requisites. Health care information systems have very crucial data on the patient. Therefore, the chapter concentrates on electronic health record information systems, which require the development of a strong mechanism to protect unauthorized access to the data.

Chapter 11 identifies approaches combining several classification techniques with PSO for intrusion detection. A general presentation of the PSO algorithm is provided. PSO-based techniques for intrusion detection are introduced and detailed. The most common datasets and evaluation measures are discussed. Finally, a summary discussion about PSO-based intrusion detection techniques is provided, along with possible directions and insights.

Chapter 12 introduces the various types of vulnerabilities and their mitigation techniques. The biggest challenge for an organization is to prevent the web applications or portals from unauthorized activities, because web applications are available to all users

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24/7, through the internet. Therefore, violating an implicit or explicit security policy is discussed, to counter the system's hardware or software vulnerabilities.

We hope that the works published in this book will serve the communities concerned with cybersecurity, the IoT, and Industry 4.0.

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Editors



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2005, 2007, 2009, and 2019, respectively. He has six years of teaching experience and four years of research experience. He has also filed 1 IP and obtained 2 copyrights for his research work. He has been awarded 2 gold awards and 1 merit award for his research. His research interests include the development of handy medical devices using optical-based sensors, by deploying signal-processing algorithms, and machine learning techniques for the automatic classification of cardiopulmonary conditions. To date, he has authored and coauthored around 19 researched and reviewed manuscripts, with an accumulated impact factor of 14.573.



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DATA SCIENCE FOR EFFECTIVE HEALTHCARE SYSTEMS

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Preface

This book primarily introduces the importance of data science in the field of healthcare. Data science has proven to be a gamechanger in the optimization of disease prevention, drug discovery, diagnosis, treatment, hospital operation, and post-care monitoring. Initially, the basic concepts, applications, and challenges related to data science will be covered to lay down a strong foundation for its importance in healthcare. A large volume of data is generated in healthcare in processes primarily from clinical trials, genetic information, electronic medical records (EMRs), billing, wearable data, care management databases, scientific articles, social media, and internet research. A global pandemic like COVID-19 has dramatically increased the need and the importance of data science and analytics.Data science in healthcare industry is mainly used for predictive analysis that uses artificial intelligence, machine learning, deep learning to predict possibility of an event occurring in the future based on known present variables and facts. The various available and emerging tools and techniques to manage this voluminous healthcare data results in improving patient outcomes and reduce healthcare costs. Various techniques such asregression and classification have been covered here for better insights into healthcare data analysis and its related advantages. This book also focuses on the importance of visual analytics to observe the medical history of a patient for further courses of action to cure the diseases. This book is also meant to enlighten the importance of data science in drug discovery, pandemic like COVID-19 needs fast simulation techniques to observe the reaction of drugs inthe body so that the drug can be approved by competent authorities and used to cure the disease.

In nutshell, the tools and techniques of data science have changed the way to manage, analyze, and leverage healthcare data for better and optimized prediction.The main motive of this book is to bring the research and findings together for clear directions for future work.

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1.2.2 Patient Sentiment and Behavior Data

Mobility sensor data includes sensor data or streaming data from home monitoring, medical monitoring, telehealth, smart devices, and sensor-based wireless. Biometric data includes fingerprints, handwriting, and iris scans.

1.2.3 Clinical Information and Notes

Eighty percent of health information is unstructured, consisting of photos, papers, transcribed notes, and clinical notes. These semi-structured to unstructured clinical records (patient discharge summaries, medical photographs, diagnostic testing reports, etc.) and papers constitute novel data sources.

1.2.4 Web- and Social Networking–Based Data

Google and other search engines, Internet consumer use, and social networking sites all contribute to web-based statistics (Twitter, LinkedIn, Facebook, blog, smartphones, and health plan websites).

1.2.5 Genomic Data

Genomic data represents a large volume of new gene-sequencing information. Genotyping, gene expression, and DNA sequencing are all examples of genomic data.

1.3 Big Data 5 V's in Healthcare

Gartner identified eight important sources of big data in health in 2016 [5]. The four V's Veracity, Volume, Velocity, and Variety have been coined by Ernst & Young and others to describe it. Similarly, McKinsey also identified five "rights" that it may provide: "right provider", "right living", "right care", "right value", and "right innovation" [6].

1.3.1 Volume

Terabytes and petabytes of data are used by healthcare systems. Personal information, 3D imaging, genomics, personal medical records, radiological images, and biometric sensor readings are all stored in these systems [7]. This complicated data structure may now be managed and analyzed by healthcare systems. Storage, manipulation, and use of such complicated data are now possible due to the advent of cloud computing. According to KPMG (Klynveld Peat Marwick Goerdeler) report, healthcare data had surpassed 150 exabytes in 2013 and is growing at a speedy rate of 1.2–2.4 exabytes each year [8].

1.3.2 Velocity

The underlying explanation for data's exponential increase is velocity [9], which states how quickly data is generated. Data is being generated at an ever-increasing rate. Due to the amount and diversity of data acquired, the speed with which unstructured and structured data is generated forces a conclusion based on its outcome.

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1.3.3 Veracity

Data veracity refers to the degree of certainty that a data interpretation is consistent. Varied data sources have different levels of data reliability and dependability [10]. Unsupervised machine learning algorithms, however, are employed in healthcare to make choices that data may be useless or ambiguous [11]. The purpose of healthcare analytics is to extract useful insights from this data so that patients can be treated effectively and the best decisions can be made.

1.3.4 Variety

It refers to the data's format, whether it's unstructured or structured, medical images, video, audio, text, or sensor data. Clinical data is structured data that must be collected, stored, and analyzed using specialized equipment. Structured data accounts for only 5% to 10% of overall healthcare data. Images, audios, videos, e-mails, and healthcare data, such as prescriptions, hospital medical reports, radiographic films, and physician's observations, are examples of unstructured or semi-structured data [12].

1.3.5 Value

This V, unlike the other 4Vs, is too unique since it reflects the anticipated results of big data processing. We're continuously looking for new ways to collect and extract the true value from the vast data. Investment should be the one to store data as the quality of the governance strategy and approach determines the value of data. Another important consideration is that certain data has a different risk value at the time of collection, but that risk can change with time [13].

Five more key traits have been identified by researchers, totaling 10V's of big data. Variability, Validity, Vulnerability, Volatility, and Visualization are the five extra traits. Healthcare data is separated into structured and unstructured data, which includes Electronic Medical Records (EMR) reports, medical photographs, and so on [14]. A large amount of data helps improve the worth of healthcare by utilizing creative analyses. The huge volume of data associated to healthcare can be analyzed by distributing the process using cloud centers and big data. Not only have big data increased the size of data but it has also increased the value that can be derived from it. To put it in another way, big data has shifted the focus of Business Intelligence away from reporting and decision-making toward prediction. Understanding innovative diseases and therapies, predicting results early, taking instantaneous decisions, improving health, boosting treatment, lowering expenses, and improving healthcare quality and worth are all instances of a value in healthcare.

1.4 Big Data Analysis in Healthcare Industry

Big data analysis can change the healthcare scenario. The ability to use technological equipment by healthcare professionals and make decisions about their clinical and other data streams has been changed for better comprehend. The five processes that make up big data healthcare analytics include data acquisition, data storage, data management, data

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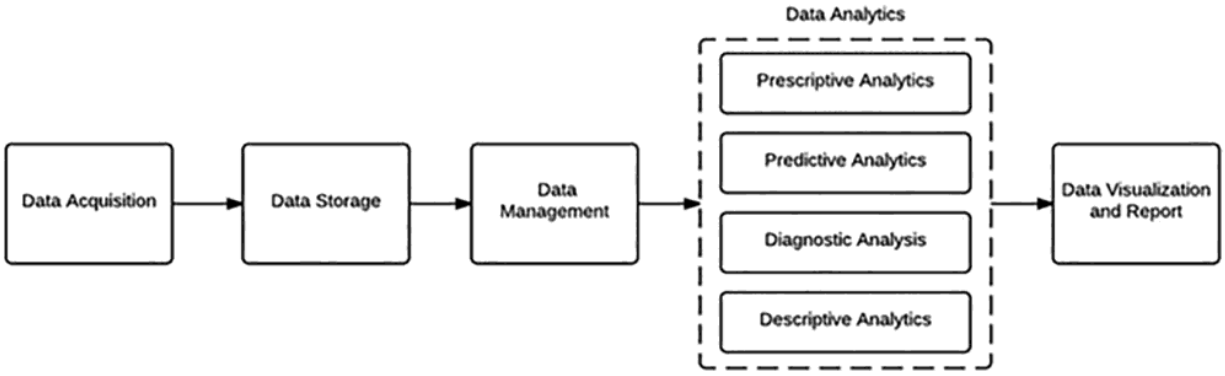

FIGURE 1.2 The process of big data analytics in healthcare [32].

analytics, and data visualization and reporting. Figure 1.2 depicts the process of big data analysis in healthcare management.

1.4.1 Data Acquisition

The type of data can be classified into unstructured, structured, or semi-structured, and it comes from both primary such as clinical decision support systems, electronic health records (EHRs), and Computerized Provider Order Entry (CPOE) and secondary resources such as laboratories, pharmacies, Health Maintenance Organization (HMOs), government sources, and insurance companies [15]. In healthcare, EHRs, social media, image processing, web-based data, and smartphones, among other things, are the most significant sources of big data.

1.4.2 Data Storage

In this epoch of technology, storage is crucial. Since the amount of data in the healthcare industry grows, we need a storage platform that is both efficient and huge. With such a big number of users, cloud computing is the most promising technology. Clouds offer the scalability and capabilities needed to obtain access to data, boost awareness, speed up the development of scalable analytics solutions, and generate income. It reduces the necessity of maintaining expensive computing gear and software.

1.4.3 Data Management

In healthcare, it encompasses structuring, cleansing, mining, and controlling the data. It also contains a mechanism for determining whether any row or omitted data exist. That information must be handled in a proper way. It aids in the risk assessment of patients and the creation of a customized discharge plan. Apache Ambari and HCatalog are the two important data management solutions. The process of obtaining files or important information from big healthcare databases is known as data retrieval. In healthcare, big data analysis usually includes information recovery and data mining [16].

1.4.4 Data Analytics

Data analytics is the procedure of converting raw data into information. The four forms of big data analytics applied in healthcare are descriptive, diagnostic, predictive, and prescriptive analytics [17].

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The descriptive analysis offers specific information on each attribute such as features, number of features, and the size of the data set.

Predictive analysis aids in the "forecasting" of future events based on current data. It deciphers data insights and provides useful information to businesses in the form of recommendations. It also provides probabilistic estimates of future outcomes [18].

Prescriptive analytics makes use of predictive data outcomes to allow persons to "prescribe/determine" numerous activities to take and steer them toward a result. Before making a decision, it aims to assess the impact of future decisions and provide advice on alternative outcomes.

1.4.5 Data Visualization

Data visualization is the process of displaying analytic conclusions from healthcare data in a graphical layout to make better decisions. It can be used to interpret data patterns and associations.

1.5 Big Data Analytics Tools in Healthcare

Big data analytics is used to process the unprocessed data. The data, which is still unprocessed, is accessed, retrieved, and processed using service-oriented architecture. Another technique is data warehousing, which involves gathering data from a variety of sources and preparing it for processing, even if the data isn't available in real time. From several sources, data is processed and prepared. Although the data is unstructured or structured, the big data analytics platform can accept a variety of data formats [19]. Some of the analytics tools are listed below (Table 1.1).

1.6 Applications of Big Data in Healthcare

1.6.1 Data Analytics in COVID-19

Big data technology can save a lot of data on people who have been infected with COVID-19. It assists in gaining a complete understanding of the nature of the virus. In future, the knowledge acquired can be used to teach new preventive actions. This technology is used to save data from COVID-19 affected instances of all types (recovered, infected, and expired). This information can be used to track down cases and provide resources for better public health protection. Patient physiology, patient-reported travel, patient location, comorbidity, proximity, and existing symptoms are just a few examples of digital data modalities that can be used to provide insights at the community and population levels [24].

1.6.2 Hadoop-Based Applications

Because most of the data is unstructured, extracting relevant information about clinical operations, patient care, and research is a huge problem for the business. The Hadoop can

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TABLE 1.1

Various Big data Platforms in Healthcare [20]

Platform/ Technology	Description
MapReduce	It is a programming archetype for forming Big Data applications that execute in parallel across multiple nodes. It's a method for analyzing big amounts of complex data [21].
Hadoop	Apache Hadoop is a distributed platform to deal with huge datasets through clusters of computers ranging in size from one to thousands [22].
Pig and Pig Latin	To work with a wide range of data types, Pig's programming language is used. The PigLatin programming language and its runtime version, which executes PigLatin code, are the two main modules.
Hive	Apache Hive is a query and analysis tool that runs on top of the Hadoop databases and file systems. Hive is an SQL-like Hadoop database and file system querying tool [23].
Cassandra	It is a standalone database system. It's a complex system that's meant to deal with massive volumes of data spread over several utility servers. Also, it offers continuous service and eliminates the possibility of a single point of failure.
Jaql	It is a query language for analyzing bulky data collections. It transforms "high-level queries" into "low-level queries" for parallel execution of MapReduce jobs.
Lucene	Lucene has been included in several open-source projects and is widely used for text analytics and searches. Its scope comprises the library and full-text indexing search within a Java program.
Mahout	Mahout is an open-source Apache project aimed at developing scalable machine learning models for Hadoop-based big data analytics.

assist the healthcare sector in managing this massive volume of data. In the healthcare sector, following are some of the applications of Hadoop ecosystem:

- **Genomics and Cancer Treatment:** To struggle against cancer, it is important to organize massive amounts of data efficiently. Individual genetics has an impact on cancer mutation patterns and responses, which helps to explain why some tumors are incurable. When recognizing cancer patterns, it is discovered that it is vital to provide customized therapy for certain malignancies based on patient's genetic composition. For mapping three billion DNA base pairs, researchers can use Hadoop's MapReduce technology to discover the best cancer therapy for individual patients.
- **Fraud Prevention and Detection:** In the first few years, health-based insurance companies used a variety of approaches to detect fraud and develop methods to prevent it. Companies utilize Hadoop to identify fraudsters by using data from prior health claims, voice recordings, earnings, and demographics to create apps based on a prediction model. By combining authentic medical claim bills, real-time Hadoop-based health apps, voice data recordings, weather forecasting data, and other data sources, Hadoop NoSQL database can assist in avoiding medical claim fraud at an early stage.
- **Network in Hospital:** Hadoop NoSQL database is used by various hospitals to accumulate and manage massive volumes of data from a variety of origins linked to patient care, payroll, and finances allowing them to detect risky patients along with deducting daily costs.

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- **Patient's Vital Monitoring:** Using bigdata technologies, hospital employees around the world can connect their job output. Several hospitals in many parts of the world use Hadoop-based components in the Hadoop Distributed File System, such as the Impala, HBase, Hive, Spark, and Flume frameworks, to convert massive amounts of unstructured data generated by sensors that take patient vital signs, heartbeats per minute, blood pressure, blood sugar level, and respiratory rate into structured data. Without Hadoop, these healthcare professionals would be unable to analyze the unstructured data supplied by patient healthcare systems.

1.6.3 Big Data in Public Health and Behavior Research

In public behavior and health, big data concentrates on biological data collected by portable equipment, for instance vitals, electrocardiograms, wearable devices, contagion, and daily health records.

- **Electrocardiogram:** Traditional electrocardiographic tracing investigations are essential for understanding the reasons and mechanisms of arrhythmias and other related disorders; however, the data does not allow for the prediction of the initiation of cardiac damage before it occurs. As a result, new metrics must be established for use in various preclinical cardiovascular diagnoses. The introduction of Big Data which collects higher complexity information characterized by volume, variety, and velocity is making a significant contribution to the control, contrast, and management of big data sets [24].
- **Omics Data:** The term "omics" refers to large records in the molecular and organic sciences (e.g. macrobiotics, metabolomics, proteomics, genomics, etc.). The purpose of using big data is to recognize ill approaches and improve the precision of medical therapy. The advancement of genomics, proteomics, metabolomics, and other kinds of Omics knowledge in earlier eras has resulted in a massive amount of data related to molecular biology [25].

1.6.4 Source of Valuable Data

In the healthcare industry, technological advancements in the utilization of gadgets have brought with them the new possibilities for generating and collecting data. Most data repositories in healthcare, such as those in other industries and organizations, combine data from a diversity of sources, including social media, EHRs, and medical devices [26].

- **EHRs:** In a more organized sense, data in a healthcare facility is stored in EHRs to offer a multifaceted view of patients' records. The EHR is a database of electronic healthcare data that generally pertains to individuals, medical records, and administrative information. Sub-schemes such as admission, discharge, and transfer of patients' schema, recurring engagements and planning schema, the technique for inputting prescription schema, and notes on routine medical checks are all included in a traditional EHR framework [27].
- **Medical Supplies and Equipment:** Medical devices and sensors such as pulse oximeters, blood pressure monitors, glucose monitors, and other sensors generate massive amounts of data that might reveal important information about a patient's physical condition. One of the motivating factors for embracing big data

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in healthcare is the explosion of the Internet of Things and its ability to provide speedy access to medical needs. Body Sensor Networks and their continued application in healthcare will offer healthcare providers the ability to scan critical parameters and, as a result, precisely predict imminent medical hazards such as epidemics and pandemics [28].

- **Social Media:** In the healthcare industry, social media is also a valuable source of information. Patient behavior data and sentiment data on patient recovery are collected. Furthermore, social media posts such as blogs, Twitter feeds, Facebook status updates, and web pages can expose and provide an indicator of a person's health, mood, and state of mind, which is important to health professionals.

1.6.5 Big Data in Medical Experiment

Molecular biology is concerned with the communication and supervision of biological activity inside cells, for example, communications between proteins, RNA, and DNA. It is an important aspect of both biological and medical research. The study of proteins and genes has a secure interaction with the features of genetics and biochemistry. Macromolecule blotting and probing, polymerase chain reaction, molecular cloning, microarrays, and other techniques are used in molecular biology. A person's body comprises organs, tissues, and cells, along with cross-sectional images of tissues and organs, which is used to display the structure of the human body for considering medical measures. Biological laboratory specimens, such as human body data sets, are collected from human bodies and stored in biorepositories. Before a new medicine, vaccine, or piece of medical equipment is used, clinical trials must be performed. A medical experiment is a form of test or study used in clinical or medical research to determine the efficacy of a new medical therapy on humans [29].

1.6.6 Medical Research Using Big Data

Research articles and organized knowledge are currently produced at a rapid rate as the medical/clinical area has developed. There are also a lot of obsolete materials under the clinical/medical section. The study creates a substantial involvement to the subject of big data in healthcare.

1.7 Challenges with Healthcare Data Management

1.7.1 Challenges Associated with Manpower

- **Human Interaction:** Despite technological advancements, there are still some areas where a human could achieve better outcomes than a machine. As a result, humans must be involved at every level of big data analytics. To offer meaningful solutions, experts from various fields (those who understand the problem and data storage) must interact with big data tools. The scarcity of skilled and knowledgeable individuals is once again an impediment to the implementation of big data analytics [30].

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- **Keeping Big Data Experts:** Even though corporations may discover the greatest big data professionals with healthcare experience, hiring them is tough and expensive. Given the severe competition, retaining highly skilled data scientists and analysts is also difficult [17,31].
- **Deficiency of Talent:** When businesses choose to use big data technology, a need for qualified data analysts who can understand healthcare data arises [15]. Data scientists and analysts with experience in the healthcare field and those who can apply the right tools to the data, generate results, and analyze them to give actionable insights are in high demand. However, only a few people have the essential skills and abilities to apply analytics to healthcare [16].

1.7.2 Challenges in Data and Process

- **Data Integrity:** The authenticity and integrity of healthcare data is an issue when combining multiple forms from various origins [1,8,6]. Data from X-rays, physiological pathology reports, bedside monitors, and recordings from various tests may be used to compile patient data. Before analyzing this large amount of data, an information extraction method is required, which extracts the necessary data and delivers in an acceptable format to analyze the data. It's a technical difficulty to guarantee the accuracy and thoroughness of this process. Furthermore, sensor malfunctions and human errors may result in inadequate and incorrect data, which could result in severe health concerns and unpleasant occurrences for patients [11]. Furthermore, errors caused by poor data quality are to blame for increased expenses for healthcare companies. As a result, data cleaning and normalization, which involves removing noise and unnecessary data, is difficult in making effective utilization of data.
- **Big Data Privacy and Security:** Patient record is stored in a variety of places and can be accessed through a variety of endpoints, including medical records, pathology reports, and insurance claim information. To track patient health and enable the transmission of patient data across various parties, a variety of applications are utilized, each with varying levels of security. Out-of-date software can jeopardize the security of health data, leaving it vulnerable to cyber-attacks. Personal information, such as a person's name, occupation, and income, can cost healthcare providers a lot of money if it is accessed and misused [30]. Furthermore, disclosing private health data raises privacy concerns for patients [8,32]. Because of the unconstrained actions of data breaches, managing large data security and privacy remains a technical concern, even with the technical controls and measures in place.
- **Interoperability:** The issue of interoperability occurs when data is generated by multiple healthcare equipment and devices [1,12,5]. Because these devices use different platforms and software, the data they generate is in different formats. To make full use of this data, the devices must be able to interact and exchange data in a common format that is interoperable with other devices.
- **Data Storage and Linkage:** Traditional IT equipment in organizations were not capable to handle such vast amounts of data as the volume of healthcare data rises exponentially [8]. Furthermore, data redundancy difficulties arise as a result of data storage among multiple departments within an organization [9]. Analyzing

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data that is fragmented and incomplete becomes tough. Even the most advanced algorithms fail to cope with disintegrating data. The huge volume and a variety of data from various sources make it difficult to combine and aggregate these sources into repositories [10].

- **Data Collection:** Healthcare data is multidimensional and highly segmented, and it comes from a variety of sources [1]. Due to a lack of synchronization across several data sources, there may be gaps in the information provided. Furthermore, the organization of the data available from these sources varies greatly. Healthcare data, however, contains organized patient's demographic information, physician observations, diagnostic metaphors such as MRI and CT scans, and visuals that are not in a structured format. As a result, bringing together disparate data silos from many sources and transforming them into a uniform format suitable for storage in the system is difficult [14]. Furthermore, continuous data collection is difficult due to real-time or near-real-time data production [8].

1.7.3 Overall Organizational Challenges

- **Actionable Insights at the Right Time:** With correct tools and analytics solutions, big data could manage huge information or data than intuition. Actionable intuitions are much important than simple responses to the questions posed because of the activities they stimulate. As a result, the priority is to gain timely insights that inspire action. Given the importance of timely healthcare choices, another problem to consider is the development of triable information in realtime [33].
- **The Discrepancy in Technology:** Despite the increased interest in healthcare digitization, most businesses continue to rely on outdated technologies. It's a challenge to replace a historical data storage and management system with cutting-edge technology. Due to the large volume of data held in physical records in healthcare, digitalization would necessitate a significant amount of effort, human resources, and time. Another difficult task is to bridge the technological divide [34].
- **Unknown Purpose:** Lack of clarity in the aim of big data analytics to an organization has also become a hurdle in its advancement. Organizations use big data technologies as a source of competitive advantage without clearly defining their business goals. Force-fitting new technologies will result in a lack of direction. It's once again difficult to define the business goals for using big data analytics [35].
- **Identifying Useful Information and Tools:** The next step is to find and store relevant data once firms become familiar with commercial use cases for big data technology. As a result, the appropriate tools for working with such data must be discovered. It's also difficult to figure out what tools and solutions are available.
- **Sharing:** Data sharing is another stumbling block to the successful deployment of big data analytics. Organizations must exchange data with other healthcare organizations to reap the benefits of big data technology for the community. Although more openness and data availability would allow for faster judgments, firms are wary of sharing data due to competitive pressures. This obstructs the effective use of big data analytics in healthcare.
- **Economic:** The most critical initial difficulty for healthcare businesses adopting a data-driven culture is managing the expense of data warehouses and infrastructure required to hold massive amounts of data. In reality, the required

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computational resources also increase initial investment for performing big data analysis. Hence, for small and medium organizations, it would be costly, while major businesses are wary of making such an investment without knowing what they would get in return.

1.8 Conclusion

Big data analytics, which makes use of a plethora of heterogeneous, unstructured, and structured data sources, has a critical responsibility in the future of healthcare. A variety of analytics is already being used to aid the healthcare workers and patients. Genetic data processing, physiological signal processing, and medical image analysis are the major areas of interest. The exponential growth in the volume of healthcare data compels computer scientists to devise novel ways to process such a massive amount of data in a manageable amount of time. Big data analytics brings heterogeneous data together from various domains including medical informatics, medical imaging, sensor informatics, computational biomedicine, bioinformatics, and health informatics. Furthermore, the properties of big data give an excellent foundation in healthcare and medicine for developing applications to use promising software platforms.

Data scientists face hurdles in integrating and implementing a large volume of medical data acquired across multiple platforms. As a result, it is suggested that a healthcare revolution is required to bring analytics, health informatics, and bioinformatics together to encourage tailored and additional effective therapies.

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Preface: Emergent Converging Technologies and Biomedical Systems

This book will provide a platform and aid to the researchers involved in designing systems that will permit the societal acceptance of ambient intelligence. The overall goal of this book is to present the latest snapshot of the ongoing research as well as to shed further light on future directions in this space. The aim of publishing the book is to serve educators, researchers, and developers working in the area of recent advances and upcoming technologies utilizing computational sciences in signal processing, imaging, computing, instrumentation, artificial intelligence, and their applications. As the book includes recent trends in research issues and applications, the contents will be beneficial to professors, researchers, and engineers. This book will provide support and aid to the researchers involved in designing the latest advancements in communication and intelligent systems that will permit the societal acceptance of ambient intelligence. The "Next Generation Technology: Artificial Intelligence in Healthcare and Cyber Intelligent Systems" book encompasses all branches of artificial intelligence, computational sciences and machine learning which are based on computation at some level such as AI-based Internet of things, sensor networks, robotics, intelligent diabetic retinopathy, intelligent cancer genes analysis using computer vision, evolutionary algorithms, fuzzy systems, medical automatic identification intelligence system and applications in agriculture, healthcare, smart grid, instrumentation systems, etc. It presents the latest research being conducted on diverse topics in intelligence technologies with the goal of advancing knowledge and applications in this rapidly evolving field. Authors are invited to submit papers presenting novel technical studies as well as position and vision papers comprising hypothetical/speculative scenarios.

The overall goal of this conference is to present the latest snapshot of the ongoing research in convergent technologies and biomedical systems as well as to shed further light on future directions in this area. Authors were invited to submit papers presenting novel technical studies as well as position and vision papers comprising hypothetical/speculative scenarios. The objective of the International Conference on Emergent Converging Technologies and Biomedical Systems, (ETBS-2021) is to provide a platform for researchers, engineers, and academicians as well as industrial

professionals from all over the world to present their research results and development activities on biomedical engineering and applications.

ETBS-2021 tries to investigate, simulate, and analyze very complex issues and phenomena in a real-life situation. ETBS-2021 aims to,

- Bring the research fraternity together in the field of biomedical engineering and converging technologies.
- Investigate the future prospective directives by employing recent advances.
- Encourage practitioners/researchers to enhance their ability for problem-solving in optimization.

More complex systems arising in biology, medicine, and management systems remain intractable to conventional mathematical and analytical methods. The conference deals with various topics such as imprecision, uncertainty, partial truth, and approximation to achieve tractability, robustness, and low solution cost. It extends its application to various disciplines of engineering and science.

For the proper review of each manuscript, every received manuscript was first checked for plagiarism, and then, the manuscript was sent to three reviewers. In this process, the committee members were involved, and the whole process was monitored and coordinated by the general chair. The technical program committee involved senior academicians and researchers from various reputed institutes. The members were from India as well as abroad. The technical program mainly involves the review of the paper. An overwhelming response was received from the researchers, academicians, and industry from all over the globe. A total of **325** research papers were received, out of which 60 papers were accepted and registered and presented during the three-day conference; acceptance ratio is **18.4%**.

The papers were from PAN India covering all the states like Maharashtra, Uttar Pradesh, Haryana, Punjab, Rajasthan, Sikkim, West Bengal, Tamil Nadu, Kerela, Andhra Pradesh, Madhya Pradesh Delhi, etc. and many international countries like Finland, Siberia, Oman, Bangladesh, USA, etc. The authors are from premium institutes IITs, NITs, Central Universities, PU, and many other reputed institutes.

The editors would like to express their sincere gratitude to general chairs, plenary speakers, invited speakers, reviewers, technical program committee members, international advisory committee members, and local organizing, committee members of ETBS-2021, without whose support, the quality and standards of the conference could not be maintained. Editors would like to express their deepest sense of gratitude to the Patron and Presiding Chair of the conference ETBS-2021 **Prof. (Dr.) Som Nath Sachdeva**, Honorable Vice-Chancellor, Kurukshetra University, Kurukshetra; Chief Guest **Prof. Rajive Kumar**, Member Secretary, AICTE; Guest of Honor "**Ms. Kamiya Khatter**," Editor at Springer Nature, Applied Sciences and Engineering; and Keynote Speakers **Dr. Ahmed A. Elngar**, Associate Professor of Computer Science Beni-Suef University, Faculty of Computers and Artificial Intelligence, Egypt; **Dr. Utku Kose**, Associate Professor, in Suleyman Demirel University, Turkey; and **Dr. Celia Shahnaz**, Professor, Department of EEE, BUET, Bangladesh. A special thanks

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Abbreviations

%	Percent
3D	Three-dimensional
4aPEONB	4-arm PEO norbornene
AAL	Allyl alcohol
Amim	1-allyl-3-methyl imidazolium
AMP	Allyl mercaptan
BABP	Bili acid-binding protein
BEA	2-Bromoethylamine
bFGF	Basic fibroblast growth factor
Bmim	1-butyl-3-methyl imidazolium
BOD	Biochemical oxygen demand
BSA	Bovine serum albumins
BSCA	Bromosuccinic acid
C_2C_{12}	Myofibroblast skin cell line
CAA	Monochloro acetic acid
CO_2	Carbon dioxide
COD	Chemical oxygen demand
DALS	Dialdehyde starch
DEP	Diethyl phosphate
DES	Deep eutectic solvents
DFP	Diisopropyl fluorophosphates
DFUs	Diabetic foot ulcers
DMF	Dimethylformamide
DMLS	Direct metal laser sintering
DMSO	Dimethyl sulfoxide
DO	Dissolved oxygen
DOX.HCl	Doxorubicin hydrochloride
DTT	Dithiothreitol
ECM	Extracellular matrix
EDTA	Ethylenediaminetetraacetic acid

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EG	Ethylene glycol
EGDE	Ethylene glycol diglycidyl ether
Emim	1-ethyl-3-methyl imidazolium
FAL	Formaldehyde
FDA	Food and drug administration
FDM	Fused deposition modeling
FTIR-ATR	Fourier transform infrared spectroscopy-attenuated total reflection
GAL	Glutaraldehyde
GDE	Glycerol diglycidyl ether
GLX	Glyoxal
GNP	Genipin
HA	Hyaluronic acid
HFIP	Hexafluoroisopropanol
IAA	Iodoacetamide
IAC	Iodoacetic acid
IF	Intermediate filaments
ILs	Ionic liquids
ISO	International organization for standardization
KCN	Potassium cyanide
KH	Keratin hydrolysates
LMW	Low molecular weight
LS	Low sulfur content
MEC	Mercaptoethanol
MMP	Metalloproteinases
MSH	O-(2,4,6-trimethyl benzene sulfonyl) hydroxylamine
MW	Molecular weight
MWCO	Molecular weight cut-off
NEM	N-Ethylmaleimide
NFs	Nanofibers
nKer	Keratin nanoparticles
NPs	Nanoparticles
OSPW	Oil sand process affected water
OVAT	One variable at a time
PA6	Polyamide-6
PBS	Phosphate-buffered saline
PCA	Poly-e-caprolactone
PCL	Poly(ε-caprolactone)
PDA	Polydopamine
PDLA	Poly-*d*-lactic acid
PE	Polyethylene
PEG	Polyethylene glycol
PEGDE	PEO diglycidyl ether
PEI	Polyethylenimine
PEO (or PEG)	Polyethylene oxide (or Polyethylene glycol)

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PEOMEM	PEO methyl ether methacrylate
PG	Propylene glycol
PGA	Polyglycolic acid
PGPR	Plant growth-promoting rhizobacteria
PHA	Polyhydroxyalkanoates
PHB	Polyhydroxybutyrate
PHBV	Poly(3-Hydroxybutyrate-co-3-hydroxyvalerate)
pKi	Isoelectric point
PLA (or PLLA)	Polylactic acid
PLGA	Poly(lactic-co-glycolic acid)
PLLA	Poly-*l*-lactic acid
PNPAMM	P(NIPAM)n-NH-maleimide
POSS	Polyhedral oligomeric silsesquioxanes
PP	Polypropylene
PPG	Polypropylene glycol
PS	Polystyrene
PVA	Polyvinyl alcohol
PVP	Polyvinylpyrrolidone
R′3P	Phosphines
RSM	Response surface methodology
SDS	Sodium dodecyl sulfate
SDS–PAGE	Sodium dodecyl sulfate–polyacrylamide gel electrophoresis
SE	Steam explosion
SEM	Scanning electron microscope
SFE	Steam flash explosion
SLA	Stereolithography
SLS	Selective laser sintering
TCEP	Tris(2-carboxyethyl)phosphine
TDI	Toluene diisocyanate
TFA	Trifluoroacetic acid
TFE	Trifluoroethanol
TGA	Thermogravimetric analysis
TLCK	Tosyl phenylalanyl chloromethyl ketone
UV	Ultraviolet
UVB	Ultraviolet B
VOCs	Volatile organic compounds

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Large-Scale Data Streaming, Processing, and Blockchain Security

Hemraj Saini
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Data processing has become an important field in today's big data-dominated world. The data has been generating at a tremendous pace from different sources. There has been a change in the nature of data from batch-data to streaming-data, and consequently, data processing methodologies have also changed. Traditional SQL is no longer capable of dealing with this big data. This chapter describes the nature of data and various tools, techniques, and technologies to handle this big data. The chapter also describes the need of shifting big data on to cloud and the challenges in big data processing in the cloud, the migration from data processing to data analytics, tools used in data analytics, and the issues and challenges in data processing and analytics. Then the chapter touches an important application area of streaming data, sentiment analysis, and tries to explore it through some test case demonstrations and results.

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Preface

Medical informatics, also known as healthcare analytics, is a useful tool that can assess and monitor health-related behavior and conditions of individuals outside the clinic. The benefits of medical informatics are significant, including improving life expectancy, disease diagnosis, and quality of life. In many individual situations, a patient requires continuous monitoring to identify the onset of possible life-threatening conditions or to diagnose potentially dangerous diseases. Traditional healthcare systems fall short in this regard.

Meanwhile, rapid growth and advances have occurred in the digitization of information, retrieval systems, and wearable devices and sensors. Our times demand the design and development of new effective prediction systems using machine learning approaches, big data, and the Internet of Things (IoT) to meet health and life quality expectations. Furthermore, there is a need for monitoring systems that can monitor the health issues of elderly and remotely located people. In recent times, big data and IoT have played a vital role in health-related applications, mainly in disease identification and diagnosis. These techniques can provide possible solutions for healthcare analytics, in which both structured and unstructured data are collected through IoT-based devices and sensors. Machine learning and big data techniques can be applied to collected data for predictive diagnostic systems. However, designing and developing an effective diagnostic system is still challenging due to various issues like security, usability, scalability, privacy, development standards, and technologies. Therefore machine learning, big data, and IoT for medical informatics are becoming emerging research areas for the healthcare community.

Outline of the book and chapter synopses

This book presents state-of-the-art intelligent techniques and approaches, design, development, and innovative uses of machine learning, big data, and IoT for demanding applications of medical informatics. This book also focuses on different data collection methods from IoT-based systems and sensors, as well as preprocessing and privacy preservation of medical data. We have provided potential thoughts and methodologies to help senior undergraduate and graduate students, researchers, programmers, and healthcare industry professionals create new knowledge for the future to develop intelligent machine learning, big data, and IoT-based novel approaches for medical informatics applications. Further, the key roles and great importance of machine learning, big data, and IoT techniques as mathematical tools are elaborated in the book. A brief and orderly introduction to the chapters is provided in the following paragraphs. The book contains 23 chapters.

Chapter 1 presents a survey of machine learning and predictive analytics methods for medical informatics. This chapter focuses on deep neural networks with typical use cases in computational medicine, including self-supervised learning scenarios: these include convolutional neural networks for image analysis, recurrent neural networks for time series, and generative adversarial models for correction of class imbalance in differential diagnosis and anomaly detection. The authors then continue by assessing salient connections between the current state of machine learning research and data-centric healthcare analytics, focusing specifically on diagnostic imaging and multisensor integration as crucial research topics within predictive analytics. Finally, they conclude by relating open problems

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of machine learning for prediction-based medical informatics surveyed in this article to the impact of big data and its associated challenges, trends, and limitations of current work, including privacy and security of sensitive patient data.

Chapter 2 presents a proposed model for geolocation aware healthcare facility with IoT, Fog, and Cloud-based diagnosis in emergency cases. An end-to-end infrastructure has been modeled for the healthcare system using geolocation-enabled IoT, fog, and cloud computing technology to identify the nearest hospital or medical facility available to the patient. It has also achieved 25%–27% less delay and 27%–29% less power consumption than the cloud-only environment.

Chapter 3 aims to capture the status of medical computer vision threats and the recent defensive techniques proposed by researchers. This chapter intends to shed light on the vulnerability of machine learning models in medical image analysis, e.g., disease diagnosis, and to become a guide for any researcher working in medical image analysis toward the development of more secure machine learning-based computer-aided diagnosis systems.

Chapter 4 demonstrates a model for skull stripping and tumor detection from brain images using 3D U-Net. The demonstrated model has been tested over 373 MRIs of the LCG Segmentation Dataset, showing good standard performance over metrics of dice coefficient, and the accuracy results are competitive with the existing methods.

Chapter 5 addresses the issue of corrupted laparoscopy video by haze, noise, oversaturated illumination, etc., in minimally invasive surgery. To effectively address the issue, the authors have proposed a novel algorithm to ensure the enhancement of video with faster performance. The proposed C^2D^2A (Cross Color Dominant Deep Autoencoder) uses the strength of (a) a bilateral filter, which addresses the one-shot filtering of images both in the spatial neighborhood domain and psycho-visual range; and (b) a deep autoencoder, which can learn salient patterns. The domain-based color sparseness has further improved the performance, modulating the classical deep autoencoder to a color dominant deep autoencoder. The work has shown promise toward providing a generic framework of quality enhancement of video streams and addressing performance. This, in turn, improves the image/video analytics like segmentation, detection, and tracking the objects or regions of interest.

Chapter 6 presents an alternative way of estimating respiratory rate from ECG and PPG by using machine learning to improve estimation accuracy. The proposed methods are based on respiratory signals extracted from raw signals and use a support vector machine (SVM) and neural network (NN) to estimate respiratory rate. The proposed methods achieve comparable accuracy to current methods when the number of classes is low. Once the number of classes increases, the accuracy drops significantly.

Chapter 7 serves as an introductory guideline to address the challenges and opportunities while designing machine learning-enabled Healthcare Internet of Things (H-IoT) networks. It provides a discussion on traditional H-IoT, challenges, and opportunities in the Network 2030 paradigm. It also discusses potential machine learning techniques compatible with H-IoT and points out open issues and future research directions.

Chapter 8 presents a skin lesion segmentation approach based on the Elitist-Jaya optimization algorithm. The proposed method contains two stages: image preprocessing and edge detection. The experimental sample consists of a set of 320 images from the skin lesion dataset. The outcomes proved that the proposed approach improved the segmentation accuracy of the affected skin lesion area and outperformed the compared methods.

Chapter 9 provides its readers with an all-encompassing review that will enable a clear understanding of the current trends in glove-based gesture classification and provide new ideas for further research. The

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authors have analyzed deep learning approaches in terms of their current performance, advantages over classical machine learning algorithms, and limitations in specific classification scenarios. Furthermore, they present other deep learning approaches that may outperform current algorithms in glove-based gesture classification.

Chapter 10 presents an ensemble approach for evaluating the cognitive performance of the human population at high altitude. The authors identify the key multidomain cognitive screening test (MDCST) and clinical features among the lowlander ($\leq$350 m) and highlander ($\geq$1500 but $<$4300 m) populations, staying at an altitude $\geq$4300 m for a prolonged duration. A goodness-of-fit test was applied to the two population cohorts for identifying significant independent measures. Rule-based mining was followed to discover associative rules between the clinical, behavioral, and cognitive screening parameters. Conclusively, a unique set of association rules have been identified with at least 30% support and more than 60% confidence in behavioral and clinical features associated with the cognitive parameters.

Chapter 11 presents the role of machine learning in expert systems for disease diagnostics in human healthcare. The authors discuss essential existing expert systems for human disease diagnosis in detail. They also provide a brief evaluation of various techniques used for the development of expert systems.

Chapter 12 presents an entropy-based hybrid feature selection approach for medical datasets. A stable linear-time entropy-based ensembled feature selection approach is introduced, mainly focusing on medical datasets of several sizes. The suggested approach is validated using three state-of-the-art classifiers, namely C4.5, naïve Bayes, and JRIP, over 14 benchmark medical datasets (drawn from the UCI machine learning repository). The empirical results achieved from the datasets demonstrate that the proposed ensemble model outperforms the selected learners.

Chapter 13 shows how to utilize machine learning algorithms to create models that can predict healthcare systems' critical issues. The chapter's discussion relates to the COVID-19 pandemic and highlights the solutions offered by machine learning in such scenarios. The chapter also highlights the significance of feature engineering and its impact on machine learning models' accuracy. The chapter ends with two case studies. The first case study shows how to build a prediction model that can predict the number of diabetic patients who will visit certain hospitals in a specific geographic location in future years. The second case study analyzes health records during the COVID-19 pandemic.

Chapter 14 presents an interpretable semisupervised classifier for predicting cancer stages. Authors illustrate the self-labeling gray-box applications on the omics and clinical datasets from the cancer genome atlas. They show that the self-labeling gray-box is accurate in predicting cancer stages of rare cancers by leveraging the unlabeled instances from more common cancer types. They discuss insights, the features influencing prediction, and a global representation of the knowledge through decision trees or rule lists, which can aid clinicians and researchers.

Chapter 15 presents an overview of applications of blockchain technology in smart healthcare. The authors overviewed the fundamental blockchain concepts and applications to be used for different aspects of the smart healthcare industry and proposed a live patient monitoring system by deploying blockchain technology in the model. Keeping an eye on recent technologies in connected healthcare, they finally presented various research factors and potential challenges where blockchain technologies can play an outstanding role in realizing the concept of smart optimization in the healthcare industry.

Chapter 16 focuses on clustering and classification techniques for the prediction of leukemia. The proposed work consists of Phase I, which will be dealing with the collection of datasets and visualization of datasets, whereas Phase II will be dealing with the machine learning and data mining

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techniques for the prediction of leukemia disease. The authors claim that the proposed techniques would give higher performance than the existing techniques.

Chapter 17 presents a performance evaluation of fractal features toward seizure detection from electroencephalogram signals. The authors have evaluated the ability of three well-known fractal dimension feature extraction methods (the Katz fractal dimension, Higuchi fractal dimension, and Petrosian fractal dimension) to classify epileptic and nonepileptic electroencephalogram signals. The features are fed to an SVM classifier for the classification of epileptic and nonepileptic electroencephalogram signals. The SVM classifier results show that the fractal features are good measures to characterize the complex information of epileptic signals.

Chapter 18 presents an integer period discrete Fourier transform-based algorithm to identify tandem repeats in the DNA sequences. The authors have discussed the importance of tandem repeats in diverse applications. They proposed an integer period discrete Fourier transform (IPDFT)-based algorithm to detect the tandem repeats in DNA sequences. A comparison of the proposed algorithm's performance has also been made with existing methods.

Chapter 19 discusses the scope, applicability, and usage of blockchain technology to preserve patients' sensitive medical data. A framework is also proposed that allows patients and hospitals to store medical records. The framework allows patients to share the information by providing access to their data and by invoking smart contracts for automatic payments for their medical claims.

Chapter 20 presents a novel approach to securing e-health applications in the cloud environment. The authors provide an algorithm to secure data in e-health applications in the cloud environment. A new architecture for e-health applications in the cloud environment is proposed, which will provide application-level security and server-level security using certificates.

Chapter 21 presents different ensemble learning algorithms and explains how these algorithms can be used to classify health disorders. The authors have discussed an ensemble classifier approach for thyroid disease diagnosis using the AdaBoostM algorithm.

Chapter 22 presents a review of the latest artificial intelligence research in this immense medical science field, including various architectures and approaches, with special attention given to brain tumor analysis. The authors discuss various deep learning architectures used to diagnose brain tumors and compare results with existing architectures. They have examined case studies from basic clustering techniques such as K-means clustering to fuzzy and neurotrophic C-means clustering techniques and kernel graph cuts (KGC) to advanced artificial intelligence techniques such as deep convolution neural networks (DCNs), atrous convolution neural networks (ACNs), and unit architectures to find the area of interest in the coherent/incoherent regions.

Finally, Chapter 23 focuses on machine learning in precision medicine. An overview of how machine learning is used in precision medicine and its potential use in the detection, diagnosis, prognosis, risk assessment, therapy response, and discovery of new biomarkers and drug candidates is presented in this chapter.

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List of Abbreviations

AES	Advanced Encryption Standard
ASCII	American Standard Code for Information Interchange
BCH	Bose, Chaudhuri, and Hocquenghem
BER	Bit error rate
CDMA	Code division multiple access
CS	Compressed sensing
DCT	Discrete cosine transform
DFT	Discrete Fourier transform
DIBR	Depth-image-based rendering
DICOM	Digital Imaging and Communications in Medicine
DWPT	Discrete wavelet packet transform
DWT	Discrete wavelet transform
ECC	Error-correcting codes
EPR	Electronic patient record
GA	Genetic algorithm
HMM	Hidden Markov model
HVS	Human visual system
ICA	Independent component analysis
ICT	Information and communication technology
IWT	Integer wavelet transform
LSB	Least significant bit
LZW	Lempel–Ziv–Welch
MPEG	The Moving Picture Experts Group
MSE	Mean square error
NC	Normalized correlation
NROI	Non-region of interest
NVF	Noise visibility function
PCA	Principal component analysis
PN	Pseudorandom noise
PSNR	Peak signal-to-noise ratio
QF	Quality factor

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ROI	Region of interest
SNR	Signal-to-noise ratio
SPIHT	Set partitioning in hierarchical trees
SVD	Singular value decomposition
SVM	Support vector machine
WBCT	Wavelet-based contourlet transform

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Microbial Exopolysaccharides as Novel and Significant Biomaterials

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Microbial Exopolysaccharides: An Introduction



Kuttuvan Valappil Sajna, Swati Sharma, and Ashok Kumar Nadda

Abstract Microbes secrete high molecular-weight polysaccharides of diverse structures into the surrounding environment termed exopolysaccharides (EPSs). EPSs serve multifarious roles which aid the microbes to thrive at different ecosystems. Many EPSs are industrially/clinically relevant polymers owing to their biocompatibility, biodegradability, non-toxic nature and distinct physicochemical properties. Considering their past success for various applications ranging from hydrocolloids to biomedical applications, microbial EPSs still hold considerable attention of biotechnologists. They are high-value products, and their market value will grow in the coming years due to their potential nutraceutical, therapeutic and industrial potential. The objective of the chapter is to update the readers with recent findings on microbial EPSs. This chapter also gives interesting insights into physiological roles and biosynthesis of microbial EPS. The chapter also discusses the recent advances in applications of microbial EPSs and their commercial prospects.

Keywords Microorganisms · Polysaccharides · Hydrocolloids · Polymers · Biomedical application

1 Introduction

Microbes are the source of many biotechnological products due to their metabolic diversity and ease of cultivation. One such product-exopolysaccharides (EPSs) are widely used as the polymers in various industries owing to distinct physicochemical

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properties, non-toxic nature, biocompatibility, biodegradability and the ease of production. Microbial polysaccharides are of two types—intracellular polysaccharides and extracellular polysaccharides. Extracellular polysaccharides are further classified into capsular polysaccharides that encapsulate the microbes (exocellular polysaccharide) and exopolysaccharide (EPS) which secreted into the surrounding environment [1]. Intracellular polysaccharides are the storage polysaccharides serving as a rapid carbon source under nutrient deprivation [2]. Capsular polysaccharides play a significant role in microbial pathogenesis. The immunogenic property of capsular polysaccharide makes them a good target for vaccine development [3]. EPSs play diverse roles from biofilm formation to pathogenesis.

The first EPS discovered was dextran by Louie Pasteur in the nineteenth century as a microbial product in the wine industry [4]. The contribution by Allene Jeanes in the mass level production of dextran and discovery of xanthan revolutionized the industrialization of microbial EPS. EPSs are high molecular weight compounds with the molecular weight ranging from 0.5 × 106 to 2 × 106 daltons. EPSs may be of homopolymeric or heteropolymeric in sugar composition and can be linear or branched, structurally [5]. Apart from the monosaccharide composition and structural complexity of EPSs, EPSs may contain functional groups such as acetyl, carboxyl, sulfate, phosphate, pyruvate and uronic acid groups, which all determine the physicochemical and biological properties of EPSs.

Microbial EPSs are inevitable for modern human lifestyle as the ingredient in food and personal care formulations. They have immense clinical applications including emergency medicine or an ingredient in pharmaceutical formulations. They are also used extensively in the petroleum industry, household product formulations and construction applications. Considering the current R&D scenario in microbial EPS, their clinical, lifestyle and other implications will be accentuated in the near future. Table 1 summarizes commercially available microbial EPS with potential industrial/clinical applications.

2 Novel Exopolysaccharides with Therapeutic/Industrial Significance

Considering the past success of EPSs for various applications ranging from hydrocolloids to biomedical applications, exopolysaccharide still holds considerable attention of biotechnologists. Many novel EPSs with significant clinical/industrial applications have been reported in the last decade (Table 2). Some of these microbial sources are already known for EPS production. Novel variation in EPS can be pinpointed by investigating the monosaccharide composition of EPS. Strain-specific EPS is encoded by unique EPS biosynthetic genes. Diversity of epsE gene in *Lactococcus lactis* strains result in strain-specific EPS production [25]. Some of the most common sources for the isolation of EPS producing microbes are dairy products, fermented products and plant parts. Identification of lactic acid bacteria

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Table 1 Summarizes commercially available microbial EPS with potential industrial/clinical applications

EPS	Microbial strain	Structure	Industrial/ clinical uses	References
Dextran	*Leuconostocmesenteroids*	α-1,6-Glucan with branching of α-1,3-glycosidic linkage	Clinical applications—plasma volume extender, antithrombotic agent, blood substitute, vascular surgery, drug delivery agent, clinical management of iron deficiency anaemia, preservation solution for organs, and wound healing agent. Other uses—food packaging, photographic uses, separation technology, cell culture techniques and cryoprotectant agent	De Belder [6], Bhavani and Nisha [7], Abir et al. [8], Debele et al. [9], Rutherford et al. [10], Aman et al. [11], Candinas et al. [12], Zhu et al. [13]
Xanthan	*Xanthomonas campestris*	A polymer of D-glucose, D-mannose and D-glucuronic acid	Additive in food, medical and personal care formulations; used as drilling fluid in oil field drilling and building materials for construction applications	BeMiller [14], Akpan et al. [15, Plank [16]
Pullulan	*Aureobasidium pullulans*	Glucan of α-(1-6) and α-(1-4) glycosidic linkage	Food and pharmaceutical additive; oral care ingredient	Singh et al. [17]

(continued)

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Table 1 (continued)

EPS	Microbial strain	Structure	Industrial/ clinical uses	References
Gellan	*Sphingomonas elodea*	A polymer of tetrasaccharide units comprised of D-glucose, D-glucuronic acid, D-glucose L-rhamnose	Food, pharmaceutical and personal care formulation; an additive in household products; also used in tissue culture media preparations	Iurciuc et al. [18]
Curdlan	*Agrobacterium* sp.	(1-3)-β-glucan	Food additive; used in pharmaceutical formulation and drug delivery system	Zhang and Edgar [19]
Scleroglucan	*Sclerotium rolfsii*	β-1,3-β-1,6-glucan	Petroleum recovery; used in nutraceutical and pharmaceutical industry; in food and personal care formulations; construction applications	Castillo et al. [20]
Schizophyllan	*Schizophyllum commune*	β-1,3-β-1,6-glucan	Therapeutic application, cosmetic application	Leathers et al. [21]
Bacterial cellulose	*Acetobacter xylinum*	β-1-4 glucan	Hydrocolloid dressing; cosmetic and textile industrial application	Wang et al. [22–24]

secreting a novel EPS composed of unusual monomer like *N*-acetylglucosamine from a fig leaf highlight the importance of bioprospecting of environmental source such as these for EPS producers [26]. Exploring the ecological hotspots and extreme environments can lead to the discovery of the microbes producing novel EPS with significant biotechnological implications. Delbarre-Ladrat et al. [27] that the majority of bacterial species inhabiting deep-sea hydrothermal vents has the potential of producing structurally diverse high-value EPS, which emphasized the bioprospecting of marine environment for EPS producing microbes.

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Table 2 Novel EPS of therapeutic/industrial significance

EPS	Source organism	Monomeric composition	Potential application	Reference
EPS-NA3	*Lactobacillus coryniformis*	α-rhamnose, α-mannose, α-galactose, and α-glucose	Antioxidant and antibiofilm agents	Xu et al. [28]
α-mannan	*Pseudoalteromonas* SM20310	2-α- and 6-α-mannose	Cryoprotection	Liu et al. [29]
EPS-1 and EPS-2	*Bacillus amyliliquefaciens C-1*	Glucose, mannose, galactose and arabinose (EPS-1); Glucose and mannose (EPS-2)	EPS-1 as an antioxidant agent	Yang et al. [30]
Neutral EPS	*Lactobacillus paracasei* IJH-SONE68	*N*-acetylglucosamine	Anti-inflammatory agent	Noda et al. [26]
Acidic EPS	*Lactobacillus plantarum* SN35N	Glucose, galactose, and mannose	Anti-inflammatory agent	Noda et al. [31]
Pseudozyma EPS	*Pseudozyma* sp. NII 08165	Glucose, galactose, and mannose	Emulsifying and suspending agent	Sajna et al. [32, 33]
DM-1 EPS	*Bacillus licheniformis* strain DM-1	Proteoglycan	In situ microbial enhanced oil recovery	Fan et al. [34]
EPS	*Lactobacillus fermentum* R-49757	D-glucose and D-mannose	Not investigated	Do et al. [35]
EPS-S3	*Pantoea* sp. YU16-S3	Glucose, galactose, *N*-acetyl galactosamine and glucosamine	Wound healing applications	Sahana and Rekha [36]
EPS	*Lactobacillus paraplantarum*	Glucose, galactose and mannose	Emulsifying and texturing agent	Sharma et al. [37]
EPS-SN-1	*Bacillus velezensis SN-1*	Glucose, mannose and fructose	Antioxidant agent	Cao et al. [38]
EPS	*Bifidobacterium breve* Iw01	Rhamnose, arabinose, galactose, glucose, and mannose	Anticancer activity	Wang et al. [22–24]
Nat-103	*Natronotaleasambharensis* AK103^T	Mannose, glucose and glucuronic acid	Antioxidant activity	Singh et al. [39]
EPS	*Lactobacillus mucosae* VG2	D galactan	Not investigated	Fagunwa et al. [40]

3 Physiological Roles and Ecological Aspects of EPS

EPS serve multifarious roles which aid the microbes to thrive in different ecosystems. EPS plays a varying role from biofilm formation, quorum sensing to pathogenesis and the functions depend on ecological niche of host organisms. Physiological roles of EPS are unravelled using the approach of knocking out EPS biosynthetic genes to create mutant deficiencies in EPS production. Pullulan

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produced by a desert isolate *Aureobasidium melanogenum* confers adaptation for living in the harsh desert environment by protecting from various abiotic stresses [41]. EPS produced by an arctic sea isolate *Pseudoalteromonas* strain SM20310, plays a significant role in environmental adaptation of strain in sea ice by providing high salinity tolerance and cryoprotection [29]. EPS has implication in the protection of plant growth-promoting *Rhodotorula* sp. from adverse environmental conditions [42]. Similarly, pH buffering property of cyanobacterial EPS matrix protects the dryland cyanobacteria from acid damage [43].

On solid surfaces, EPS facilitates the growth of bacterial communities as biofilm by leading bacterial cell adhesion and bacterial cell aggregation. Caro-Astorga et al. [44] revealed that each EPS produced by *Bacillus cereus* serve distinct roles. EPS1 contributes to bacterial motility, while EPS2 is involved in biofilm formation and gut colonization, thus playing a role in host-pathogen interaction. Being an integral part of biofilm, EPS makes the bacterial colonies recalcitrant to a wide range of antimicrobial agents. During the biofilm formation by *Pseudomonas aeruginosa*, production of matrix EPS 'psl' and the intracellular signalling molecule 'c-di-GMP' that stimulates the synthesis of biofilm matrix EPS is in the feedforward control loop. Hence, targeting the biofilm signalling mechanism can be an effective strategy to tackle chronic *P. aeruginosa* infections [45]. Another EPS, pel is cationic and hold the extracellular DNA in the biofilm matrix, apart from being the structural element of biofilm [46].

Studies on EPS produced by *Lactobacillus* species revealed the role of EPS in bacterial surface properties and host interaction. EPS affected the surface properties such as colony phenotypes and bacterial surface charge. Gene deletion studies revealed that EPS plays a significant role in bacterial cell aggregation. Concealing the surface structure with EPS might be one of the tactics to reduce the cell-cell interaction and the role of EPS in host cell interaction is strained specific [47–49]. EPS 1, a major virulence factor of a phytopathogenic bacteria *Ralstonia solanacearum* regulate the feedback loop of quorum sensing [50].

In the case of lactic acid bacteria, EPS protect the bacteria from bacteriophage, nisin and lysozyme [51]. EPS is the major arsenal for microbes to compete with each other for food and space. Toska et al. [52] suggested that EPS is involved in the antagonistic interaction between bacterial species and lead to the successful establishment of bacterial communities. In Gram negative bacteria such as *Vibrio cholerae*, EPS protect bacteria from other bacterial attacks by inhibiting the type 6-secretion system (T6SS). Type 6 secretion system by gram-negative bacteria is used to deliver the toxic protein into adjacent eukaryotic and bacterial cells. Deletion of EPS biosynthetic genes makes the *V. cholerae* more susceptible to T6SS attack by heterologous bacteria. On other hand, the same EPS of *V. cholerae* will not affect its T6SS attack on other bacteria [52].

EPS plays an important role in the establishment of plant microbial symbiosis. Plant root attachment of nitrogen-fixing bacteria *Paraburkholderia phymatum* is determined by the production of an EPS, cepacian [53]. Plant-growth promoting soil-borne *P. aeruginosa*, *P. syringae*, *P. putida*, and *P. fluorescens* produce EPS 'alginate'. Alginate play an important role in Zn^{2+} biosorption and phenazine

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biosynthesis, a biocontrol agent produced by fluorescent *Pseudomonas* strain. Increased alginate production affects the rhizosphere compatibility with improved biofilm formation and enhanced root colonization [54]. EPS helps to maintain the spore physiology and improve spore survival. *pzX* is an eps exclusively produced during sporulation of *Bacillus* species. Composition of amino sugar provides unique properties to *pzX* like lowering the surface tension and inhibiting cell-spore aggregates formation [55]. Metagenomic analysis of biological soil crust showed the presence of EPS and lipopolysaccharide (LPS) producing bacterial species. Here, EPS and LPS act as soil glue for soil aggregate formation that aid the formation of biological soil crust [56].

EPS plays a crucial role in etiology of dental caries. Demineralization of teeth by cariogenic biofilms leads to the formation of the oral cavity. In the presence of carbohydrates, cariogenic microbes produce organic acids that leach calcium from the teeth. A study showed that cariogenic microbes such as *Streptococcus mutans*, *Lactobacillus rhamnosus*, and *Candida albicans* produce EPS that have a high calcium-binding affinity, which attributes to the calcium tolerance of the microbes. Apart from structural anchorage to the biofilm, EPS also serve as a survival tool of cariogenic microbes to defuse high calcium concentration [57]. Targeting EPS can be an effective strategy to control cariogenic microbes [58]. However, in the case of catheter-associated urinary tack infection, EPS secreting *P. aeruginosa* adopt exopolysaccharide independent biofilm formation [59]. Hence, understanding the role of microbial EPS is crucial for developing therapeutic interventions against pathogenic microbes in which EPS production can be targeted. Furthermore, ecological functions of microbial EPSs promote their huge agronomical implications.

4 Biosynthesis and Metabolic Regulations of EPSs

Functional genomics analysis provides valuable information on EPS biosynthesis, export, and regulation. Identifying the gene targets can pave the ways to engineer high EPS producing strains or strains that produce tailor-made EPS [60]. Genomic analysis of microbes can reveal microbial potential to produce unknown exopolysaccharides. Borlee et al. [61] identified a novel EPS biosynthetic gene cluster involved in biofilm formation of *Burkholderia pseudomallei*. Genome annotation of EPS producing thermophilic bacteria *Geobacillus* may improve its prospects as a microbial cell factory for EPS production [22–24]. Padmanabhan et al. [62] studied differential gene expression during EPS biosynthesis by *Streptococcus thermophilus* ASCC 1275 in different sugar-containing media at stationery and log phases. They observed a correlation between high EPS production and upregulation of genes involved in sugar metabolism. A similar observation of increased UDP-glucose and UDP-galactose synthesis associated with a high yield of EPS, by *S. thermophilus* S-3 was reported by Xiong et al. [63]. Proteomic analysis revealed that upregulation of proteins involved in sugar

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transport, EPS assembly and amino acid metabolism was also associated with high EPS production [62, 64].

Availability of whole genome sequence of EPS producing microbes facilitates the metabolic engineering strategies for EPS production [65]. Evaluation of EPS production by gene knockout mutants, gene overexpression mutants and gene complementation mutants of EPS biosynthetic genes can shed light on the role of each EPS biosynthetic genes in EPS production [66]. CRISPR-Cas9 genome editing had enabled researchers to produce EPS variants with different monomeric composition from *Paenibacillus polymxa.* These EPS variants can give insights into the structure-function relationship of polysaccharides and aid to create customized EPS with desirable properties [67]. *Xanthomonas campestris* strains were engineered to produce xanthan gum variants with distinct secondary structure and rheological properties, which may be suitable for application in various industries. Structure-activity relationship of these tailor made-xanthan gums revealed that terminal mannose is one of the major determinants of rheological properties of xanthan gum, while the terminal mannose and internal acetyl group are integral to its double-helical conformation [68]. Genome editing and metabolic engineering could yield tailor-made EPS with improved stability and higher performance, which can have huge commercial potential when compared to native EPS.

5 Applications and Commercial Prospects of EPS

Due to the presence of a large number of hydroxyl groups, microbial EPS have been long used as hydrocolloids, which modify the rheology of the system by altering the flow behaviour and texture. In food and personal care industry, they serve as a thickening, gelling, stabilizing, emulsifying and water-binding agents [69, 70]. Xanthan gum is a widely used thickener in food formulation. In food and confectionary, xanthan gum has become more prominent in recent years due to its status as vegan-friendly. In gluten-free baking, xanthan gum provides structure and elasticity to dough or batter, and as an egg substitute, it emulsifies and thickens the food preparations. Xanthan gum based thickened fluid appears promising for treatment of patients with oropharyngeal dysphagia. Apart from safety and efficacy, it is resistant to α-amylase and preferred by patients, when compared to starch-based thickener [71, 72]. The concentration, type and setting time of xanthan gum-based food thickeners are the main factors in designing the infant food formulation used for paediatric dysphagia [73]. Gellan gum exhibit excellent gelling properties. To overcome the limitation of the gellan gum such as low mechanical strength and high gelation temperature, blending with natural or synthetic polymer has been employed [74]. Synergistic hydrogels of xanthan gum and gellan gum with other natural polymers are promising for the preparation of food packaging materials [75].

Antioxidant property and water-absorbing/retention properties are some of the features of EPS attractive for cosmetic applications [76]. 'Lubcan' an EPS with

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remarkable skin lubricating property produced by *Paenibacillus* sp. ZX1905 could be a low-priced replacement of hyaluronic acid in cosmetic formulations [77]. Extremophilic microbes may provide EPS with excellent keratinocyte protective ability from temperature or radiation-induced damage. An EPS of momomers-*N*-acetyl glucosamine, mannose and glucuronic acid produced by an artic marine bacterium *Polaribacter* sp. SM1127 could be an excellent cosmetic ingredient as it is dermatologically safe, possess better moisture retention properties than hyaluronic acid and good antioxidant activity, and protect human dermal fibroblast from low temperature-induced damage [78]. Radiation-resistant *Deinococcous radiodurans* derived EPS (deinopol) protect keratinocytes from radiation-induced ROS damage [79].

Potential bioactivities reported for EPS include antitumor, antioxidant, immunomodulatory, antiviral, antibacterial, anti-inflammatory, and cholesterol-lowering properties. Consumption of bioactive EPS can have potential health benefits [80]. Antitumor property of EPS stems from its ability to modulate oncogenic pathways. EPS produced by many lactic acid bacteria can induce apoptosis and cell cycle arrest in tumour cells, without any toxicity to normal cells [81]. EPS secreted by probiotic yeasts-*Kluyveromyces marxianus* and *Pichia kudriavzevii* were reported to induce apoptosis in colorectal cancer cells by inhibiting AKT-1, mTOR, and JAK-1 pathways [82]. Though many studies demonstrated the antitumor potential of EPS, the viability of EPS as a coadjuvant for cancer therapy needs to be addressed by in-depth in vivo studies. Some researchers observed that the sugar composition of EPS primarily determines its antitumor property. For instance, Tukunmez et al. [83] observed that the apoptotic induction by *Lactobacilli* EPS was related to the mannose content of EPS. The mode of action of *Lactobacilli* EPS is by upregulation of Bax, Caspase 2 and 9 and downregulation of Bcl-2 and Survivin leading to caspase-mediated apoptosis [83].

EPSs have been commonly used in pharmaceutical formulations for controlled and sustained release of drugs, coating of pills or as suspension stabilizers. Presence of hydroxyl groups and free carboxyl groups in EPS enables the structural modification of EPSs, improving the biostability and mechanical properties or impart novel functionality to EPSs, thus broadening their applications [84]. Adding hydrophobic moiety to xanthan gum reduces its solubility and porosity, and modified its rheology. The resulting amphiphilic xanthan gum reduced the surface tension/interfacial tension and stabilized the emulsion, which improves its prospects for pharmaceutical applications, in comparison to native xanthan gum [85]. Du et al. [86] reported an antibacterial hydrogel made of hydrophobically modified chitosan and oxidized dextran with improved wound healing properties than that of traditional gauze. Similarly, a thermoreversible hydrogel made with xanthan and konjac glucomannan appear promising for in situ would healing [87].

Non-immunogenicity, biocompatibility and biodegradability determine the applicability of EPS in biomedical application. Dextran is the most clinically used bioabsorbable EPS. Dextran has been used as a plasma extender and an antithrombotic agent. Dextran is neutral in charge, exhibit excellent pharmacokinetics and is easily degraded by dextranase enzyme in our body [88]. Acetalated

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dextran (Ac-Dex) is modified dextran with hydrophobic nature. It can be easily formulated to micro/nanoparticle, which can encapsulate a diverse payload. Its pH-sensitive nature makes it an effective drug delivery system for protein, miRNAs and chemotherapeutic drugs [89–91]. Studies with natural compound ganothalamine revealed promising application of Ac-Dex as an encapsulating agent for the sustained release of the anticancer drug [92]. Wannasarit et al., [93] synthesized a conjugated dextran-based polymeric nanoparticle which can mimic viral entry to the cell. Adapting a viral mode of delivery of therapeutics to the cytoplasm is a good approach to bypass the lysosomal degradation that happens after the internalization of the drug. The prepared poly(lauryl methacrylate-comethacrylic acid)-grafted acetalated dextran carrying the payload of asiatic acid showed improved therapeutic efficacy than treatment with asiatic acid alone. Pinho et al. [94] prepared a dextran-based photocrosslinked membrane which shows potential as implantable devices for biomedical application. In vivo studies using rat models indicated that the developed dextran-based membrane is biocompatible.

With the aim to restore or regenerate the damaged tissue, tissue engineering comprises of cells and growth factors in a biomaterial that acts as the scaffold for cell growth. Biocompatibility, gelation and mechanical properties are the attractive properties of EPSs for their use as biomaterials in tissue engineering [95]. Microbial EPS containing hexosamine and uronic acid as monomers and acetyl/sulfate groups as functional groups hold great therapeutic potential due to their structural resemblance with mammalian glycosaminoglycans (GAG). Using bacterial GAG-like polymers over mammalian GAG have the following advantages. Bacterial EPSs are produced by fermentation that is more feasible when compared to strenuous extraction of GAG from animal tissue. Bacterial EPSs are free of prions and viruses as in the case of mammalian GAGs. EPS produced by marine isolated *Vibrio diabolicus* and *Alteromonas infernus* are promising candidates for tissue repair and remodelling. Chemical modifications of these depolymerized polysaccharides using *N*-deacetylation and sulfation can yield heparin-like polymers [96–98]. Cross-linked dextran is an effective injectable hydrogel for cartilage regeneration [99]. Capsular alginate extracted from *Azotobacter agile* exhibit lower cytotoxicity on mesenchymal stem cells than algal alginate. Moreover, tailor-made alginate with attractive properties to serve as a biomaterial can be produced by metabolic engineering of host bacterium [100].

The petroleum industry has been using EPS as a viscosifier for the drilling purpose. In situ EPS production by *Pseudomonas stutzeri* XP1 isolated from oil reservoir could enhance the oil recovery that demonstrated the potential of EPS for enhanced oil recovery [101]. EPS can be a potential bioadsorbent for heavy metal removal. They are environmentally friendly, cost-effective, and require milder conditions to operate. Metal adsorption by EPS depends on ionic nature of metal, its size and charge density. Positively charged heavy metals can be sequestered using anionic charged EPS [102]. When arsenic degrading bacteria was cultivated in arsenic-containing media, they produced EPS that can effectively sequester arsenic. These EPS are rich in polyanionic functional groups, which result in electrostatic to

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covalent binding with arsenic [103]. Similarly, studies also demonstrated the excellent flocculating activity of microbial EPS [33, 104].

EPS can be effective and sustainable soil strength improver. Using EPS as the soil stabilizer can alleviate the negative environmental impact associated with traditional soil stabilizers such as lime and cement. Improvement in soil shear strength and soil fabric was noted on addition of xanthan gum to the organic peat matrix, due to the hydrogen and electrostatic binding between xanthan gum and clay particle [105, 106]. Xanthan gum and sodium alginate could alleviate soil erosion and reduce the collapsible potential of soil material [107, 108]. Water adsorption and moisture-retention abilities of soil can be greatly improved by the addition of xanthan gum [109].

Exopolysaccharide-derived oligosaccharides can be considered for sustainable agricultural practices. Plant growth-promoting biostimulants can greatly benefit agriculture by stimulating the nutrient uptake, enhancing the photosynthetic activity of plants and protect the plants by mitigating abiotic stress [110]. Low molecular weight oligo-gellan prepared by depolymerization of gellan gum is promising as a biostimulant, which improved the plant growth and survival of Red Perilla plants under normal and stress conditions. Biostimulatory activity may be due to elicitation of plant polyphenol content and other secondary metabolites, leading to high antioxidant activity [111]. Though gellan gum also confers some biostimulatory effects on plants, the oligo-gellan exhibited better performance [112].

6 Conclusions

Microbial EPSs are one of the industrially significant microbial products, which are used as the functional ingredient in the food, pharmaceutical, personal care and other industries. Functional application of EPS is correlated to their structural complexity, which determines their physicochemical properties and bioactivities. Besides, the structural modification of EPS and synergistic manipulation with natural or synthetic polymers to broaden the applications of EPS, researchers are actively searching for novel EPS with versatile physicochemical properties or unique bioactivities which can have industrial/therapeutic applications. For that, they pursue the bioprospecting of EPS producing microbes from different environmental samples, specifically extreme environment. The ability of microbes to produce unknown exopolysaccharide is also being studied by genomic analysis.

Some latest studies shed light on the role of EPS in host-microbial symbiosis and pathogenesis. Understanding the physiological roles of EPS secreted by pathogenic or opportunistic microbes is quite crucial for developing novel therapeutic strategies against these microbes. Employing multiple omics techniques and metabolic engineering strategies in the field of microbial EPS can greatly expand the knowledge in EPS biosynthetic pathways and also, leads to the generation of tailor-made EPS with superior properties.

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Microbial EPS possess excellent rheological, emulsifying, and water-retention properties, which makes them highly sought-after industrial polymers in food, personal care, pharmaceutical and oil-drilling industry. In addition to this, they possess stability in a wide range of temperature and pH that heighten their commercial prospects. Furthermore, EPS may possess biological activities such as antioxidant, antitumor, immunomodulatory and antimicrobial properties and are promising for therapeutic and nutraceutical applications. Structural modified EPS with natural or synthetic polymers make an effective hydrogel with implications in clinical and biomedical field as wound dressing and tissue engineering applications. Growing researches demonstrate the potential use of EPS for bioremediation, soil conservation and sustainable agricultural practices.

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NANOMATERIALS FOR BIOCATALYSIS

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CHAPTER 1

Nanobiocatalysis: an introduction

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1.1 Introduction

The most common enzymes are made of protein structure mostly used in the biocatalysis industry owing to their high specificity, activity, and selectivity under mild conditions (Garcia-Galan, Berenguer-Murcia, Fernandez-Lafuente, & Rodrigues, 2011; Kumar et al., 2019; Sharma, Sharma, Meena, Kumar, & Kanwar, 2018). Enzymes are highly efficient in their action and can increase the rate of reaction up to 10^{19} folds and employed at low concentrations compared with chemical catalysts (Osbon & Kumar, 2019). In the last decades, there is a rise in the potential use of enzymes in fishery waste valorization, pharmaceutical research, food modification, agroindustry, biofuel production and laundry (Choi, Han, & Kim, 2015; Narancic, Davis, Nikodinovic-Runic, & OC, 2015; Sharma & Kumar, 2021; Sharma et al., 2019). In brief, enzymatic processes are cost-effective, ecofriendly, and more sustainable. However, applications of enzymes are limited by their low stability and the requirement of reusability properties when they are applied in industrial processes (Kumar, Wu, & Liu, 2018; Patel, Singh, & Kumar, 2017; Sharma, Meena, & Kanwar, 2018). Fortunately, in the last few years, immobilization becomes a powerful tool that allows increased industrial applications of enzymes in many fields. After immobilization, the biocatalyst is expected to tolerate harsh conditions including extreme pHs, high temperature, high ionic strengths, solvents with enhanced activity, and reusability (Kumar, Patel, & Mardan, 2018; Kumar, Gudiukaite, & Gricajeva, 2020; Sharma, Sharma, Kamyab, & Kumar, 2020). However, various methodologies for recovering enzymes from the reaction system are poorly developed. Hence, it is important to choose the enzyme proper matrix with robust, separable, and biocompatible features. Among the various carriers used for enzyme immobilization, magnetic nanoparticles could be simply segregated from the reaction mixture by the use of external magnets (Sharma, Verma, Kumar, & Kamyab, 2018).

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With the continuous growth in nanotechnology, nanomaterials have been evolved and widely used for enzyme immobilization (Rahman, Culsum, Kumar, Gao, & Hu, 2016). The range of nanomaterials was established by considering quantum mechanics approach that ranges between 1 and 100 nm with exceptional electric, magnetic, optical, and structural properties. The living cells are "nanometric entities," and the size of cell metabolic components exceeds several times 100 nm. Some nanomaterial occurs naturally, and some are engineered to perform specific functions and utilized at industrial level. The size of nanomaterial and their ability to engineer nanomaterial according to specific requirements offers various advantages compared to other traditional bulk materials used for enzyme immobilization (Indu, Mandal, & Dubey, 2020). The development of nanomaterial with exceptional features and functions comprises (1) addition of functional group on the nanomaterial surface for immobilizing enzyme, (2) creation of a special structure for facilitating substrates and products diffusion, increasing the surface area, reusing nanomaterial (3) improving thermal and mechanical stability of nanomaterial. Moreover, nanomaterials can be in the form of tubes, fibers, rods, or particles. Nanoscale materials such as nanotubes, nanofiber, nanowires, nanoparticles, and nanosheets have been reported for immobilization of several enzymes (Kumar, Park, & Patel, 2019; La, Truong, & Pham, 2020; Sharma et al., 2017; Yogeswaran & Chen, 2008). As emerging materials, efforts have been made to design a nanomaterials with various components such as metal oxides (Fe_3O_4, SiO_2, Cu_2O), noble metals (Au), polymers (i.e., polycaprolactone, polylactic glycolic acid, aldehyde-derived pluronic polymers) carbon-based (carbon nanotubes, carbon dots) and complex compounds such as ($Mn_3(PO_4)_2$, $Cu_3(PO_4)2{\cdot}3H_2O$, $Cu_4(OH)_6)SO_4$, $Ca_8H_2(PO_4)_6$, and $Co_3(PO_4)_2{\cdot}8H_2O$) (An, Li, & Zhang, 2020). In recent years, various nanomaterials reported for enzyme immobilization are summarized in Table 1.1.

Nowadays, nanomaterials have been broadly utilized in chemistry, medicine, environmental monitoring and remediation, pharmacy, and microelectronics. Advances in nanoscience develop various nanomaterials, and enzymes immobilization on these nanomaterials has been considered as a propitious method to increase enzyme performance. Generally, the enormous benefits of nanomaterials as immobilization matrices can be expected as their huge specific surface area/volume ratio, unique mechanical, physicochemical, and cost-effective features (Kumar, Kim, Patel, & Lee, 2018; Liu & Dong, 2020; Nadda & Kanwar, 2012; Rahman et al., 2016). It must be noted that it is crucial to control the matrix -biocatalyst interactions to know about the modifications that could be made and its possible applications. Nanomaterials can be expected to meet the necessities of the immobilization matrix, while some may not be appropriate for the immobilization of some enzymes, because of enzymes tend to aggregate displaying detrimental properties and/or just by denaturing the protein structure. Furthermore, the linking between the nanomaterial and enzyme has been reported by physical methods such as encapsulation, entrapment, absorption, and/or by chemical methods like covalent attachment, ionic bonds, hydrophobic interactions and

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Table 1.1 Various nanomaterials reported for enzyme immobilization.

Nanomaterial	Enzyme	Immobilization method	Immobilization yield (%)	Application	Reusability	Reference
Multiwalled carbon nanotubes (MWCNTs)	Asparaginase	Adsorption	90.0	Food industry, biosensor	–	Cristóvão, Almeida, and Barros (2020)
Polyacrylic acid coated magnetic silica nanocomposite	Lipase	Covalent	–	*p*-NPP hydrolysis	5	Esmaeilnejad-Ahranjani, Kazemeini, Singh, and Arpanaei (2016)
Chitosan nanoparticles	Lysozyme	Ionic	–	Antimicrobial activity	8	Wang, Li, and Jin (2020)
Magnetic nanoparticles	Asparaginase	Covalent	–	L-asparagine hydrolysis	8	Orhan and Aktaş Uygun (2020)
Superparamagnetic few-layer graphene oxide	Lipase	Electrostatic	–	Biodiesel production	5	Nematian, Shakeri, Salehi, and Saboury (2020)
Hollow core-mesoporous shell silica nanospheres	Protease	Physical and covalent	75.6	Laundry detergent formulations	12	Ibrahim, Al-Salamah, and El-Toni (2016)
Gold nanoparticles	Horseradishperoxidase	Chemical and absorption	–	Biosensor	–	Luo, Xu, Zhang, Yang, and Chen (2005)
MWCNTs	Laccase	Covalent	76.7	Removal of diclofenac	7	Xu, Tang, Zhou, Li, and Zhang (2015)
Iron oxide nanoparticles	Glucosidase	Covalent	93.0	Biofuel production	16	Verma, Chaudhary, Tsuzuki, Barrow, and Puri (2013)
ZnO nanowires	Lipase	Adsorption	–	Esterification of phytosterols with oleic acid	12	Shang, Li, and Zhang (2015)
Chitosan-MWCNTs	Galactosidase	Covalent	95.0	Aroma enhancement of tea extract	10	Çelik, Dinçer, and Aydemir (2016)
MWCNTs	Laccase	Covalent	–	Dye decolorization	10	Othman Abdelmageed, González-Domínguez, Sanromán, Correa-Duarte, and Moldes (2016)
Graphene oxide	Horseradish peroxidase	Electrostatic	–	Phenolic compounds removal	7	Zhang, Zheng, and Zhang (2010)

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Table 1.1 (Continued)

Nanomaterial	Enzyme	Immobilization method	Immobilization yield (%)	Application	Reusability	Reference
Amino-functionalized magnetic nanoparticles	Lipase	Covalent	62.0	*p*-NPB hydrolysis	11	Hu, Pan, Yu, Liu, and Xu (2009)
PEGylated graphene oxide nanosheets	Cellulase	Covalent	70.5	Saccharification of lignocellulose	3	Xu, Sheng, and Wang (2016)
Gold nanoparticles	Cholesterol oxidase	Covalent	–	Biosensor	-	Saxena, Chakraborty, and Goswami (2011)
Organic-inorganic nanocomposites	Laccase	–	75.3	Dichlorophenol removal	8	Qiu, Qin, Xu, Kang, and Hu (2019)
Molybdenum sulfide nanosheets	β-amylase	Covalent	92.0	Industrial processes	10	Li, Nandgaonkar, and Wang (2017)
Polyethyleneimine-modified superparamagnetic Fe_3O_4 nanoparticles	Lipase	Covalent and adsorption	91.7	Ethyl valerate synthesis	12	Khoobi et al. (2015)
Polymeric materials	Glucosidase	Entrapment	93.0	Cellobiose hydrolysis	6	Javed, Buthe, Rashid, and Wang (2016)
MWCNTs	Glucosidase	Adsorption	–	Lactose hydrolysis	6	Ansari, Satar, Kashif Zaidi, and Ahmad (2014)

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combined or other more sophisticated methods. Moreover, the nanoporous materials provide an excellent surface area for the covalent binding or entrapment of biocatalyst, substrate and products diffusion through the matrix, drugs, and biomolecules but the major task is to make the desired structure with appropriate biocompatibility and surface properties. Nowadays, several attempts have been made for the synthesis of mesoporous materials and blend it with other molecules or structures so as to make a matrix having large surface area to volume ratio and suitable pore size (Szczęśniak, Choma, & Jaroniec, 2020). Furthermore, some basic parameters that should be considered during enzyme immobilization on nanomaterials are minimal enzyme deactivation, high immobilization yield, effective catalyst reutilization, high specific activity that keeps the selectivity (i.e., chemo-, stereo- and regio-), and recovered activity (Cipolatti, Valério, & Henriques, 2016; Rana, Sharma, Kumar, Kanwar, & Singh, 2020). In the present chapter, we provide an overview of various nanomaterials utilized in biocatalysis and their applications.

1.2 Metallic nanomaterials

Nanomaterials containing metals are commonly known as metallic nanomaterials. Hence, metallic nanomaterials have been generally utilized for fabricating nanobiocatalysts. Some metallic nanoparticles are also considered to be nontoxic and can be used in drug delivery, radiotherapy enhancement, biosensors, magnetic resonance imaging, and gene delivery (Ren et al., 2011; Yamada, Foote, & Prow, 2015). Since the 1970s, the utilization of magnetic particles has increased in the field of medicine and bioscience. Therefore the applications of metal and metal oxide nanomaterials in immobilizing the enzyme are discussed in this section.

1.2.1 Metal nanomaterials

The first category of nanomaterials made up of platinum, zinc, gold, silver, thallium, iron, and cerium are known as metal nanomaterials. Functional groups (e.g., amino, phosphate, carboxylate, thiolate) are added onto the metal nanomaterial to form a robust interfacial reaction with the biocatalyst, and subsequently to improve enzyme immobilization (Ghodake, Shinde, & Saratale, 2019; Yaqoob, Ahmad, & Parveen, 2020). Metal nanomaterials have been synthesized by numerous methods like coprecipitation, hydrothermal synthesis, thermal reduction, biosynthesis, and micelle synthesis (Misson, Zhang, & Jin, 2015). Among these nanomaterials, gold nanomaterials are mostly utilized for enzyme immobilization because of their good biocompatibility, porous network structure, large surface area, mechanical and thermal stability (Cipolatti et al., 2016). In catalysis, there is growing interest in immobilizing enzymes on gold nanomaterials, even though these are not considered as viable matrix due to economic issues for most of applications at industrial level. Previously, α-amylase

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immobilized on gold nanorods by hydrophobic and electrostatic binding was employed for starch processing and the immobilized α-amylase exhibited improved thermal and storage stability (Homaei & Saberi, 2015). Saxena et al., (2011) functionalized gold nanoparticles using N-hydroxysuccinimide and N-ethyl-N'-(3-dimethy laminopropyl carbodiimide) for immobilization of cholesterol oxidase and successfully used the immobilized enzyme for detection of cholesterol in human serum sample. Moreover, the immobilization of various enzymes on nanoporous gold resulted in an enhanced enzyme stability and biocatalytic performance (Wang et al., 2011).

Furthermore, silver nanoparticles have been proved to be beneficial for medical applications because of exceptional antimicrobial effect against bacteria, viruses, and complex microbial structures such as biofilms (Yaqoob et al., 2020). Previously, lactose peroxidase was immobilized on silver nanoparticles showing enhanced antimicrobial activity as compared to free lactoperoxidase (Sheikh, Yasir, & Khan, 2018). The most known antimicrobial mechanism of metal nanoparticles is metal ion release, redox properties, and interference with molecular transport and metabolism, denaturing molecules and/or inhibiting central metabolism, etc., (Sangaonkar & Pawar, 2018). The antimicrobial activity of metallic nanoparticles could be because of their nanosize and high surface area to volume ratio, residual charges in surface which allows them to penetrate inside the bacterial membrane.

1.2.2 Metal-oxide based nanomaterials

Metal oxide nanomaterials including iron oxide, zinc oxide, and titanium oxide are mostly used to immobilize biocatalysts. With large surface area, high biocompatibility, TiO_2 nanocarriers have been mostly utilized for immobilizing biocatalyst and in the various applications such as wastewater treatment, biosensor, and so on. The most common methods for synthesis of TiO_2 nanomaterials are hydrothermal, direct oxidation, solvothermal, sol-gel, and chemical vapor decomposition methods (Liu & Dong, 2020). Lipase was immobilized on phenylaminopropyl trimethoxysilane functionalized mesoporous TiO_2 by hydrophobic interactions and used for the synthesis of cinnamyl acetate. In addition, immobilized enzyme retained good operational stability after ten successive runs and showed improved thermal stability (Gao et al., 2018). Furthermore, horseradish peroxidase was immobilized on TiO_2 nanotube coated with polydopamine for constructing a novel photoelectrochemical bio-sensing platform (PEC). The PEC exhibited good selectivity as well as sensitivity for the biosensing of H_2O_2 (Li, Li, & Zhao, 2018).

In recent years, ZnO with different nanostructures are a promising matrix for enzyme immobilization, as they are nontoxic, biocompatible, chemically stable having high catalytic efficacy, strong absorption ability, and displays antimicrobial activity. The wet chemical route is mostly used to fabricate ZnO nanostructures, including nanorods, nanosheets and nanoparticles. The ZnO nanostructure shows high

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isoelectric point with negatively charged surface in the reaction medium, and appropriate for electrostatic absorption of the biocatalyst. Ahmad et al., showed a new method for making glucose biosensor using glucose oxidase absorbed on a single ZnO nanofiber (Ahmad, Pan, Luo, & Zhu, 2010). The result showed that a single ZnO nanofiber is a good matrix for immobilizing the enzyme and could be utilized in numerous applications. On the other hand, Fe_3O_4 nanoparticles are frequently utilized for the development of iron oxide magnetic nanoparticles, because they have a large surface area, less mass transfer resistance, and easy separation from the reaction medium (Orfanakis, Patila, & Catzikonstantinou, 2018). Previously, the lipase immobilized on polyethyleneimine functionalized super magnetic Fe_3O_4 by absorption and covalent attachment was used for the synthesis of ethyl valerate. The study showed that immobilized enzyme retained 80% of original activity after 12 reaction cycles (Khoobi et al., 2015). Despite various reported methods for immobilization of the enzyme on a metallic nanomaterial, there is still demand for efficient and cost-effective methods.

1.3 Carbonaceous nanomaterial

Carbonaceous materials such as graphene, reduced graphene oxide, and carbon nanotubes (CNT) have been widely used for enzyme immobilization because of their superior benefits. These nanomaterials have engrossed wide attention in various applications (Table 1.1), including drug delivery, catalysis, bioremediation, and contaminant biotransformation (Anwar, Kim, & Kumar, 2017; Czepirski et al., 2016). With the recent development in nanotechnology, the role of carbonaceous materials will be more and more significant in the future.

1.3.1 Graphene and graphene oxide

Graphene is one atom thick two-dimensional honeycomb crystal structure of carbon atoms, which seems to be an ideal matrix for immobilization owing to its large surface area ($\sim 2630\ m^2\ g^{-1}$) that helps to enhance enzyme loading, strong mechanical strength increases the reusability of biocatalysts, and extraordinary thermal, optical and electrical features. Graphene-based nanomaterials mostly interact with enzymes by VanderWaals forces, hydrophobic and electrostatic interactions. In addition, graphene immobilized biocatalysts are mostly used in biosensors because of their exceptional electric conductivity (Ahmad et al., 2010). In a previous study, glucose oxidase was immobilized on polyvinylpyrrolidone-protected graphene for the creation of an electrochemical glucose biosensor. The biosensor exhibited a broader linearity range (2−14 mM), that ensured blood sugar detection (Shan et al., 2009). On the other hand, graphene oxide is the precursor of graphene, has been widely used for enzyme immobilization as they exhibit ultrahigh surface area, thermal and mechanical properties. Graphene oxide has oxygen-containing functional groups like carboxyl, hydroxyl,

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and epoxy which are useful for enzyme immobilization (Compton & Nguyen, 2010). The three most popular methods reported for the synthesis of graphene oxide are Staudenmaier, Hummers and Brodie (Compton & Nguyen, 2010). Xu et al., (2016) covalently immobilized cellulase on graphene oxide nanosheets and used for saccharification of lignocellulose. After immobilization cellulase retained 70% of its original activity. Various authors reported that enzyme immobilized in graphene oxide has shown different operational stability, catalytic efficiency, and application potential.

1.3.2 Carbon nanotube

CNTs are one-dimensional hollow tubes made up of carbon atoms. CNTs are of two types of single-wall carbon nanotubes (SWCNTs) with three isoforms and multiwalled carbon nanotubes (MWCNTs) that have been mostly used for enzyme immobilization. CNTs exhibit extraordinary electrical, thermal, and mechanical properties. Arc discharge, chemical vapor deposition and laser ablation methods are used for the synthesis of CNTs. CNTs show increasing application possibilities in enzymes immobilization, especially for the synthesis of biofuel cells and biosensors (Feng & Ji, 2011). Previously, laccase was immobilized on to MWCNTs for the biodegradation of diclofenac. The results of this study showed that immobilized laccase exhibits better storage stability, reusability and high biotransformation efficiency of diclofenac (Xu et al., 2015). Also, using the carbodiimide coupling technique, laccase was covalently immobilized on MWCNTs and used for dye decolorization. Immobilized laccase showed enhanced thermal stability and retained 95% of activity after 12 cycles of repetitive use (Othman Abdelmageed et al., 2016). Furthermore, β-glucosidase immobilized on MWCNTs and used for aroma enhancement of tea extracts. The immobilized enzyme showed better reusability, thermal and storage stability (Çelik et al., 2016). Moreover, to completely examine the potential of CNTs enzyme complex, it is important to find an optimum technique for enzyme immobilization.

1.4 Other nanomaterials

Besides the nanomaterials discussed here, other nanocarriers such as silica, cellulose, metal-organic frameworks (MOFs), chitosan, and other bio-based nanomaterials have also been utilized for enzyme immobilization, some of them will be analyzed in detail in the following chapters. Moreover, silica can be modified using a silane blocking agent to add reactive groups including carboxyl, epoxy, thiol, and amino groups for immobilizing the biocatalyst. According to morphological and physicochemical features silica can be categorized into natural, micro, meso, macro, and synthetic material. Nowadays, mesoporous silica also known as nanosilica is mostly studied and has various benefits such as huge surface area ($300-1500\ m^2\ g^{-1}$), uniform pore diameter (2−40 nm), inert and stable at higher temperature (Zhou & Hartmann, 2013). Besides silica, chitosan and

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cellulose-based nanomaterials are mostly combined with other materials for enzyme immobilization. Particularly, chitosan, a biopolymer obtained by partial deacetylation of chitin, and can be regarded as an attractive matrix for enzyme immobilization because of its low cost, biodegradability, and presence of functional groups (Tang, Qian, & Shi, 2007). Recently MOFs are getting attention because of their large pore volume, three-dimensional structure, and tremendous absorption ability. Some enzymes including lipase, catalase, and carbonic anhydrase have been successfully immobilized onto MOFs (Ren, Feng, & Wen, 2018). Integration of enzyme as guest species into MOFs would provide an artificial biocatalytic system promising for biosensing, biomedical devices, and biocatalysis (Sharma A. et al. 2020; Sharma T. et al., 2020).

1.5 Conclusion

Nanomaterial immobilized biocatalysts generally exhibit improved activity, stability, and reusability by creating a unique microenvironment. Although large-scale production of immobilized enzyme is a vital matter for their applications because of technical and economic issues. However, at the same time, it cannot deny that immobilization nanotechnology could makes enzymes commercially available in reactions where selectivity and purity of enzymes are important like in delicate processes of chemical precursor's synthesis, biomedicine, and pharma. With efforts from many academic fields like biochemistry, bioprocess engineering, molecular biologyt, and others, the production of immobilized enzyme reactors including microchannel, packed bed, and fluidized bed reactors could be successfully commercialized in the future.

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EMERGING MATERIALS AND TECHNOLOGIES

Nanomaterials for Water Treatment and Remediation

Edited by
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Preface

Wastewater management is one of the major challenges across the world. Various chemical and biological methods of treatment have been developed to treat contaminated water. New materials with intriguing physical and chemical properties provide opportunities to address these challenges. Nanomaterials have a large surface area to volume ratio, high surface reactivity (e.g., catalytic activity), and increased multifunctionality widely used to remove contaminants from surface water and groundwater contaminated with organic/inorganic pollutants via advanced oxidation and chemical reduction, sorption, complexation, (co)precipitation, or membrane filtration. Consequently, nanomaterials have been modified or hybridized with one or more nanomaterials to achieve multifunctionality by tuning size, morphology, dimensionality, surface properties, etc. The nanocomposites of various inorganic nanoparticles with organic material have also been proven effective in removing the various impurities from contaminated water. The major pollutants, chemical pesticides, pharmaceutical wastes, fertilizers, heavy metal ions, dyes, paints and refinery waste, sugar mills textiles fibers contaminated the major volume of drinking water on the Earth's surface. In this volume, we compile up-to-date information on the various nanomaterials-based techniques used to treat polluted water.

This book primarily focuses on the recent developments of the rational design, synthesis of advanced nanomaterials and their applications for water treatment and remediation through various techniques such as adsorption, advanced oxidation process, chemical oxidation and reduction reactions, membrane-based separation, and synergistic multifunctional all-in-one nanodevices. It includes (i) rational design of nanoporous materials with tunable pore structure; (ii) fabrication of nanomaterials by surface chemistry engineering; (iii) role of nanomaterials assisted oxidation and reduction processes; (iv) design of nanomaterial supported membrane-based separation; (v) multifunctional nanomaterials for water treatment. This volume also comprehensively discusses the types of nanomaterials and their interfacial modification effect in removal, absorption and degradation features, and the effect of various factors that could influence the mechanism, capacity, and stability of nanomaterials.

To this end, the book consists of 14 chapters that reflect the progression from introductory to focused topics. **Chapter 1** introduces the fundamentals of various water treatment techniques using nanomaterials. Starting with basic water treatment methods, the principles of adsorption, filtration, coagulation, flocculation, photocatalytic degradation, ozonation, chemical oxidation reactions, and reverse osmosis using membranes are reviewed. **Chapter 2** presents the synthesis of heterostructures, modification of semiconductor interface using co-catalysts, photodegradation of antibiotics and other organic matter using visible-light-active semiconductors. In **Chapter 3,** Akhundi and Habibi-Yangjeh summarized the latest progress in constructing g-C_3N_4-based nanocomposites and their employment for the degradation of organic pollutants. They provide an overview of advancements, existing challenges, and opportunities for future development. **Chapter 4** highlights the applications of 2D materials for advanced membrane fabrication and photocatalytic treatment of

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pollutants and microorganisms. Recent advances in the fabrication of thin-film composite-based membranes using 2D materials such as graphene, graphene oxide, MXenes, transition metal dichalcogenides, photo-catalytically active 2D materials (g-C_3N_4, iron oxide, manganese oxide, metal oxyhalide, boron nitride) for water purification and separation of textile dyes, metal cations, heavy metals and various pharmaceutical products are discussed in detail. The next chapter (**Chapter 5**) presents several advancements made in aspect of TiO_2 based nanomaterials for applications in water treatment and pollutant remediation. Several methods including modifying the electronic band structure of TiO_2 using different techniques such as self-doping, metal/non-metal doping, co-doping, coupling with a narrow band gap semiconductor, different surface modifications, sensitization by metal complexes dyes or organic and capping with other semiconductor or metal nanoparticles are discussed for wastewater treatment. **Chapter 6** describes the extensive research on nanoparticles for heavy metal remediation. They extensively discuss the removal of heavy metals like arsenic (As), cadmium (Cd), chromium (Cr), etc. and the mechanism behind the pollutant clean-up along with the use of various advanced characterization techniques. The reusability, metal recovery from waste effluents, prospects, and current challenges are also discussed. **Chapter 7** introduces photoactive polymers for organic pollutants oxidation and heavy metals reduction, the inactivation of bacterial species, the synergistic effects obtained through the combination of inorganic semiconductors and the photoactive polymer-based membranes. A brief overview of the latest scientific advances in the development of photoactive polymer and composites to overcome the present shortcomings for fabricating visible-light-driven photocatalysis for water treatment along with their operating principles is also presented. In the following **Chapter 8**, Kowalska's group focus on plasmonic nanomaterials for wastewater treatment and water purification, including degradation of organic compounds and microorganisms, and removal of inorganic pollutants. The photocatalysts with advanced structures, such as faceted oxides and photonic crystals, and mechanisms clarifications have been discussed in detail. They include several examples of plasmonic photocatalysts, including noble metal/semiconductor and noble metal/semiconductor/semiconductor composites, which may provide an efficient approach for removing dyes from water. Suhasini and Thiagarajan demonstrate the potential of magnetic nanoparticles for wastewater remediation water through recycling and reuse as an efficient, practical, and low-cost water treatment method. **Chapter 9** reviews the fundamental theory and concepts of magnetic nanoparticle separations and integrating various nanocomposites, polymers, and layered double hydroxides for water remediation. **Chapter 10** emphasizes the various nanofiber membrane development especially using the electrospinning technique for the removal of various pollutants. They describe several factors and parameters that affected the performance of the nanofiber membranes under experimental conditions. They provide an overview of recent applications of nanofiber membranes in removing different types of hazardous pollutants in wastewater that contains heavy metal, oil, dye, and pharmaceutical pollutant and challenges and future strategies for sustainable development and applications of the nanofiber membranes in the field of wastewater treatment. In **Chapter 11**, Hassani and Khataeeb reported various forms of carbon nanomaterials (such as carbon nanotubes, graphene, reduced graphene

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oxide-based materials, fullerene, activated carbon, biochar, carbon quantum dots and graphitic carbon nitride etc.) for the elimination of pharmaceuticals and personal care products by advanced oxidation processes (AOPs), including photocatalysis, sonocatalysis, Fenton and Fenton-like process, electrochemical process, sulfate radical-based AOPs, and hybrid AOPs by the aid of carbon nanomaterials. **Chapter 12** highlights the recent advances in the use of metal–organic frameworks (MOFs) and their derivatives for the efficient removal of contaminants in wastewater. In particular, photocatalysis, sulfate radical-based advanced oxidation process, heavy metals and organic pollutants removal, and MOFs-mixed matrix membranes strategies are detailed in the discussion. They present an overview of the synthesis, components, and secondary building units of MOFs together with MOF-derived materials and the interaction mechanisms between these frameworks and the contaminants. In **Chapter 13**, Yang and Que's group reviews the progress of Low-dimensional metal chalcogenide nanomaterials for photocatalytic water treatment and remediation. They demonstrate that properties of these materials can be adjusted by the degree of quantum confinement in 0D quantum dots, 1D nanorods and 2D nanoplatelets, by material composition, and by forming heterostructures. This chapter summarized the fundamental photocatalytic mechanism insight into the exciton and carrier properties and their dependences on the dimensionality and chemical composition in metal chalcogenide nanomaterials. In **Chapter 14**, Samsudin and Sufian emphasized a panorama of the recent advances related to the fabrication and construction of emerging semiconductor photocatalysts for the treatment of antibiotic residues. They describe the fundamental principles of the advanced oxidation process, semiconductor photocatalyst, the degradation pathways of antibiotics, and invigorating perspectives on the future directions. A comprehensive understanding of the engineering of advanced nanomaterials, fundamentals, challenges, and applications offers a useful guide for a broad readership in various fields of catalysis, material sciences, environment, and energy to find the latest information. This book, titled *Nanomaterials for Water Treatment and Remediation*, comprises 14 high-quality chapters written by 50 experts from 13 countries. I would like to thank all the contributors. We owe special thanks to individual authors for their excellent chapters. We would also like to express my sincere gratitude to the publisher CRC and to the team of Dr. Allison Shatkin (Senior Publisher), Prof. Boris I. Kharissov, Gabrielle Vernachio and others involved in the successful production of this book.

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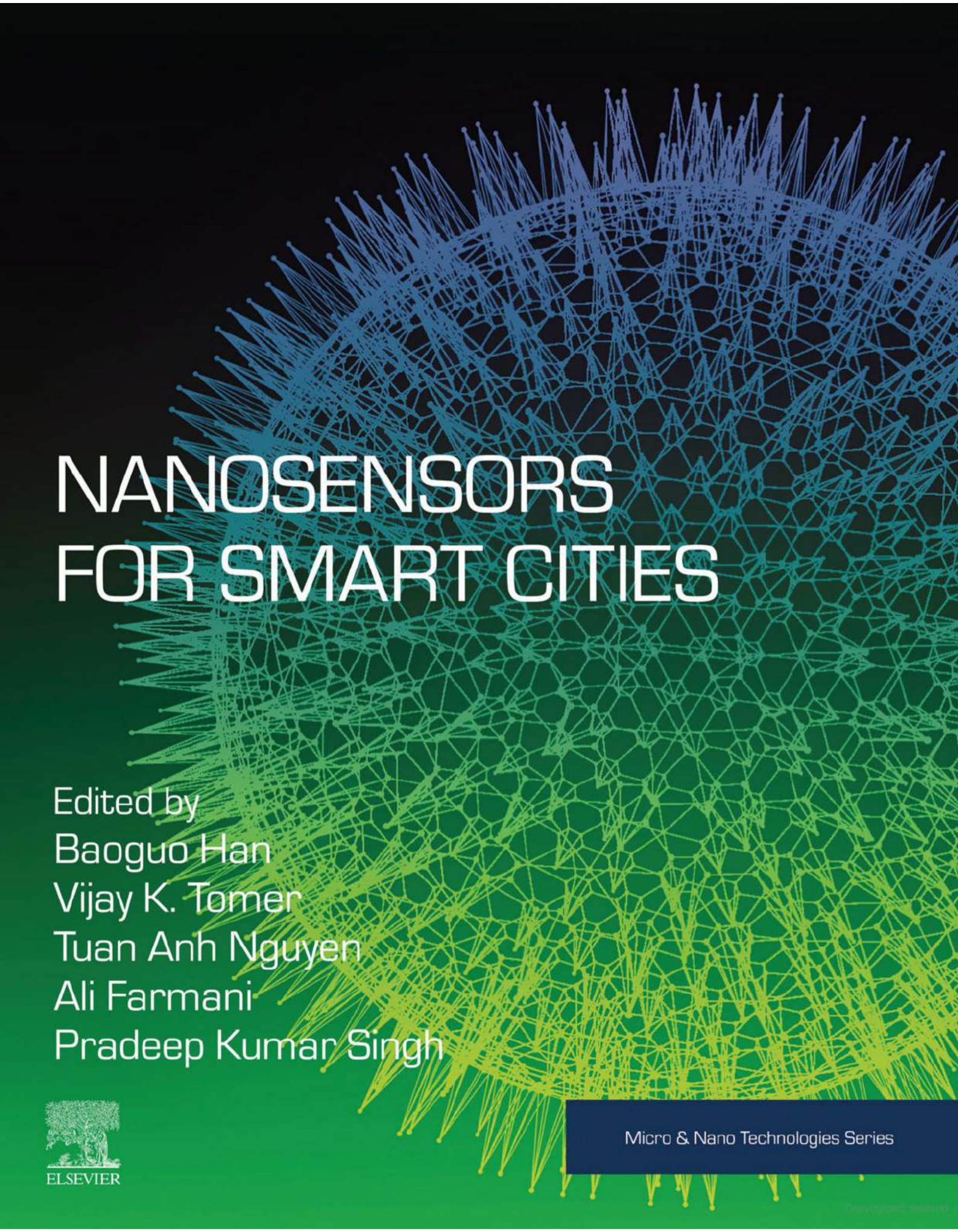

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The book provides a detailed description of how OMICS can help crop science and horticulture to enhance crop yields, resistance and nutritional values.

Burgeoning world population, decreased water supply and land resources, coupled with climate change, result in severe stress conditions which is a great threat to the global food supply. To meet these challenges, exploring OMICS technologies could lead to improved yields of cereals, tubers and grasses that may ensure food security. Improvement of yields through crop improvement and biotechnological means are the need-of-the-hour, and the current book "OMICS-Based Approaches in Plant Biotechnology", reviews the advanced concepts on breeding strategies, OMICS technologies (genomics, transcriptomics and metabolomics) and bioinformatics that help to glean the potential candidate genes/molecules to address unsolved problems related to plant and agricultural crops. The first six chapters of the book are focused on genomics and cover sequencing, functional genomics with examples on insecticide resistant genes, mutation breeding and miRNA technologies. Recent advances in metabolomics studies are elucidated in the next 3 chapters followed by 5 chapters on bioinformatics and advanced techniques in plant biotechnology and crop breeding.

Audience

The information contained in the volume will help plant breeders, plant biotechnologists, plant biochemists, agriculture scientists and researchers as well as policy makers in using this applied research to focus on better crop breeding and stress adaptation strategies.

Rintu Banerjee, Ex-MNRE- Chair-Professor, Indian Institute of Technology, Kharagpur has created a niche of her own in the area of Biomass Deconstruction/ Biofuel Production/Enzyme Technology. In the process of her innovative development, she was granted 8 Indian, 3 international (US, Japanese and Chinese) patents. She has published more than 180 papers in peer-reviewed national/international journals.

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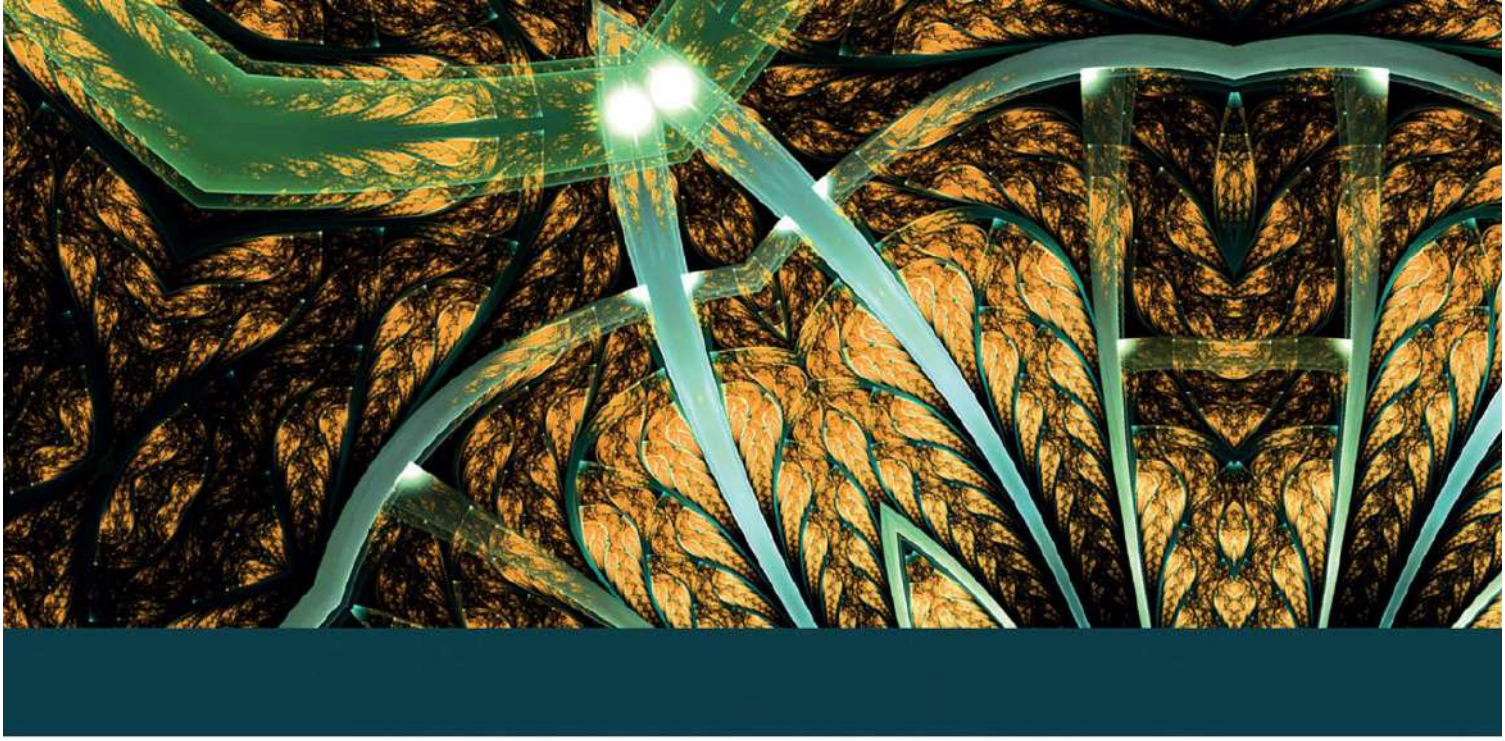
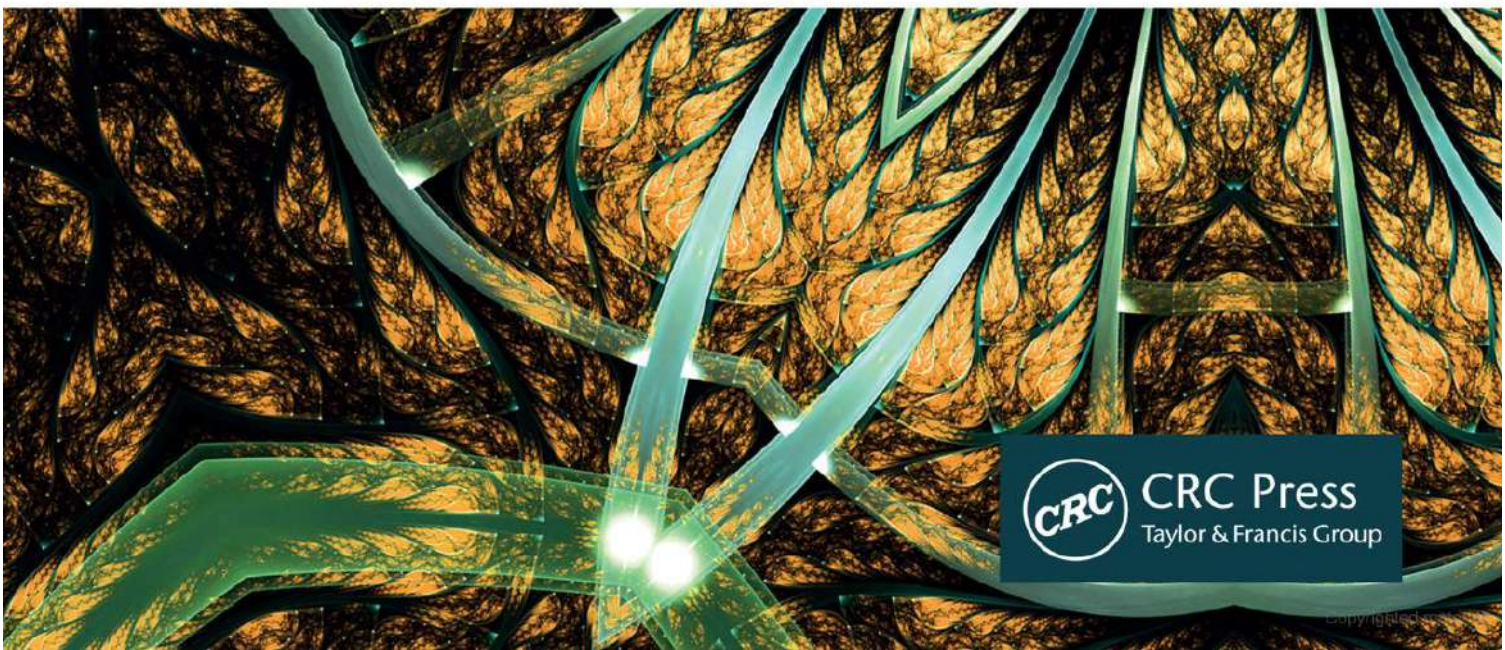


COMPUTATIONAL INTELLIGENCE AND DATA SCIENCES

PARADIGMS IN BIOMEDICAL ENGINEERING

Edited by
Ayodeji Olalekan Salau, Shruti Jain
and Meenakshi Sood



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Preface

Computational intelligence is closely related to artificial intelligence where heuristic as well as metaheuristic algorithms are designed to provide better and optimized solutions in a reasonable amount of time. These algorithms have been effectively used in a variety of biomedical, bioinformatics, and biological science application domains in health informatics and computer science. The practice of recent biomedical research most times requires sophisticated technologies to manage patient information, plan diagnostics, prognostics, procedures, interpretations, and investigations. This provides a conceptual foundation as well as practical inspiration for computer science, decision science, information science, cognitive science, and biomedicine, which are all rapidly growing engineering and scientific areas.

Computational intelligence approaches are gaining attraction in the field of health informatics as a way to improve people's health. In this book, we focus on the applications of computational intelligence techniques in the domain of biomedical engineering and computer science. The applications of computational intelligence techniques in the domain of biomedical engineering is the subject of this book. In the healthcare sector, biomedical engineers develop algorithms that use artificial intelligence and corresponding hardware for decision modules for diagnosis and prognosis of diseases such as arrhythmia, cancer, and diabetes and other health-related issues in humans for early and more accurate detection and prevention. The use of intelligent strategies to undertake all of these actions could lead to more efficient outcomes.

Ayodeji Olalekan Salau
Shruti Jain
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We may have inadvertently left out many others, and we sincerely thank all of them for their support.

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MICROBIAL BIOTECHNOLOGY FOR FOOD, HEALTH, AND THE ENVIRONMENT

PLANT-MICROBIAL INTERACTIONS AND SMART AGRICULTURAL BIOTECHNOLOGY

EDITED BY

Swati Tyagi, Robin Kumar,
Baljeet Singh Saharan,
and Ashok Kumar Nadda

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Edited by
Swati Tyagi, Robin Kumar, Baljeet Singh Saharan,
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Preface

Farmers have great potential to adapt to and accept climate change. The global economy has changed and has been able to develop sustainable agriculture with high rates of growth. This helped us to solve the problem of food shortage. In this age, climate change has brought new and complicated challenges. To combat these challenges, it is necessary to understand the root causes, after which proper implementation of the solutions is required. On the other hand, the overuse of chemical fertilizers and pesticides has caused many environmental problems, including water acidification, greenhouse effect, and depletion of the ozone layer. These problems can be addressed using biopesticides and biofertilizers, which are beneficial, environmentally friendly, natural, and easy to use. Microbial biofertilizers control soilborne diseases, maintain soil structure, and provide nutrients to plants. They play a vital role in sustainable agriculture. Arbuscular mycorrhizal fungi are important soil microbes that form symbiotic associations with most terrestrial plants and are mainly responsible for the uptake of phosphorus. Another group of microbes are biological nitrogen-fixing bacteria, which are universally potent bioinoculants used to promote plant growth. The use of *Rhizobium* in legume crops to support agricultural productivity is increasing day by day. Such types of bioinoculants are easily available to farmers. Moreover, the mass production of these biofertilizers is done in laboratories, and they can easily be stored as liquid or carrier-based bioformulations at room temperature. Phosphate-solubilizing bacteria are also extremely important, as they have been reported to increase P uptake by converting insoluble to soluble forms. *Azotobacter* and *Azospirillum* are two other very important bacteria. The response of these organisms is commonly seen in increasing yields. Apart from these microbes, cyanobacteria also contribute significantly to the nitrogen economy of sustainable agriculture. The tripartite relationship between legumes, rhizobia, and mycorrhiza is the most efficient combination to promote growth and achieve higher productivity in plants, trees, and vegetables. Cyanobacteria are excellent suppliers of nitrogen. Their importance for abundant crop production cannot be ignored and has been felt by farmers. They are easy to multiply and can now be obtained in bottles or packets throughout the year. In fact, the application of microbial bioinoculants is a very effective and natural method to increase and maintain the mineral economy of nature. Their use reduces the need for chemical fertilizers, making them the only effective alternative for self-sustaining farming.

Microbe–host or microbe–microbe interactions are important strategies for colonization and establishment in different agro-climatic conditions/regions. This communication/crosstalk covers all aspects of the microbial communities', e.g., signaling, chemotaxis, genetic exchange, metabolite conversion, intermediary metabolism, and physicochemical changes that lead to genotype selection. The survival rate of microbes in the environment depends on biodiversity because the high genetic variability increases the competitiveness and reduces the chances of intruders settling in the respective climatic conditions. Hence, these interactions are the result of

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a coordination that results in acclimatization and adroitness and enables the filling of various niches by limiting biological and abiotic stresses or exchanging growth factors and signals. Several mechanisms might be involved in this exchange, such as secondary metabolites, biofilm formation, cellular transduction signaling, quorum sensing system, and siderophores. The final unit of interaction is the expression of each organism's genes in response to environmental stimuli responsible for the production of the biomolecules involved in such associations. Hence, in this book, we focus on the molecular mechanisms involved in such interactions in the molecular strategy used by various microbes, which influence the constitution and structure of microbes.

The challenges are varied and unpredictable, but with the experience of farmers and expertise of our scientists, it is possible to make agriculture smarter. There has been great demand for a book on *Plant-Microbial Interactions and Smart Agricultural Biotechnology*, wherein different issues concerning microbial interactions and smart agriculture have been described.

This book will certainly provide useful information dealing with a diverse group of microbes, beneficial effects, and the bottlenecks in their implementation. Students, researchers, biotechnologists, microbiologists, botanists, soil biologists, industrialists involved in the mass production of biofertilizers, producers, environmentalists, and all other users should find this book extremely useful. The goal of this book is to provide essential information on the use of different microbes and their secondary metabolites for the treatment of various diseases affecting crops. This book also describes the potential of microbes (tiny factories) in improving crop yield, plant health, and the biomolecules' production efficiency for smart agriculture.

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1 Plant-Microbe Interaction for Sustainable Agriculture

Swati Tyagi, Robin Kumar, Baljeet Singh Saharan, and Ashok Kumar Nadda

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1.1 INTRODUCTION

The world's population is growing exponentially, and, with this increasing population, the rate of urbanization/industrialization has also increased. This has increased the demand for food, which has accelerated the depletion of natural resources (Vejan et al. 2016). To meet this demand, an excessive and irrational use of agrochemicals, such as fertilizers, herbicides, and fungicides, has been adopted in the past, influencing agriculture practices and polluting soil, water, and ecosystems and causing an ecological imbalance. However, these practices cause more serious challenges rather than solving the demand; therefore, it is necessary to improve crop productivity organically or naturally in a sustainable manner in harmony with the ecosystem. These issues pushed agricultural scientists to look for alternative options and understand the underlying molecular mechanism of plant-microbe interactions that can provide fresh perspectives (Tyagi et al. 2021). In the natural environment, plants and microbes constantly interact with each other, and these interactions are highly diverse and can be broadly categorized as favourable, neutral, or harmful, depending on their effect on the plant health and development process (Tyagi, Lee et al. 2020).

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In past decades, many studies have been conducted to understand the important molecular players involved in plant-microbe interactions, and a lot of information has been discovered; however, this information is not enough, and many queries still need to be addressed. Microorganisms interacting with plants exhibit enormous potential to improve plant health and development as a natural catalyst or to trigger a negative response in the form of disease or stress (van de Mortel et al. 2012). Queries such as how do these microbes interact and exhibit different responses, what are the signalling pathways involved, what makes the interaction harmful or beneficial, what are the immune factors in plant and microbes that affect the overall response in both the interacting partners must be answered to understand the overall interaction process in plants and microbes and will provide the landmark information that can be used to identify and mark the pathogens or beneficial microbes and their interaction effect on the crop plants.

In this context, beneficial microorganisms such as plant growth-promoting rhizobacteria (PGPR) or plant growth-promoting fungi (PGPF) are considered potential elements to improve plant growth and development and, hence, can serve as natural and sustainable alternatives to fertilizers and pesticides (van Loon et al. 1998). In past decades, several PGPFs and PGPRs were identified, characterized, and found to improve plant growth and nutritional quality, soil health, and fertility in a sustained manner. For example, some members of the bacterial genera *Bacillus*, *Trichoderma*, and *Fusarium* prevent plant diseases by subduing plant pathogens, thereby serving as biocontrol agents (Tyagi et al. 2020). Application of PGPR and mycorrhizal fungi enhance plant growth under various stress conditions. Both fungal and bacterial endophytes are found to be active stress relievers of the host plant (Voisard et al. 1989). Studies with many microbial inoculants have demonstrated their beneficial role in plant growth through effective root colonization and induction of plant growth support mechanisms. Overall, the exploitation of beneficial microorganisms and their useful interactions with plants offer promising and eco-friendly strategies in the development of organic agriculture globally (Eckardt 2002). However, microbes can cause a serious threat to agricultural production by causing severe diseases and are considered to be phytopathogens (El-Tarabily et al. 2000). Plant-pathogen studies must be undertaken to identify new pathogens, how they affect plant health, and how the already reported pathogens are developing resistance and evolving. All this information about plant-microbe interaction, whether it is beneficial or harmful, lies in the genetic material, and, thus, the genes involved in these interactions must be identified, characterized, and annotated. There is an urgent need to link the plant studies with "OMICS" to address these questions and provide some useful gene quantitative trait loci (QTLs) controlling specific traits to the breeders that can be used in breeding programs and thus improve the crop varieties in terms of productivity or quality.

1.2 BENEFICIAL PLANT-MICROBE INTERACTIONS

With the start of the green revolution, the use of chemical fertilizers, insecticides, and pesticides increased dramatically to improve agricultural yield and productivity.

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However, despite several studies reporting their negative impact on the ecosystems, soil health, and humans, they are still in use (Tyagi et al. 2021). To overcome these potential hazards, the use of microorganisms for crop improvement has been proposed and, over the years, this proposal has been widely accepted by innovative farmers and agriculturists. Several plant growth-promoting microorganisms (PGPM) – including PGPRs, PGPFs, arbuscular mycorrhizae (AMF), and endophytes (bacteria/fungi) – have been reported to influence plant growth positively (Tyagi et al. 2021). These PGPMs either directly secrete plant growth-promoting compounds in the form of volatile organic compounds (VOCs), plant hormones, siderophores, etc. to boost the plant health or use indirect mechanisms such as the release of lytic enzymes, antibiotics, and other defence molecules which antagonise the pathogen growth and promote the plant growth as well as develop resistance against the plant pathogens (Asari et al. 2016). VOCs are compounds with a high vapour pressure that makes them highly diffusible in soil and the plant canopy, thus, making them an ideal molecule for crosstalk between plants and microbes (Asari et al. 2016). VOCs generated by plants and microorganisms can act as signalling molecules activating a series of molecular events that ultimately regulate a wide range of physiological processes of plants and microorganisms (Tyagi et al. 2019). VOCs released by plants determine the type of microbiota that can live in the phytosphere and prime the plant defensive system to upcoming stresses (Tyagi et al. 2018; Tyagi et al. 2019; Tyagi, Lee et al. 2020). Microbes also emit VOCs in response to environmental conditions and can stimulate plant growth and induce resistance/tolerance to biotic/abiotic anxious factors (Tahir et al. 2017; Tahir et al. 2017). Thus, biogenic VOCs represent a rich and complex chemical vocabulary that can help to uncover the hidden secrets that can be used for modern sustainable agriculture. On the other hand, metal-resistant siderophore-producing bacteria help a plant to thrive under heavy metal stress by alleviating the metal toxicity. Heavy metals, being noxious in nature, enter the food chain and result in the toxicity of plants and animals (Chen et al. 2016). With the expansion of industries, the pollution of these toxic metals is increasing at a very fast pace. The removal of these heavy metals by natural means is the need of the hour. The toxication of soil by these metals can be removed through phytoremediation, mycoremediation, and microbial remediation (Chen et al. 2016). One such way of microbial remediation includes the application of siderophores that are synthesized naturally by microbes and are helpful in forming a complex with heavy metal. Siderophores have been used mostly for clinical studies but have the potential to play a critical role in cleaning the environment (Rajkumar et al. 2010). Siderophores provide heavy-metal detoxification and cleaning of the environment by natural means. Some microbes improve the growth of the plants and serve as biofertilizers (Rajkumar et al. 2010). These microbes form spores and provide a competitive environment for other microbes. Many PGPR/F(s) secrete lytic enzymes such as chitinase, cellulase that can degrade the insoluble organic polymers into soluble compounds that can be utilized by the plants (Tyagi, Lee et al. 2020). Additionally, microbes induce systemic resistance in plants and provide protection against biotic and abiotic stress. Several reports have been published that show the potential and mechanism of action of how microbes secrete different molecules that

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induce resistance against fungal/bacterial pathogens as well as improve the plant growth and development process (Tyagi et al. 2021). Also, the secondary metabolites released by microbes are taken by plants to resist the abiotic stresses such as drought, salt, etc. These interactions among plants and different classes of microbes are much more important to understand so that they can be utilized as alternatives for chemical based agri-products and to ensure the plant health under unfavourable conditions.

1.3 HARMFUL PLANT-MICROBE INTERACTIONS

In plant-microbe interaction studies, it is reported that fungi are more likely to cause more yield losses than other phytopathogens because of their highly evolving nature. Usually, the fungal phytopathogens are host specific, but survival on alternative hosts has also been reported for many of them, which helps the invading pathogen to breach the plant's immune system and develop resistance (Tyagi, Lee et al. 2020). Other phytopathogens, such as bacteria, viruses, and nematodes, also negatively impact plant health and decrease productivity. These pathogens interact with the plant host, breach the plant's immune system, and develop disease in the host, which, later in the course of infection, kills the plant or reduces productivity. Pathogens secrete effector proteins that interact with plant proteins and initiate the infection process. Also, pathogens secret toxins that shut down the expression of defence-related genes, making them vulnerable to infection. Though previous studies provide informative insights regarding these interactions, much still remains unknown and needs to be addressed (Tyagi et al. 2021).

1.4 MICROBIAL IMMUNITY AGAINST HOST PLANTS

To initiate infection in the host plant, microbes must fight against the plant's defence system. Microbes use different virulence-related biomolecules that interact with the host. In the case of bacteria, type II, III, and IV secretion systems release virulence-related biomolecules that interact with the host to initiate and progress the infection (Tyagi et al. 2021). Similarly, fungi secrete enzymes that degrade the host cell wall/membrane-related molecules and allow the pathogens to enter into the host. On the other hand, viruses' particles enter the host through mechanical and chemical injury caused by external factors or by biological vectors (Tyagi et al. 2021). Once the viral particle enters the host, it can replicate itself and induce the infection response. It is very important to understand the mechanism of how pathogens enter the host and what molecules are involved in infection progression as well as how they initiate the infection. Understanding this molecular crosstalk between plant and microbes will help us to develop resistant or less susceptible plant/crop varieties (Tyagi et al. 2021).

1.5 PLANT IMMUNITY AGAINST INVADING PATHOGENS

In nature, plants, as a defending host, and microbes, as infecting pathogen, are constantly racing to initiate/mitigate infection. Several microbes, including bacteria, fungi, and viruses, cause a number of diseases in plants, and plants have to deal

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with these invading pathogens to survive (Tyagi et al. 2020). The success rate of any infection is dependent on the susceptibility of the host and the environmental conditions favouring the establishment of infection. To fight invading pathogens, plants have two layers of defence: 1) constitutive and 2) induced. The constitutive defence system includes the physical and chemical barriers that are uniformly present in all plant species and act as the first line of defence (Tyagi et al. 2021). On the other hand, the induced defence system is activated when the pathogen attacks the host and either tries to breach or has breached the first line of defence (Figure 1.1).

Over time, different research groups have introduced different models of plant-microbe interaction to explain plant immunity and response toward the invading pathogens. The most accepted model among them is the zig-zag model (Tyagi et al. 2021). The plant defence system is activated by cell-to-cell communication followed by a complex series of events between the host plant and pathogen or its component. Depending upon the type (bacteria, fungi, virus, etc.) and nature (biotrophic, necrotrophic, etc.) of invading pathogen, the immune system employs different biomolecules (Tyagi et al. 2018). Generally, plants' cell walls or cell membranes have

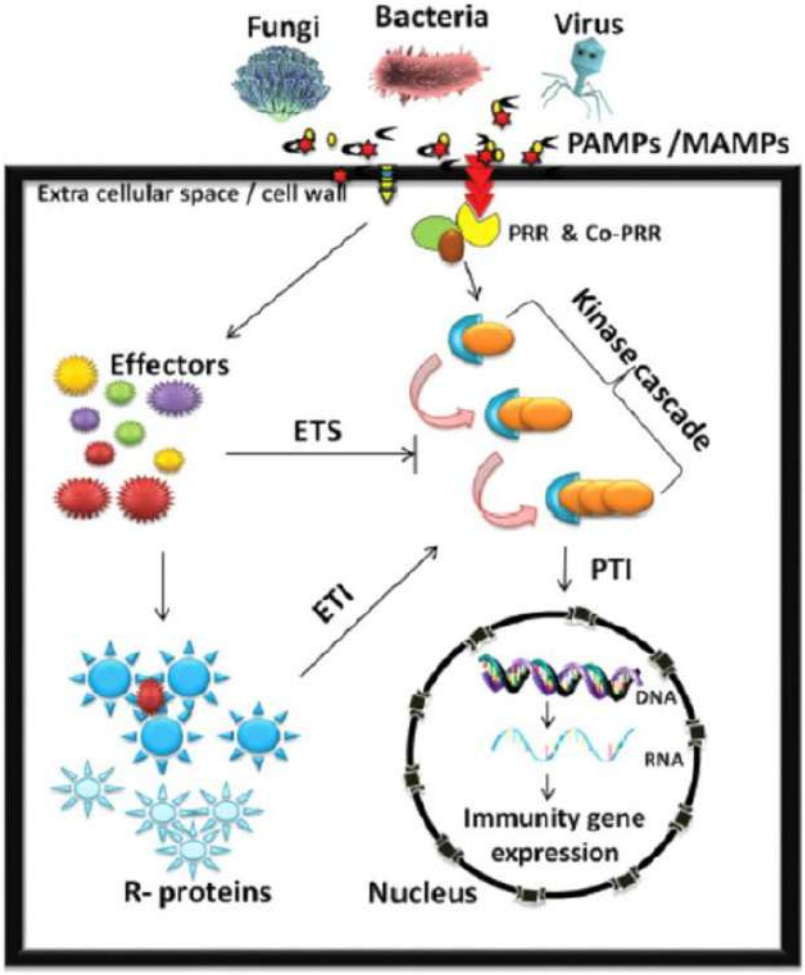

FIGURE 1.1 Plant immune system: The figure illustrates the interaction between plant microbes and the underlying mechanism involved in plant defence.

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a different set of receptors often called protein recognition receptors (PRR) or wall-associated kinases (WAKs). On pathogen encounter, this set of receptors identify the pathogen or microbe associated molecular patterns (PAMP/MAMP) and recruit the PAMP/MAPMP-triggered immune (PTI) system to fight the invading pathogen (Tyagi et al. 2018). To breach this defence, pathogens induce effector-triggered susceptibility (ETS), which causes some pathogens to secrete effector proteins that quash the PTI by employing susceptibility (S) proteins that enable the disease to advance. In this scenario, the plant's immune system initiates another line of defence by employing resistance (R) genes. R genes recognize the effectors or avirulence genes from pathogens and activate effector-triggered immunity (ETI) (Tyagi et al. 2021). These two induced defence systems (PTI and ETI) then alter the expression of different sets of genes, such as mitogen-activated protein kinase (MAPKs), plant hormones, transcription factors, and other pathogenesis-related genes that further induce hypersensitive response, reactive oxygen species (ROS) generation, cell-wall modification, stomata closure, or secretion of anti-microbial proteins and compounds, e.g., chitinases, protease inhibitors, defensins, and phytoalexins, etc. (Tyagi et al. 2018).

1.6 USE OF OMICS TECHNIQUES FOR PLANT-MICROBE INTERACTION STUDIES

The OMICS technologies that collect the information in the form of deoxyribonucleotide (DNA), ribonucleotide (RNA), proteins, or metabolites can shed light on the cellular structure and function of an organism. Out of these, the information that is stored in the form of DNA sequences is not much affected by the environmental condition; however, RNA, proteins, and metabolites are strongly influenced by external factors (Crandall et al. 2020; Sharma et al. 2020). The study of DNA sequences can be performed by genomics or next generation sequencing (NGS) techniques. While the study of RNA can be achieved by transcriptomics, proteins by proteomics, and metabolites by metabolomics. These technologies, either alone or in combination with others, can provide the desired information. The advancement of NGS made it possible to uncover the secrets lying within the genome of any organism (Crandall et al. 2020; Sharma et al. 2020). It became easy to sequence the genome of an organism, understand the mechanism of infection, detect the genetic variations, modify the gene/genome of an organism, and provide different prospects for developing resistance against plant pathogens or improving plant growth and development by introducing a specific gene or trait. It is now possible to study the genotype–phenotype relationship with the highest resolution through linkage mapping. Different approaches such as traits associated mapping, QTL mapping, genome-wide associate studies (GWAS), and haplotype analysis have been used to study these associations to improve plant traits and productivity (Crandall et al. 2020; Sharma et al. 2020). On the other hand, transcriptomic studies characterize and quantify the RNAs present in each sample (plant, organ, tissue) in a particular condition and provide the connection between the genotype and phenotype (Crandall et al. 2020; Sharma et al. 2020). RNA sequencing,

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isoform sequencing, microarray analysis, etc. are different approaches that have been used to capture the transcriptomic information (Crandall et al. 2020; Sharma et al. 2020). In addition to this, proteomic studies are based on the full proteins present in a particular sample in a specific condition. The proteomic studies use two-dimension gel electrophoresis (2DE), liquid chromatography (LC), mass spectroscopy (MS), and coupled approaches such as LC/MS etc. Similarly, metabolomics is the study of by-products/metabolites as distinct molecules involved in a plant in a specific condition (Crandall et al. 2020; Sharma et al. 2020). The techniques employed for metabolomics also include LC/MS, nuclear magnetic resonance spectroscopy (NMR), capillary electrophoresis (CE), and time-of-flight (TOF)-MS devices. On the other hand, advances in molecular biology techniques made it easier to modify the genome of a host either by introducing some genes that can breakdown the toxins, abolish the activity of cell-wall degrading enzymes, excrete antimicrobial compounds, or delete the genes that are susceptible to pathogen attack (Crandall et al. 2020; Sharma et al. 2020). A number of gene editing approaches, such as RNA interface, zinc finger nuclease (ZFN), transcription activator-like effector nuclease (TALEN), CRISPR : Cas9, etc., have been discovered that exhibit potential in the field of genome editing in agriculture and other fields of science (Tyagi et al. 2020). Though these molecular and OMICs techniques seem sophisticated and have proven to be very informative, and a wealth of receptors, genes, genomes, proteins, and metabolic products have been accumulated that can be used to improve the plant-microbe relationship for sustainable agriculture.

1.7 FUTURE PERSPECTIVES

Plant-microbe interaction studies can provide promising solutions for sustainable agriculture. These studies are very important to develop biofertilizers, biopesticides, and bioremediation processes. In the past, several studies were performed that have been very useful, but they are not enough. It is very important to find new genes and targets and understand their mechanisms of action during beneficial or harmful interaction with plants. Therefore, it is necessary to couple the OMICs and biotechnological approaches to understand the genetics of and in-depth knowledge of plant growth, development, disease, traits, and stress (abiotic/biotic) management.

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DISCLOSURE OF POTENTIAL CONFLICTS OF INTEREST

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Acronyms

AES	Advanced Encryption Standard
ANP	Analytic Network Process
ANS	Autonomic Navigation System
API	Application Programming Interface
BAN	Body Area Network
BI	Business Intelligence
CADS	Continuous Authentication on Data Streams
CCAF	Cloud Computing Adoption Framework
CI	Computational Intelligence
CIA	Confidentiality, Integrity, and Availability
CMED	Cloud based MEDical system
CPU	Central Processing Unit
CS	Cloud Server
CSA	Cloud Service Architecture
CSP	Cloud Service Providers
DCTP	Data Collection based on Trajectory Prediction
DDOS	Distributed Denial of Service
DEMATEL	Decision-Making Trial and Evaluation Laboratory
DES	Data Encryption Standard
DNA	Deoxyribo Nucleic Acid
DoS	Denial of Service
DSA	Digital Signature Algorithm
DSMS	Data Stream Management System
ECG	Electrocardiogram
e-CLV	Electronic Customer Lifetime Value
E-commerce	Electronic Commerce
EDOS	Economic Denial of Service
e-Governance	Electronic Governance
EHR	Electronic health Records
ELS	E-commerce Logistics System

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E-RS	Enhanced Reed-Solomon
GB	Gigabyte
GDP	Gross Domestic Product
GPS	Global Positioning System
GSM	Global System for Mobile communication
HMM	Hidden Markov Model
IA	Information Accountability
IaaS	Infrastructure as a Service
ICT	Information and Communication Technology
IoT	Internet of Things
IoV	Internet of Vehicle
ISG	Information Security Governance
IT	Information Technology
ITSC	Intelligent Traffic Control System
MCDM	Multi criteria Decision Making
MD	Message Digest
MDP	Multi-Dimensional Password
ML	Machine Learning
MLA	Multi-level Authentication Scheme
MLC	Multi-level Cryptography
MOLA	Multi Objective Learning Automata
P2P	Peer to Peer
PaaS	Platform as a Service
PARAMO	PARAllel predictive MOdelling
PB	PetaByte
PCC	Predictive Cloud Computing
PccP	Preserving Cloud Computing Privacy
PHMS	Patient Health Monitoring System
PIoT	Predictive Internet of Things
PMC	Predictive Mobile Computing
POR	Proof of Retrievability
PPCA	Probabilistic Principal Component Analysis
PRDC	Permission-based RFID Data Collection Algorithm
PTT	Prediction of Trigger time
PoD	Prediction of Distance
QoS	Quality of Service
RBAC	Role Based Access Control
RBE	Role Based Encryption
RC	Rivest Cipher
RDIC	Remote Data Integrity Checking
REF	Reference
RFID	Radio Frequency Identification
RPM	Remote Patient Monitoring
RSA	Rivest Shamir Adleman
SaaS	Software as a Service

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SAMOA	Socially Aware and Mobile Architecture
SBA	Seed Block Algorithm
SDG	Stochastic Gradient Descent
SecCTP	Secure Cloud Transmission Protocol
SHA	Secure Hash Algorithm
s-Health	Smart Health
SLA	Service Level Agreement
SOAP	Simple Object Access Protocol
SQL	Structured Query Language
SSL	Secure Socket Layer
SWF	Smallest Window First
TB	Terabyte
TLS	Transport Layer Security
TPA	Third Party Auditor
TTP	Trusted Third Party
UML	Unified Modeling Language
V2V	Vehicle-to-Vehicle
VANET	Vehicular ad-hoc network
VM	Virtual Machines
VPN	Virtual Private Network
Wi-Fi	Wireless Fidelity
WSDL	Web Services Description Language
WSN	Wireless sensor networks
XML	eXtensible Markup Language

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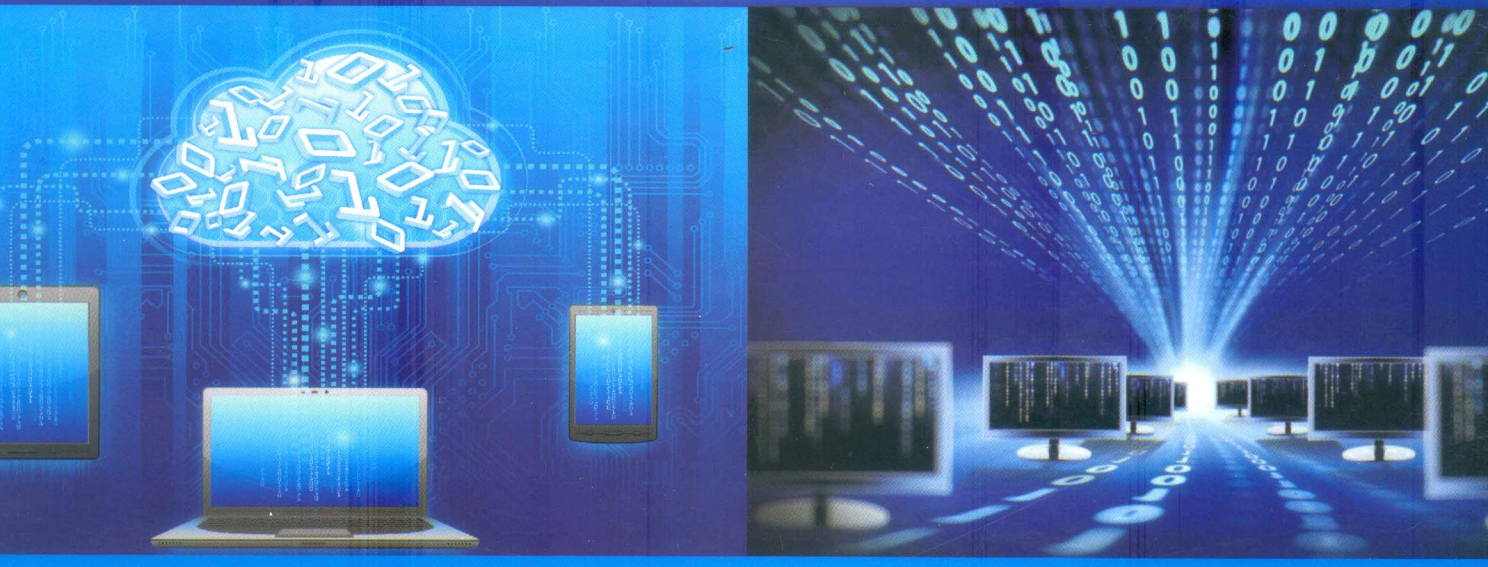

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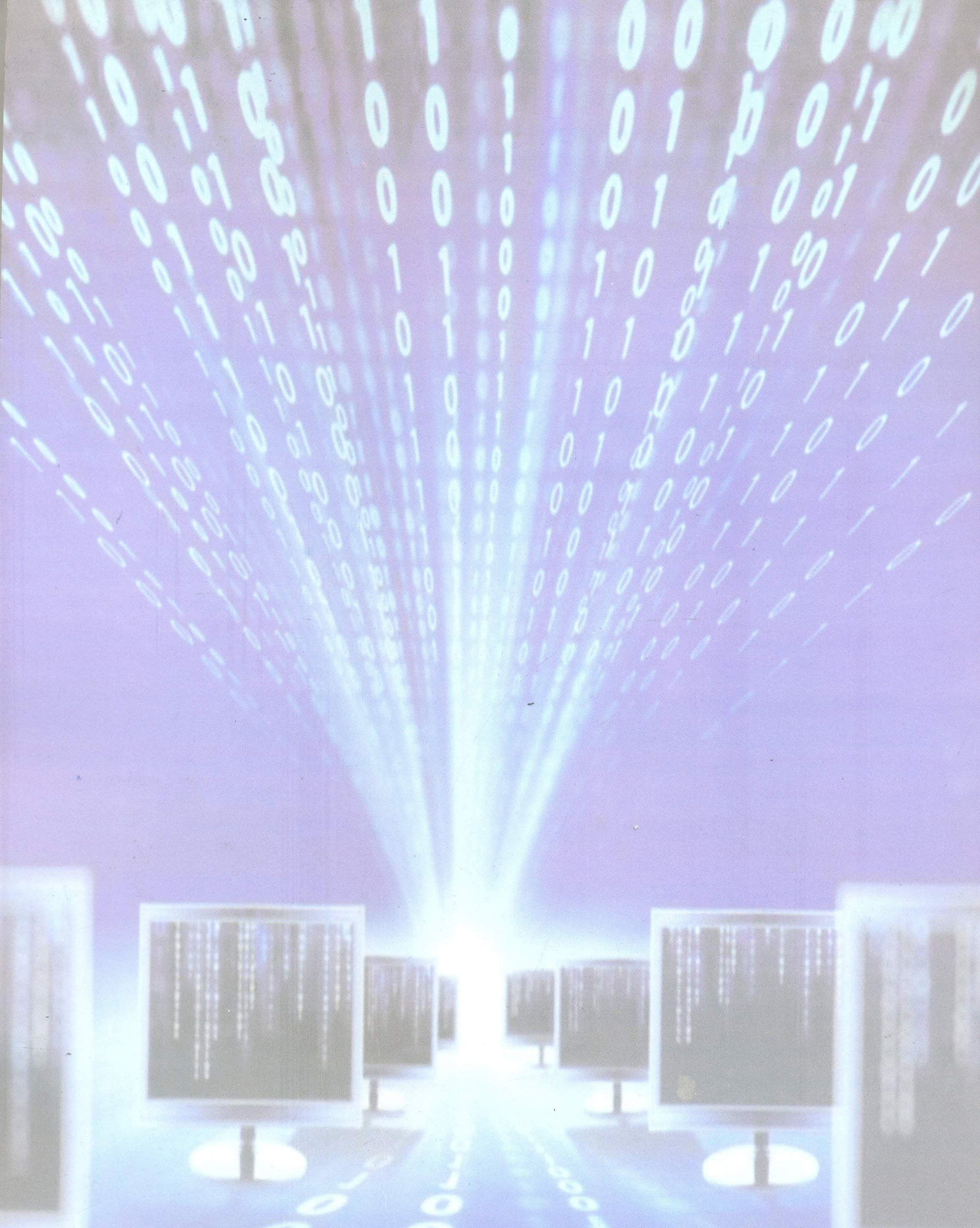

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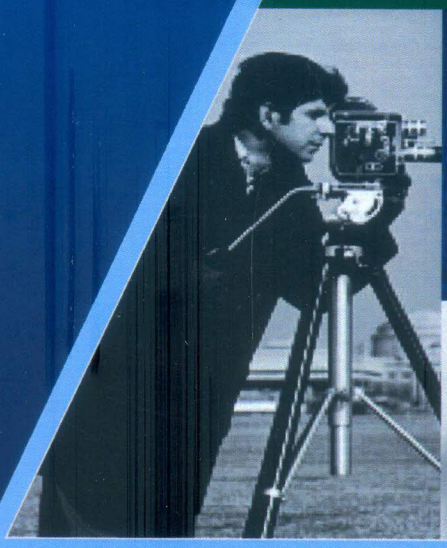

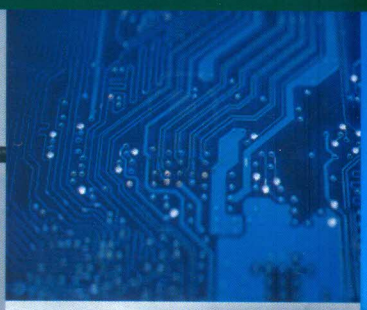





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Shruti Jain · Sudip Paul *Editors*

Recent Trends in Image and Signal Processing in Computer Vision

This book highlights recent advances and emerging technologies that utilize computational intelligence in signal processing, computing, imaging science, artificial intelligence, and their applications. It covers all branches of artificial intelligence and machine learning that are based on computation at some level, e.g. artificial neural networks, evolutionary algorithms, fuzzy systems, and automatic medical identification systems. Exploring recent trends in research and applications, the book offers a valuable resource for professors, researchers, and engineers alike.

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GUEST EDITORIAL

Guest Editorial: Robust and Secure Data Hiding Techniques for Telemedicine Applications

Amit Kumar Singh[1] · **Basant Kumar**[2] · **Sanjay Kumar Singh**[3] · **Mayank Dave**[4] · **Vivek Kumar Singh**[5] · **Pardeep Kumar**[1] · **S. P. Ghrera**[1] · **Pradeep Kumar Gupta**[6] · **Anand Mohan**[7]

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Recently, with the explosive growth of information and communication technologies, various new opportunities emerged for the creation and delivery of content in digital form which includes applications such as real time video and audio delivery, electronic advertising, digital libraries, broadcast monitoring, e-governance, e-commerce applications, copy control, media

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identification and tracking, healthcare, E-Voting Systems, remote education, web publishing and digital cinema. One of the promising applications of digital image watermarking is in the field of secure medical data transmission for various telemedicine applications. However, these advantages have the consequent risks of data piracy and authenticity, which motivate towards development of new protection mechanisms. One such effort that has been attracting interest is based on digital watermarking techniques, which is a technique for embedding data (called a watermark) into digital multimedia cover objects in such a way that the watermark can be detected or extracted later to make an assertion about the authenticity and / or originality of the object. The aim of this special issue is to solicit the state-of-the-art data hiding techniques and technical solutions in the area of telemedicine applications.

This special issue has attracted 58 manuscripts and the submissions have been strictly reviewed by least three reviewers consisting of guest editors and external reviewers, with 23 high-quality articles accepted in the end. Below, we briefly summarize the highlights of each paper.

In *Reversible data hiding in encrypted images based on multi-level encryption and block histogram modification* (10.1007/s11042-016-4049-z). Yin et al. propose a reversible data hiding technique in encrypted images (RDH-EI). The smaller location map and block histogram modification (BHM) using a self-hidden peak pixels technique contribute to reduce the quantity of side information and improve the pure payload. Further, these techniques are combined with proposed multi-level encryption (MLE) method using Josephus traversal and stream cipher an integrated RDH-EI framework. The results demonstrate that the distortion of the decrypted images is smaller, lossless recovery was achieved in every evaluated case, and the payload is larger, which is better than other state-of-the-art research used for comparison.

In *Hybrid NSCT domain multiple watermarking for medical images* (10.1007/s11042-016-3885-1). Singh et al. presents a hybrid technique of multiple watermarking for medical images using non-subsampled contourlet transform (NSCT), discrete cosine transform (DCT), multi-resolution singular value decomposition (MSVD) and Arnold transform. The method is evaluated with a different medical cover images and three different watermarks. Further, accuracy of the method is enhanced by using proper selection gain factor and NSCT sub-bands. The results demonstrate that the proposed method is suitable for recovery of multiple watermarks. Furthermore, robustness comparisons of the proposed technique show the superiority with other state-of-the-art algorithms.

In *An efficient approach for face recognition in uncontrolled environment* (10.1007/s11042-016-3976-z). Agrawal and Singh develop a framework of face recognition system that outperforms in unconstrained environments. The framework works on features based method that extracts facial landmarks from images. After quality check the patch experts are generated and used to model the

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appearance of landmarks of interests. The effect of discriminatory features is further enhanced by assigning weights to them that are to be set to the ratio of the interclass variance to the intra-class variance. The results show that the proposed framework achieves better recognition accuracy in comparison to other state-of-the-art algorithms on publically available datasets.

In *Data hiding in AMBTC images using quantization level modification and perturbation technique* (10.1007/s11042-016-3977-y). Hong et al. *present a* data hiding technique for absolute moment block truncation coding (AMBTC) compressed image using quantization level modification. Blocks of AMBTC-compressed image are classified into two categories, namely smooth and complex, according to a predefined threshold. For smooth blocks, the bitmap is replaced by secret data for data embedment. Meanwhile, the corresponding quantization levels are modified to achieve a minimum distortion. Results indicate that the modified quantization levels can be further perturbed for carrying two additional bits, if a larger payload is required. If the blocks are complex, one data bit can be embedded with no distortion by swapping the values of the two quantization levels together with bitmap flipping. In addition, a suppress threshold mechanism is used to prevent from the application of the perturbation technique at low payload to maintain the image quality. The proposed method minimizes the distortion of each stego block while ensuring high payload, thus the embedding efficiency is enhanced. Experimental evaluations demonstrate the improvement of the proposed method compared with other related state-of-art research.

In *Joint JPEG Compression and Detection Resistant Performance Enhancement for Adaptive Steganography Using Feature Regions Selection* (10.1007/s11042-016-3914-0). Zhang et al. focus a JPEG compression and detection resistant adaptive steganography algorithm using feature regions. Based on the proposed feature region extraction and selection algorithms, the embedding domain robust to JPEG compression and containing less embedding distortion can be obtained. Further, combined with error correct coding and SyndromeTrellis codes (STCs), the messages are embedded into the cover images with minimum embedding distortion, and can be extracted with high accuracy after JPEG compression, hence, the JPEG compression and detection resistant performance are enhanced at the same time. Experimental evaluations demonstrate the improvement of the proposed method compared with current J-UNIWARD steganography.

In *A blind medical image watermarking: DWT-SVD based robust and secure approach for telemedicine applications* (10.1007/s11042-016-3928-7). Thakkar and Srivastava present a blind image watermarking technique for telemedicine application using discrete wavelet transform (DWT) and singular value decomposition (SVD). Two watermark contents in the form of image and electronic patient record (EPR) watermark are embedded into the SVD blocks of selected wavelet sub-band of the medical cover image. The watermark contents are embedded in such a way that blind extraction of the contents becomes possible at the receiving end. Instead of directly embedding of EPR watermark, Hamming error correcting code is applied on it to get encoded watermark which is embedded into the image. The method is evaluated and found to be robust under different signal processing attacks including checkmark attacks. The Experimental analysis shows that the proposed work achieves better robustness in comparison to other state-of-the-art algorithms at acceptable visual quality of the watermarked image. Moreover, proposed technique is also appropriate for color image watermarking.

In *A multimodal biometric watermarking system for digital images in redundant discrete wavelet transform* (10.1007/s11042-016-4048-0). Singh et al. develop a multimodal biometric watermarking system using redundant discrete wavelet transform (RDWT). Two biometric traits iris and facial features are embedded independently into the sub-bands of the RDWT of cover image taking advantage of its translation invariant property and sufficient embedding capacity.

The ownership verification accuracy of the proposed system is evaluated based on the individual biometric traits as well as the fused trait. The accuracy is enhanced while using the fused score for evaluation. The security of the method is strengthened with usage of non-linear chaotic maps, randomization through Hessenberg decomposition, Arnold scrambling and multiple secret keys. The robustness of the method is tested for various important attacks and the verification accuracy is evaluated based on false acceptance rate, false rejection rate, area under curve and equal error rate to validate the efficacy of the proposed method.

In *Robust covert communication using high capacity watermarking* (10.1007/s11042-016-3978-x). Bhatnagar presents a high-capacity watermarking technique in which watermarkable pixels are selected from the cover image based on the census transform and hamming distance followed by the embedding which is done by proposed spectral decompositions. Finally, a reliable watermark extraction technique is developed which is free from the false-positive detection problem of singular values. The experimental evaluations demonstrate that the proposed technique is expeditiously able to withstand a various kind of extreme attacks and highly suitable for covert communications.

In *Statistical textural feature and deformable model based brain tumor segmentation and volume estimation* (10.1007/s11042-016-3979-9). Banday and Mir present a semi-automatic technique that yields appropriate segmented regions from MR brain images. The segmentation technique here utilizes fusion of information beyond human perception from MR images to develop a fused feature map. The information beyond human perception includes second order derivatives that are determined from an image. This obtained feature map acts as a stopping function for the initialized curve in the framework of an active contour model to obtain a well segmented region of interest. The segmentation is carried out in all the slices of a particular dataset with initialization of the active contour required only on the first slice which makes this method fast. The obtained segmentation results are compared with ground truth segmentation results obtained from experts manually using Jackard's Co-efficient of Similarity and Overlap index. The efficacy of this volume estimation technique is illustrated with comparison to mostly used ABC/2 method and cavalieri method. The results obtained on various case studies like Craniophryngioma, High grade Glioma and Microadenoma show a good efficacy of the method.

In *Digital watermark extraction in wavelet domain using hidden Markov model* (10.1007/s11042-016-3975-0). Amini et al. propose a watermark decoder using the vector-based hidden Markov model (HMM) in the wavelet domain. The watermark decoder is designed based on the maximum likelihood criterion. Closed-form theoretical expression for the watermark decoder is derived. The performance of the proposed decoder in terms of bit error rate values is assessed using a number of test images. The results indicate that the proposed decoder is robust for different kind of attacks and superior to other decoders in terms of providing a lower bit error rate.

In *A new reversible and high capacity data hiding technique for e-healthcare applications* (10.1007/s11042-016-4196-2). Parah et al. propose a high capacity and reversible data hiding technique capable of tamper detection and localization of medical images. The cover image is divided into non-overlapping blocks. In every block pixels are classified into two types: Seed pixels and non-seed pixels. The EPR is embedded only in non-seed pixels while as no embedding is carried out in seed pixels to facilitate reversibility. A fragile watermark coupled with block checksum is embedded in addition to EPR for detecting any tamper to the patient data during its transit from sender to receiver. Embedding has been carried out using intermediate significant bit substitution (ISBS) to prevent the technique from LSB removal/replacement attack. The technique is evaluated for perceptual imperceptibility and content authentication by subjecting it to various image processing and geometric attacks. Experimental results reveal that the proposed system is capable of providing high quality watermarked images for fairly high payload while

maintaining reversibility. Further, the proposed technique is able to detect tamper for all the image processing and geometric attacks carried out on it. A comparison of the observed results with that of some state-of-art algorithms show that the method performs better and as such is an ideal candidate for content authentication of EPR in a typical healthcare system.

In *Data hiding using pseudo magic squares for embedding high payload in digital images* (10.1007/s11042-016-3974-1). Ranjani propose a data hiding technique using pseudo magic square pattern. The pattern is generated using the Knight's move algorithm, whereas diamond encoding (DE) and adaptive pixel pair matching (APPM) embedding schemes adapts rhombic shaped and non-uniform pattern respectively. The momentous feature of the proposed embedding scheme is its ability to generate several pseudo magic squares for a given embedding parameter. The performance analysis in the experimental results reveal that the proposed algorithm not only provides increased payload with less distortion but also increases the security of the embedding processing by allowing the application to employ one among the several square patterns for every secure communication.

In *A light weight and secure video conferencing scheme utilizing public network* (10.1007/s11042-016-3973-2). Meenpal present a selective encryption technique applied on the quantized non-zero DCT coefficients of the macro-blocks belonging to I-frame of the JPEG/MPEG family such that the resultant image/video is completely obscure and is suitable for high end security applications. Also there is no reduction in the performance of compression algorithms applied later in the standard JPEG/MPEG pipeline. Experiments show that the encrypted image/video file is almost of the same size as that of un-encrypted version. Thus the scheme is suitable for telemedicine as well as other important applications.

In *Iterative quadtree decomposition based automatic selection of the seed point for ultrasound breast tumor images* (10.1007/s11042-016-3761-z). Fan et al. explore an automatic method for finding the seed point inside the tumor. Two criteria combining iterative quadtree decomposition (QTD) and the gray characteristics of the lesion are thus designed to locate the seed point. One is to seek the biggest homogenous region and the other is to select the seed region where the seed point is found. Furthermore, this study validates the proposed algorithm through various ultrasonic breast tumor images. As the quantitative experiment results show, the proposed method can automatically find the seed point inside the tumor with satisfactory performance in term of sensitivity and accuracy rate.

In *Dual domain robust watermarking scheme using random DFRFT and least significant bit technique* (10.1007/s11042-016-4095-6). Sharma et al. develop a robust and non-blind image watermarking method that uses multiple-parameter discrete fractional Fourier transform (MPDFRFT) with random DFRFT and least significant bit (LSB) technique. The simulation results validate that the embedding method has better performance in terms of robustness along with perceptibility and security over contemporary existing techniques.

In *Region-based hybrid medical image watermarking for secure telemedicine applications* (10.1007/s11042-016-3913-1). Singh and Maheshkar present a region based hybrid medical image watermarking (MIW) technique using fusion of IWT and SVD. Initially, the cover medical image is partitioned into region of interest (ROI) and the region of non interest (RONI). To detect and localize ROI tampering with high accuracy pixel wise positional and relational bits are calculated. Two original LSBs of each ROI pixel are replaced by their corresponding positional and relational bits. Original LSBs of ROI pixels are concatenated and embedded in RONI for ROI recovery in the case of tampering. Multiple watermarks i.e. EPR, hospitals logo and LSBs of ROI are embedded simultaneously as a robust watermark in RONI using IWT-SVD hybrid transform. The proposed technique is blind and free from false positive detection. Various experiments is carried out on different medical imaging modalities to evaluate the performance of the proposed

technique in terms of imperceptibility, robustness, tamper detection, localization, recovery and computation time. ROI tampering is detected and recovered with high accuracy.

In *Unified entropy-based sorting for reversible data hiding* (10.1007/s11042-016-3989-7). Xu et al. propose an entropy-based sorting (EBS) method for reversible data hiding, which uses entropy measurement to characterize local context complexity for each image pixel. Furthermore, by extending the EBS technique to the two-dimensional case, it shows generalized abilities for multi-dimensional RDH scenarios. Additionally, a new gradient-based tracking and weighting (GBTW) pixel prediction method is introduced to be combined with the EBS technique. Experimental results apparently indicate that the proposed method outperforms the previous state-of-arts counterparts significantly in terms of both the prediction accuracy and the overall embedding performance.

In *A robust blind hybrid image watermarking scheme in RDWT-DCT domain using Arnold scrambling* (10.1007/s11042-016-3902-4). Roy and Pal propose a robust and blind image watermarking technique using Redundant Discrete Wavelet Transform (RDWT), Discrete Cosine Transform (DCT), Arnold scrambling and error correction repetition code. Experimental results show that robustness is achieved by recovering satisfactory watermark data from the reconstructed cover image after applying common geometric transformation attacks, common enhancement technique attacks , JPEG compression and Checkmark attacks.

In *Accelerating Compute Intensive Medical Imaging Segmentation Algorithms Using GPUs* (10.1007/s11042-016-3884-2). Alsmirat et al. focus on Fuzzy C-Means based segmentation algorithms and accelerates the execution time of these algorithms using Graphics Process Unit (GPU) capabilities. In this research, authors are studied pure GPU and hybrid CPU-GPU implementations with CUDA. The result outcomes show that the hybrid CPU-GPU improves the execution time much better than that of the pure GPU implementations.

In *XOR based Continuous-tone Multi Secret Sharing for Store-and-forward Telemedicine* (10.1007/s11042-016-4012-z). Shivani et al. present XOR based Continuous-tone Multi Secret Sharing scheme suitable for store-and-forward telemedicine application. It also eliminates basic security constraints of visual cryptography (VC) like pixel expansion in shares/recovered secret images, random pattern of shares, explicit codebook requirement, lossy recovery of secret and limitation on number of secret and shares. Proposed technique is '*n*' out of '*n*' multi secret sharing scheme which is able to transmit '*n*' secret images simultaneously. All secrets could be revealed only after some computations with all '*n*' shares and one master share. Master share has been created with the secret key at encoding phase and it can be regenerated at the time of decoding using same secret key. Proposed technique not only preserves all basic characteristics of traditional VC but also increases the capacity of secret image sharing. From the experiments we found that irrespective of visible contents of the shares, the probability of getting back the pixel values of respective original secret images at the receiver end is very high.

In *Mobile-cloud assisted framework for selective encryption of medical images with steganography for resource-constrained devices* (10.1007/s11042-016-3811-6). Sajjad et al. address the problem of outsourcing the selective encryption of a medical image to cloud by resource-constrained devices, without revealing the cover image to cloud using steganography. In the proposed technique, the region of interest of the medical image is first detected using a visual saliency model. The detected important data is then embedded in a host image, producing a stego image which is outsourced to cloud for encryption. The cloud which has powerful resources, encrypts the image and sent back the encrypted marked image to the client. The client can then extract the selectively encrypted region of interest and can combine it with the region of non-interest to form a selectively encrypted image, which can be sent to medical specialists and healthcare centers. Experimental results and analysis

validate the effectiveness of the proposed framework in terms of security, image quality, and computational complexity and verify its applicability in remote patient monitoring centers.

In *(Two-dimensional)^2 whitening reconstruction for newborn recognition* (10.1007/s11042-016-3731-5). Singh and Om propose a (Two-dimensional)^2 whitening reconstruction (T^2WR) pre-processing step along with Principal Component Analysis (PCA) algorithm which is a state-of-the-art technique to overcome the challenge of recognizing faces under different lightening conditions. This technique is applied to newborn face database which is a rarely accessible database. The technique is compared with state-of-the-art Two-dimensional whitening reconstruction (TWR) pre-processing algorithm and indicates better performance of T^2WR over TWR. The histograms plotted for both these algorithms show that T^2WR makes for a smoother frequency distribution than TWR. The proposed method proved to be comparatively more robust in identification of newborns in variety of illumination, expression change and occlusive image.

In *Double expanding robust image watermarking based on Spread Spectrum technique and BCH coding* (10.1007/s11042-016-3734-2). Soleymani and Taherinia develop an algorithm for blind image watermarking which has a high robustness against common image processing attacks. In this research, a small watermark of size is double expanded into multi larger meaningful bits with applying BCH error correction code and spread spectrum technique in order to reduce errors in extraction phase. Consequently this method allocates smaller gain factors to smooth blocks and larger gain factors to texture and rough blocks. The simulation results show that better performance in terms of robustness and visual quality over contemporary existing techniques.

These 23 selected contributions basically can reflect the new achievements in the telemedicine applications and we hope they can provide a solid foundation for future new approaches and applications. Finally, we would like to thank all authors for their contributions, the reviewers for reviewing these high quality papers, and Editor-in-Chief, Prof. Borko Furht, for his support and guidance throughout the process.



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Signal Processing Computing and Control



Meenakshi Sood, Shruti Jain
Editors

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Computational Intelligence Techniques

SMART COMPUTATIONAL INTELLIGENCE IN BIOMEDICAL AND HEALTH INFORMATICS

Edited by
Amit Kumar Manocha, Mandeep Singh, Shruti Jain,
and Vishal Jain

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Preface

Health informatics involves multidisciplinary domains to extract information and knowledge from physiological data to use in decision making for improved human health through the effective use of recently developed technologies and algorithms. The aim is to provide a cross-disciplinary forum to share information on research, simulations and modeling, measurement and control, analysis, information extraction, and monitoring of physiological data in clinical medicine and the biological sciences. Emphasis is placed on contributions dealing with the practical, applications-led research on the use of methods and devices in clinical diagnosis, disease prevention, patient monitoring, and management. Health informatics is closely related to artificial intelligence where heuristic as well as metaheuristic algorithms are designed to provide better and optimized solutions in reasonable amounts of time. These algorithms have been successfully applied to different application domains in biomedical, bioinformatics, and biological sciences. The practice of recent biomedical research requires sophisticated information technologies to manage patient information, and plan for diagnostics, prognostics, procedures, interpretation, and investigations. This provides a conceptual framework and practical inspiration for the quickly growing and promising engineering and scientific disciplines of computer science, decision science, information science, cognitive science, and biomedicine. The objective of this book is to provide the researchers a platform to present state-of-the-art innovations, research, design, and implement methodological and algorithmic solutions to data processing problems by designing and analyzing evolving trends in health informatics and computer-aided diagnosis. This book will provide support and aid to the researchers involved in designing decision support systems that will permit the societal acceptance of ambient intelligence. The overall goal of this book is to present the latest snapshot of the ongoing research as well as shed further light on future directions in this space. This book presents novel technical studies as well as position and vision papers comprising hypothetical/speculative scenarios.

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Munesh C. Trivedi · Krishn K. Mishra
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Smart Innovations in Communication and Computational Sciences

Proceedings of ICSICCS 2017, Volume 1

Springer

Bijaya Ketan Panigrahi · Munesh C. Trivedi
Krishn K. Mishra · Shailesh Tiwari
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The book provides insights into International Conference on Smart Innovations in Communications and Computational Sciences (ICSICCS 2017) held at North West Group of Institutions, Punjab, India. It presents new advances and research results in the fields of computer and communication written by leading researchers, engineers and scientists in the domain of interest from around the world. The book includes research work in all the areas of smart innovation, systems and technologies, embedded knowledge and intelligence, innovation and sustainability, advance computing, networking and informatics. It also focuses on the knowledge-transfer methodologies and innovation strategies employed to make this happen effectively. The combination of intelligent systems tools and a broad range of applications introduce a need for a synergy of disciplines from science and technology. Sample areas include, but are not limited to smart hardware, software design, smart computing technologies, intelligent communications and networking, web and informatics and computational sciences.

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Spectrum Sharing in Cognitive Radio Networks

Medium Access Control Protocol Based Approach

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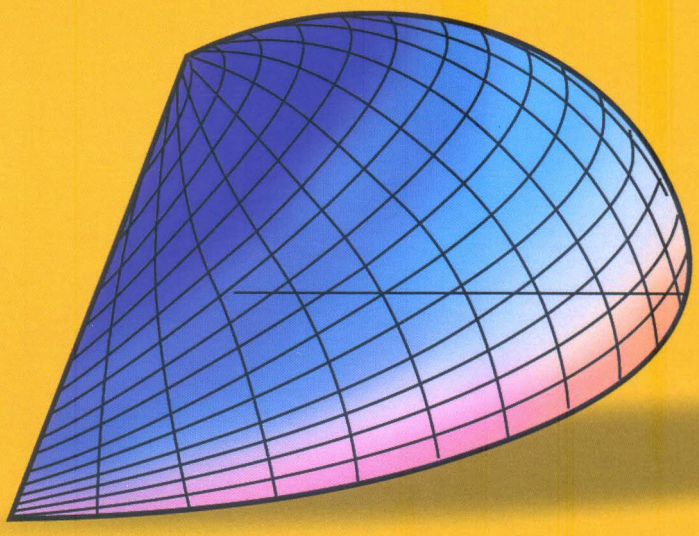

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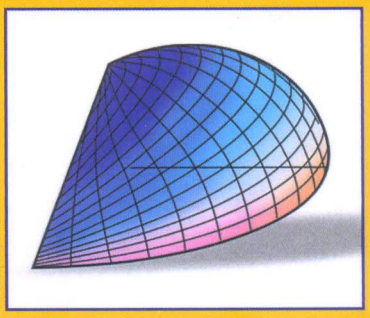

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Punit Gupta · Pradeep Kumar Gupta

Trust & Fault in Multi Layered Cloud Computing Architecture

This book discusses various aspects of cloud computing, in which trust and fault-tolerance models are included in a multilayered, cloud architecture. The authors present a variety of trust and fault models used in the cloud, comparing them based on their functionality and the layer in the cloud to which they respond. Various methods are discussed that can improve the performance of cloud architectures, in terms of trust and fault-tolerance, while providing better performance and quality of service to user. The discussion also includes new algorithms that overcome drawbacks of existing methods, using a performance matrix for each functionality. This book provide readers with an overview of cloud computing and how trust and faults in cloud datacenters affects the performance and quality of service assured to the users.

- Discusses fundamental issues related to trust and fault-tolerance in Cloud Computing;
- Describes trust and fault management techniques in multi layered cloud architecture to improve security, reliability and performance of the system;
- Includes methods to enhance power efficiency and network efficiency, using trust and fault based resource allocation.

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MOHINDRU

UNMANNED AERIAL VEHICLES

UNMANNED AERIAL VEHICLES FOR INTERNET OF THINGS

CONCEPTS, TECHNIQUES, AND APPLICATIONS



EDITED BY
VANDANA MOHINDRU
YASHWANT SINGH
RAVINDARA BHATT
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Unmanned Aerial Vehicles for Internet of Things (IoT)

Concepts, Techniques, and Applications

Edited by
Vandana Mohindru,
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Preface

Unmanned aerial vehicles (UAVs) have become one of the rapidly growing areas of technology, with widespread applications covering various domains. UAVs play a very important role in delivering Internet of Things (IoT) services in small and low-power devices such as sensors, cameras, GPS receivers, etc. These devices are energy-constrained and are unable to communicate over long distances. The UAVs work dynamically for IoT applications in which they collect data and transmit it to other devices that are out of the communication range. Furthermore, the benefits of the UAV include deployment at remote locations, the ability to carry flexible payloads, reprogrammability during tasks, and the ability to sense for anything from anywhere. Using IoT technologies, a UAV may be observed as a terminal device connected in the ubiquitous network, where many other UAVs are communicating, navigating, controlling, and surveilling in real time and beyond line-of-sight.

However, many significant research challenges should be addressed before bringing such UAV capabilities into practice. The aim of this book is to explore the theoretical as well as technical research outcomes of all aspects of UAVs. The UAV has drastically altered the perspectives of users, practitioners, and researchers in many fields of application such as disaster management, structural inspection, goods delivery, transportation, localization, mapping, pollution and radiation monitoring, search and rescue, farming, etc. The advancements introduced by UAVs are countless and have led the way for the full integration of UAVs as intelligent objects in the IoT.

This book helps to realize the full potential of the UAV for the IoT by addressing its numerous concepts, issues and challenges, and develops conceptual and technological solutions for handling them. It is comprised of 15 chapters authored by various renowned experts in the UAV and IoT fields. The book is organized as follows:

Chapter 1 presents a comprehensive survey of UAVs. The communication standards, workings, and various technologies of UAV are presented.

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Also, platforms of different types of drones in various categories, their working, types, sizes, and other technology employed in making them are explored. Furthermore, the latest ongoing technology used in drones and their recent advancements are discussed.

Chapter 2 highlights the state-of-the-art, challenges encountered and the open research issues in designing UAV-aided wireless communication networks. A few of the challenges identified and presented include the best methods of 3D deployment of drones, allocation of resources, optimization of the flight time and trajectory of UAVs, handover management, channel modeling of highly dynamic UAV channels in various scenarios of UAV-assisted networks, interference management, effects of higher Doppler shifts in mmWave networks, on-board energy availability of UAV devices, etc.

Chapter 3 focuses on the techniques available for effective battery and energy management in UAV-based communication networks. The mechanisms for the optimal utilization of energy resources by UAVs to maximize their lifespan or deployment in a network are critically examined. This helps to significantly reduce the usage of network energy that results in a prolonged network lifetime. Furthermore, potentially promising areas for future research in energy management are also explored.

Chapter 4 emphasizes the most used communication techniques in UAVs. The state-of-the-art literature regarding UAV communication techniques and a summary of the same in the form of challenges and issues that arise when developing communication methods for UAVs are presented. A comprehensive performance comparison of UAV communication techniques is provided at the end of this chapter.

Chapter 5 discusses different challenges and threats posed by UAVs such as hijacking, privacy, cybersecurity, and physical safety. Also discussed are different solutions for avoiding these issues with current technologies.

Chapter 6 bridges the landscape between the IoT and the UAV by identifying the technical and nontechnical issues facing integration. Also presented are various applications, architecture, and technologies of the UAV-enabled IoT. This chapter answers the question regarding the proximity between IoT and UAV by exploiting the mobility of UAVs.

Chapter 7 introduces the practice of using UAVs for security and intelligence and also relates how drones are employed in different domains and for different purposes, including mischievous ones. Also, new experiments are presented related to security, safety, and privacy concerns when UAV drones are engaged in dangerous activities.

Chapter 8 explores blockchain-based solutions for various security issues in UAV-enabled IoT. Though the fusion of UAVs and IoT proves disruptive,

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it is needed to address increased security issues. Identity management, authentication, UAV hijacking, secured and trustworthy data sharing in intra-UAV communications, and UAV signal jamming are explored in this chapter. Since blockchain is a decentralized technology, a distributed ledger offers solutions to some of these UAV issues presented here.

Chapter 9 introduces the efficient energy management systems in UAV-based IoT networks. The major constraint envisaged is the limited battery capacity of UAVs, proving them to be energy-constrained devices. The methods described here either harvest energy from RF signals or mmWaves, charge wirelessly from the charging station, or change the flight conditions for efficient energy utilization.

Chapter 10 contains an inclusive survey on the challenges and opportunities of IoE-enabled UAVs. There is a review of technologies enabling these opportunities, such as battery constraint, security issues, computing, and coverage constraints; and there is also an overview of UAVs. Finally, IoE-enabled UAV technology is presented that uses UAV deployment and mobility with IoE's intelligence, scalability, and diversity.

Chapter 11 provides a comprehensive survey of research for exploring applications of AI in UAV-enabled IoT systems with a specific focus on the research being conducted in the field of convergence of three disruptive technologies—namely, AI, UAVs, and the IoT—for improving the quality of life. The importance of AI in realizing an autonomous and intelligent flying IoT is emphasized.

Chapter 12 aims to follow a modular design approach to provide better functionality and a wide range of applications in all sorts of fields. It also incorporates the IoT in the UAV with all the sensor data of the surrounding environment with a UAV position that can be transmitted to a remote server and analyzed in real time.

Chapter 13 focuses on a mind-controlled UAV using brain-computer interface (BCI), which is a connection between the human brain and computers. The scope of this chapter is concentrated on the development boards which permit wireless communications.

Chapter 14 analyzes the new era farming system and the role of UAV technologies which help to improve the agricultural area to enable farmers to make cost-effective decisions while also preserving the ecosystem and changing how food is generated.

Chapter 15 explores the IoT-based UAV platform revolutionizing smart healthcare. The mobile phone industry and the IoT networks that are making robust data collection possible are rapidly being used in medical tools and software. This chapter discusses healthcare IoT technologies and their advantages for society.

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In closing, we would like to thank our contributing authors for their valuable work, without which it would have been impossible to complete this book. We would also like to express our deepest appreciation to our reviewers for submitting their valuable comments in a timely manner. Last but not least, we thank GOD for giving us the strength and wisdom to carry out this work successfully even during tough circumstances due to the COVID-19 pandemic.

We hope that the quality research work published in the 15 chapters of this book will serve the needs of those in the academic, research, science and technology communities along with all of humanity.

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A Node Clone Attack

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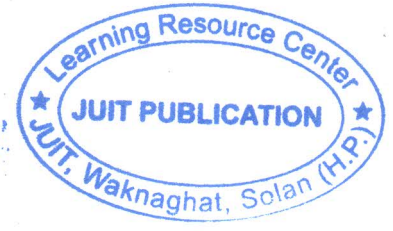
Wireless Sensor Networks Security Attacks

A Node Clone Attack



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Wireless sensor networks (WSNs) becoming popular nowadays due to the low-cost, unattended nature and the capability of self-organization of sensor nodes. Security is critical for many sensor network applications, such as military target tracking, weather monitoring and security monitoring. The deployment of sensors in a hostile environment and communication over the wireless medium, make the WSNs vulnerable to several types of attacks, like eavesdropping, Denial of Services (DoS) attacks, flooding and Sybil attack. Among these attacks, the node clone attack is a harmful attack, through which attacker compromises a node and then inject clones within the sensor networks. These clones perform various destructive operations, which obstructs the working of WSNs. The wireless sensor network requires robust mechanisms for the detection of node clone attack. This book presents security attacks classification for wireless sensor networks and the focus is given on the node clone attack. Analysis of various detection mechanisms for node clone attacks is also illustrated in this book.

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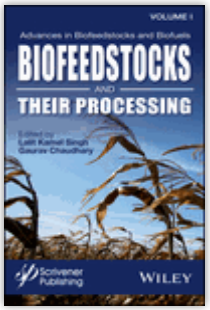

Advances in Biofeedstocks and Biofuels: Biofeedstocks and Their Processing

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The most comprehensive and up-to-date treatment of all the possible aspects for biofeedstock processing and the production of energy from biofeedstocks

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4

Present Status On Enzymatic Hydrolysis of Lignocellulosic Biomass for Bioethanol Production

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Abstract

Bioethanol is becoming a better alternative to fossil fuels. Production of ethanol by using edible feedstock such as grains, sugarcane etc., became a point of concern in terms of the food supply and demand. In such a scenario lignocellulosic biomass that includes nonedible feedstocks opened up a new avenue for the second-generation bioethanol production. Lignocellulosic bioethanol production is composed of three major steps: pretreatment, enzymatic hydrolysis and fermentation. The main factor restraining the commercialization of bioethanol lies in the development of the enzymatic hydrolysis step. During the enzymatic hydrolysis step carbohydrates (cellulose and hemicelluloses) polymers get converted into free monomeric sugars. The major problems associated with enzymatic hydrolysis are cost of the enzyme, higher incubation time for complete degradation of carbohydrates, inhibition of enzyme activity in the presence of phenolic compounds and thermal inactivation of cellulase enzyme. The present article discusses recent trends and development of the enzymatic hydrolysis process for cost-effective bioethanol production. In this review the authors cover the following points: development of cellulase-producing organisms, the enzyme production process, the

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improvement or enhancement of enzymatic hydrolysis and its future prospects for commercial lignocellulosic bioethanol production.

***Keywords*:** second-generation bioethanol, lignocellulosic biomass, cellulase enzyme, enzymatic hydrolysis

4.1 Introduction

The steady increase in energy demand and the limiting of fossil fuels are creating an energy gap which poses a serious need for alternative energy sources. The best way to fill this energy gap is the use of sustainable sources of energy, i.e, renewable. Bioethanol is one such promising renewable energy source which is capable of replacing fossil fuels usage partly because of its higher energy density, greater air-fuel ratio, more specific energy and heat of vaporization [1].

Bioethanol is differentiated as first- and second-generation ethanol based on the raw material used. First-generation bioethanol is derived from food crops such as corn and sugar cane while second-generation converts lignocellulosic biomass. But due to controversy of food versus energy, ethanol production from lignocellulosic substrates has gained significant interest as a wide variety of feedstocks can be used as materials with no significant competition with the food chain. The majority of the process cost of ethanol production is dependent on the cost of raw material and in such a scenario, lignocellulosic biomass has made the process commercially feasible.

Lignocellulosic bioethanol production highly depends on two promising steps, which are pretreatment and saccharification. Pretreatment is the critical step of removing the lignin because the extent to which the biomass becomes accessible to the enzyme for saccharification highly depends on the type of pretreatment employed. Apart from the pretreatment process, another significant step is the efficient hydrolysis during saccharification of lignocellulosic substrates as it is the rate limiting step towards techno-economical feasibility of lignocellulosic bioethanol. Enzyme cellulase catalyzes the hydrolysis of cellulose by breaking the 1, 4-β-glycosidic bonds in between the cellulose chain of biomass. Complete use of carbohydrate components in lignocellulosic biomass is reliant on the improvement or development of cost-effective/cheaper technologies for cellulase production, and also on the development of enzymatic hydrolysis of carbohydrate components to monomeric sugars (hexoses and pentoses). A previous study revealed that enzyme production is the most expensive step in lignocellulosic ethanol production [2]. It covers approximately 40% of the total cost. So, for commercial lignocellulosic bioethanol production

development of cost-effective cellulase production technology is needed. Therefore, the present chapter discusses the current status of enzymatic hydrolysis to provide insight into the hydrolysis/saccharification process.

4.2 Hydrolysis/Saccharification

The saccharification process, i.e., the hydrolysis of cellulose and hemicelluloses, can be carried out mainly in two ways, i.e., biological (enzymatic) and chemical (acidic). The acidic reaction is done by using either dilute or concentrated acid. The enzymatic process has several benefits such as low toxic compound generation, high product yield, less chemical requirements, etc. (Figure 4.1).

4.2.1 Cellulase

The cellulases enzyme system is a mixture of endo-β-glucanase (EC 3.2.1.4), exo-β-glucanase (EC 3.2.1.91) and β-glucosidase (EC 3.2.1.21). Cellulase acts on cellulose in the following manner: endo-β-glucanase acts randomly inside the cellulose chain, exo-β-glucanase acts on the external end of the cellulose chain and β-glucosidase degrade cellobiose into glucose or free monomeric sugar (Figure 4.2).

Individual enzymes are not capable of degrading the cellulose chain to a monomeric unit, hence synergistic action leads to a proper saccharification.

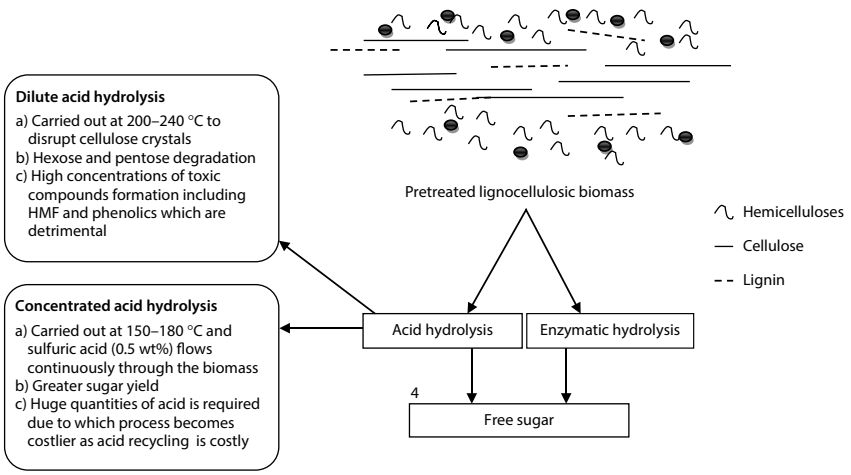

Figure 4.1 Saccharification process for lignocelluosic material.

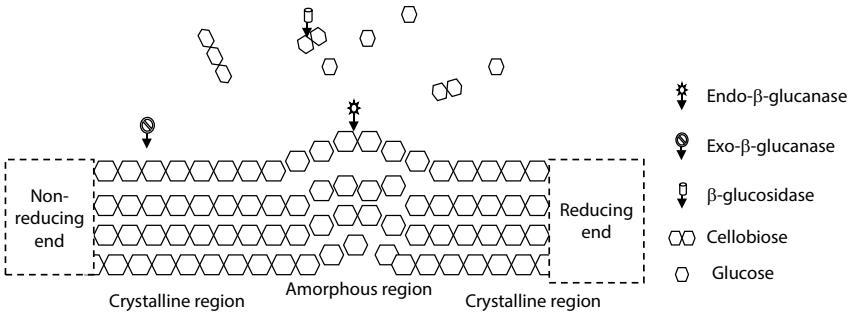

Figure 4.2 Schematic representation of cellulase mediated hydrolysis.

Major synergism has been noticed firstly between endo and exo-β-glucanase and secondly between exo-β-glucanases which act from both reducing and nonreducing end. β-glucosidase overcomes catabolic repression by preventing accumulation of cellobiose.

4.2.2 Screening of Cellulase-producing Microorganisms

There are several bacteria and fungi microorganisms capable of producing cellulase for the saccharification. Bacteria have a very low growth rate and require anaerobic growth conditions, therefore fungal cellulase have been mostly used for the given purpose (Table 4.1). The fungal cellulases production system works on the repressor/inducer phenomena where cellulose or other oligosaccharide act as inducers while glucose or other easily metabolized carbon sources act as repressors.

Trichoderma and *Aspergillus* are the most studied microorganisms for cellulase production. The crude enzyme extract of these microorganism are available for commercial use. *Trichoderma* produce endo-β-glucanase and exo-β-glucanase in higher quantity and β-glucosidase in lower quantity. In the case of *Aspergillus*, it produces endo-β-glucanase and β-glucosidase in higher quantity and exo-β-glucanase in lower quantity. It was reported that *Trichoderma reesei* QM-9414 is one of the best cellulase producers [13]. Later it was subjected to mono-colony isolation to obtain *Trichoderma reesei* KY-746. The mutated version gave higher cellulase activity [13].

Aspergillus niger is an important fungal strain for higher cellulase production. *Aspergillus niger* is a group of nine genera, and among them some possess higher potential of cellulase production. Different scientists have reported various media for cellulase production by using *Aspergillus niger* [14–16]. Abostate *et al.* [17] reported isolation of five potential *Aspergillus* sp. for cellulase production. They reported maximum

Table 4.1 Reducing sugar yield from different types of biomass.

Lignocellulosic biomass	Source of cellulase	Reducing sugar yield (mg/g dry substrate)	Incubation time (h)	References
Wheat straw	*Trichoderma reesei* NCIM 1186	371.44	24	[3]
Parthenium sp.	Commercial cellulase	574	48	[4]
Wheat straw	*Trichoderma reesei*	270	48	[5]
Wheat straw	*Trichoderma longibrachiatum*	294	72	[6]
Sorghum straw	*Coriolus versicolor*	440	168	[7]
Sargassum sp.	Commercial cellulase	326.89	72	[8]
Rice straw	Commercial cellulase	567	48	[9]
Rice straw	Commercial cellulase	414.16	72	[10]
Rice straw	*Aspergillus niger*	623.90	24	[11]
Pinus roxburghii	Locally isolated microorganism	334.00	24	[12]

endo-β-glucanase production in the case of *Aspergillus* MAM-F23. A previous study reported use of sorghum straw as a potential substrate for cellulase production [18]. Using *A. niger* under submerged fermentation, maximum cellulase production (0.77 IU/mL) was reported using sorghum straw as substrate, and lowest cellulose production (0.28 IU/mL) was reported using wheat straw as substrate. Maurya *et al*. 2012 [19] used *Trichoderma reesei* NCIM 992 for cellulase production under solid state fermentation. Kurup *et al.* (2005) compared cellulase production by different bacteria using water hyacinth as substrate. They found maximum cellulase production of 216 FPU/gds. Amira *et al*. 2012 [20] found higher xylanase activity (14.41 FPU/mg) using *Aspergillus niger* under solid state fermentation. Kumar *et al*. 2012 [21] reported maximum CMCase production (7.814 U/mg) from *Paenibacillus polymyxa*. Nair *et al*. 2008 [22] isolated 34 fungal strain strains for cellulase and xylanase production and they reported maximum cellulase production using *Trichoderma* sp. SBS60 and maximum xylanase production using *Aspergillus sydowii* SBS45. Ali and El-Dien 2008 [23] reported use of two different strains (*Aspergillus niger* and *Aspergillus nidulans*) for fungal cellulae production on water hyacinth.

4.2.3 Cellulase Production

Initial cellulase production was attempted on liquid culture but due to accumulation of free sugar catabolic repression took place, which hampered the cellulase synthesis during the microbial growth. Fed batch or continuous mode culturing can overcome the issue but adds to the overall cost.

Cellulase production on the agro industrial residues through solid state fermentation (SSF) is one of the promising technologies in terms of reduced processing cost. Carbohydrate moieties present in these cheap residues act as a carbon source for fungal growth. For cellulase production different substrates, such as wheat bran, rice straw, corn cob, sorghum straw, groundnut shell, cotton flower, saw dust, eater hyacinth, etc., have been reported [17, 24]. Table 4.2 shows the cellulase production under solid state fermentation by different fungal strains.

4.2.4 Factors Affecting the Cellulase Mediated Hydrolysis

Cellulase mediated hydrolysis consists of primarily three steps:

Adsorption of cellulase enzymes onto the surface of the cellulose

1. Bioconversion of cellulose to fermentable sugars
2. Desorption of cellulase

Table 4.2 Cellulase (CMCase) production by different fungal strains under SSF condition.

Microorganisms	CMCase activity (IU/gds)	Reference
Aspergillus niger	25.20	[25]
Fungal strains CG-10	29.04	[26]
Bacillus licheniformis	2.11	[27]
A. niger NRRL 567	425.3	[28]
Trichoderma atroviride	90.43	[29]
Aspergillus niger HN-1	416.3	[30]
Aspergillus awamori	19.00	[31]
Aspergillus fumigatus Z5	526.30	[32]
Trichoderma sp.	172.31	[33]
Humicola insolens TAS-13	18.98	[34]

3. The governing factors for these steps are mainly substrate concentration, enzyme dosage and reaction conditions.

At low substrate concentration the reducing sugar yield and reaction rates are increased but at high substrate concentration the reducing sugar yield and reaction rates are decreased. At high substrate concentration the decrease in the reducing sugar yield and reaction rates are due to end product inhibition of cellulase enzyme. Mojovic *et al*. 2006 [35] reported lower substrate concentrations were more suitable in order to avoid substrate inhibition. The authors found that at 16% suspension of corn flour the glucose yield was 76%, while when a 40% suspension was hydrolyzed the yield was only 50.2%.

High enzyme dosage enhances the reducing sugar yield but at the same time significantly increases the processing cost. Therefore, selection of optimum parameters such as temperature, pH, and incubation time at low enzyme dosage can be one approach to overcome the issues. Mahamud and Gomes [36] reported use of crude *Trichoderma* cellulase for enzymatic saccharification of alkali pretreated sugarcane bagasse. They reported maximum degree of hydrolysis (37.29%) at 50 °C. Ahmed *et al.* [37] reported that enzymatic saccharification of alkali treated bagasse rapidly increased up to 8 h and the rate of this increase was

Table 4.3 Effect of additive on cellulase mediated hydrolysis.

Additives	References
Addition of Ca(II) and Mg(II) results in lignin- metal complex formation	[42]
poly(ethylene oxide) polymer (PEO) and poly(ethylene glycol) (PEG)	[45]
Surfactants and bovine serum albumin (Tween 20, Tween 80, Triton X-100, Agrimul and SDS	[46]
Ammoniationand various N compounds	[47]

substantially reduced at later stages. Han *et al.* [38] reported maximum reducing sugar yield (341.87 mg/g dry substrate) from alkali pretreated wheat straw at 55 °C using cellulase produced from *Penicillium waksmanii*. The variation in temperature was due to different species used for cellulase production. Moreover, the hydrolysis rate was influenced by the duration of the hydrolysis process [39]. Saha *et al.* [40] achieved maximum reducing sugar yield (554 mg/g dry substrate) after 72 h of saccharification of dilute acid pretreated wheat straw at 45 °C. In the case of alkali pretreated wheat straw maximum reducing sugar yield (343.95 mg/g dry substrate) was obtained after 30 h of enzymatic saccharification [38].

Jeya *et al*. 2009 [41] reported optimization of enzymatic saccharification of alkali-treated rice straw by using CCD based RSM. The authors found a maximum saccharification rate of 88% at an enzyme concentration of 37.5 FPU/g-substrate after optimization of the hydrolysis parameters. Liu *et al*. 2010 [42] used CCD based RSM for optimization of enzymatic hydrolysis of recycled pulp. Phuengjayaem and Teeradakorn, 2011 [43] reported that maximum yield of glucose was 0.366 g/g dry substrate at the optimal condition: 1.0–2.5% of the acid pretreated sweet sorghum straw, 30 FPU/g-substrate of cellulase, pH 3–5, at 30–50 °C in 96 h. Higher reducing sugar yield in short incubation time is required for improved process economics of bioethanol production [44].

Lignin has also an adverse effect on cellulases. It affects the whole process by nonproductive adsorption and irreversible binding of enzymes which limits the accessibility of cellulose to cellulase. Various methods have been used to eliminate lignin inhibition (Table 4.3).

4.3 Future prospects of enzymatic hydrolysis

The saccharification process, though it seems similar, faces various bottlenecks which are both technical and economical. Technical problems associated with the process are inefficient cellulase adsorption and efficacy due to limited accessible substrate surface, end product inhibition and lignin, while economic issues are related to cost of raw material, cellulase enzyme, etc. Hence, the current cellulase mediated hydrolysis problem needs to be taken care of for further advancement of lignocellulosic-bioethanol technology. Use of genetically modified cellulolytic organisms by cloning cellulase coding sequences into bacteria, fungi and plants is recommended to increase the cellulase yield and productivity under stress conditions. Even genetically engineered raw materials with higher carbohydrate content and low lignin content could reduce the cost. Simultaneous saccharification and fermentation (SSF) is also considered to be cost-effective by overcoming the end product inhibition. There is a serious need to understand the mode of action of the critical factors that control interactions between biomass, cellulase and inhibitory compounds. This knowledge will provide a new avenue to identify better pretreatment and saccharification strategizes as per industrial needs.

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16th IFIP WG 6.11 Conference on
e-Business, e-Services, and e-Society, I3E 2017
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Preface

This volume presents the proceedings of the 16th International Federation of Information Processing (IFIP) Conference on e-Business, e-Services and e-Society (I3E) held at the Indian Institute of Technology, Delhi, during November 21–23, 2017. The IFIP-I3E conference is highly interdisciplinary in nature and focuses on academic contributions in varied domains of electronic business, services, and society. It had great participation from academia, industry, and practitioners who are either working directly in the domain or are in the process of exploring it. The central theme of the 16th edition of the conference was "Digital Nations – Smart Cities, Innovation, and Sustainability." The idea of digital nations perfectly aligns with the three Es of the conference series. As you get through the following pages, you will discover interesting ideas in the domains of governance, social media, and analytics that are shaping our lives today or most likely will alter the digital nations of tomorrow (Zuiderwijk and Janssen 2014; Rana et al. 2017). From any benchmark, the trajectory of technology developments in the post-Internet period is extraordinary and never seen before (Khatwani et al. 2014). It is complex but fascinating; it is bringing people and communities together, enterprises to collaborate on strengths to grab opportunities as competition becomes intense and nations to break boundaries allowing societies to interoperate across different domains and communities. It is producing an amalgamation of various cultures and the emergence of a new way of living – a society that is truly global with global citizenship (Carter et al. 2016).

In the digital society, the issues emerging are plenty and complicated due to the networkedness and possibilities of understanding the complexities through big data analytics (Janssen et al. 2012; Chauhan et al. 2016). The governance is not so much about digital spread as access is fast bridged by expanding mobile networks and broadband as it is about ability in enabling digital-based services to everyone to their expectations. The literacy gap around the globe will remain a cause of concern in the use and adoption of new media, even though the younger generation is fast in adoption. Digital literacy programs will need continuous monitoring and revision to keep pace with the technology change. The underpinning factor in leveraging the new media is having clarity about the culture and community where one is operating. This has not been explored much. Social media has fast become a widespread fascination for everyone, much more than normal social life, raising new challenges and opportunities related to community, culture, and business (Rathore et al. 2016; Lakhiwal and Kar 2016). Understanding variability in cross-cultural boundaries, particularly East vs. West, is necessary in developing a social media strategy for different contextual settings. It hardly needs any emphasis how trust plays a major role in allowing people to overcome the perception of risk and insecurity. Gender effect is also found to play a key role in social media use.

The use of information and communication technologies (ICTs) is greatly impacting the economy (Chew et al. 2010) and governance (Gupta and Jana 2003). Citizens

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Outlier Detection Among Influencer Blogs Based on off-Site Web Analytics Data

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Abstract. In the current scenario, with the exponential increase in the use of internet, organizations are continuously thriving for visibility on the web. This has opened new avenues in influencer marketing. Several portals encourage these marketers to build content for the purpose of digital marketing. However, the content building process produces a lot of spam within these websites when done in bulk. This is often done in order to establish their presence by using techniques including article spinning and keyword stuffing. This study thus attempts to identify these spam websites using a dataset comprising 2751 websites using bio inspired outlier detection approaches. We use publically available key performance indicators (KPIs) through which websites that create spam content to boost the amount of text in the domain are identified. A hybrid wolf search algorithm (WSA) and bat algorithm (BA) integrated with K-means are used to classify these websites into spam. Findings indicate that metrics including Domain Authority, Page Authority, Moz Rank, Links In, External Equity Links, Spam Score, Alexa Rank, Citation Flow, Trust Flow, External Back Links, Referred Domains, SemRush URL Links and SemRush Hostname Links play an important role in identifying spam. The proposed approach may prove beneficial in segregating spam influencer websites for effective influencer marketing.

Keywords: Outlier detection · Bio inspired computing · Wolf search algorithm · Bat algorithm · Web analytics · Spam detection · Machine learning

1 Background

The exponential increase in the use of internet in this era of digitization across the world has become an important source of competitive edge for the marketing of products and services [1]. This explosion of digital marketing has completely revamped the way business is done and also affects the brand positioning strategy of the

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organizations [2]. Organizations have realized the importance of web visibility for better customer engagement [3]. These organizations have thus started adopting ways to artificially boost their presence on the web using digital marketing specifically opening new avenues for influencer marketing. Influencer marketing is an approach to marketing that focuses on individuals that advise the decision-making consumers. Such people are referred to as influencers and often play a critical role in the customer engagement process [4]. These influencers often need to build huge amount of content in order to maximize web visibility.

The use of web analytics for enhancing digital marketing has been in practice for the last few decades. However, organizations are still not able to fully utilize the core potential of these techniques for improvising their web visibility. Studies highlight opportunities and practices in web analytics that organizations may adopt for better online marketing [5]. The optimization comprises of two primary categories of on-site (a measure of actual visitors on the website) and off-site web analytics (comprising of tools measuring website audience) [6]. One primary reason for failing to achieve the desired promotion from web analytics in online marketing is inexperienced and unskilled influencers. These influencers in order to expedite the process use unethical practices like artificially generating keywords and links to build low quality content. This not only results in that result ineffective off-site analytics but may even prove to be detrimental to the customer if detected by search engines [6, 7]. After the Google's Panda and subsequent updates such malpractices for artificially boosting the web site rank on search engines results page have resulted penalization and website delisting from search engines [8]. This study thus primarily focuses on identifying outlier influencer websites for the purpose of effective off-site web analytics.

There are several freelancing platforms including Blogmint, Influencer, Upwork and Craiglist that offer freelancers to build content on topics that may be utilized for generating back links and keywords for the customer website [9, 10]. These techniques attract traffic to the customer website and artificially boost the website rank. However, the influencers in the process to expedite the process generate low quality content that is often not original and use techniques like article spinning, keyword stuffing, link building and link farming [6] making the website quality a key driver for successful e-business [11]. The customer is often not aware of the adverse effects of such techniques and thus in the long run these may even lead to penalization by search engines. Studies in literature also discuss about website selection for advertising campaigns [12]. To avoid such spam within the website, our study proposes an outlier detection approach that uses website KPIs to identify spam influencer websites that indulge in low quality content building. Metrics like page rank, page authority, domain authority, alexa rank, google index, social shares, trust flow, citation flow, links, external equity link; external back links, referred domains and domain age are used as indicators for identifying spam influencer websites. A spam score is further associated with each of the 2751 websites considered for the analysis. A bio inspired wolf search and bat algorithm integrated with K-Means is used for subsequently segregating the outlier websites.

2 Research Methodology

This study uses a mixed research methodology where in the data collected surrounding the website KPIs for 2751 influencer blogs on unique domains. A statistical t-test is conducted on the normalized data for the two sets of influencer web domains, with low and high spam score. Further, the significant metrics are used as KPIs for analyzing whether the influencer is spam or not using bio inspired optimization approaches integrated with K-Means for mining outliers. The subsequent sub-sections highlight detailed discussions surrounding the analysis.

2.1 Data Collection and Metric Identification

The data is extracted through an API from the SEO Rank website (https://seo-rank.my-addr.com/) that provides a holistic list of selected metrics provided by various data providers like Majestic [13], Ahref [14], Moz [15], SemRush and Webmaster tools. These data providers have developed ranking mechanisms that are used worldwide for identifying the position of a page in organic search. A list of metrics considered for the analysis is demonstrated in Table 1.

Table 1. Description of website metrics for off-site analytics and digital marketing.

	Data provider	Metric	Description
1.	Moz	Domain Authority	Prediction of the ranking of domain on search engines. Depends on links, Moz Rank and other metrics
2.		Page Authority	Prediction of how a given URL may be ranked on search engines, associated with number of links, Moz Rank, and others
3.		Moz Rank	Link popularity score indicative of importance of the page on the web
4.		Moz Trust	Link trust checks for links from trustworthy sources
5.		Links In	Links to the web page, includes equity, or non-equity both internal and external links
6.		External Equity Links	Number of external equity links to the URL
7.		Spam Score	Based on number of sites penalized (de-listed) containing links to the web page
8.	Alexa	Alexa Rank	Global Alexa rank of webpage
9.		Alexa Links number	Number of links to the web page
10.		Country Rank	Alexa Rank in the popular country

(*continued*)

Table 1. (*continued*)

	Data provider	Metric	Description
11.	Majestic SEO	Citation Flow	Uses site link counts to the web page to see how influential the page is
12.		Trust Flow	Trustworthiness of the page based on link to trustworthy neighbours
13.		External Back Links	Total external back links to the web page
14.		Referred Domains	Total unique domains having links to the website
15.	SemRush	SemRush Rank	Domain rank by SemRush
16.		URL Links	Links to the mentioned web page
17.		Hostname Links	Links to the domain
18.	Ahrefs	URL Rating	Strength of web pages' back link profile and its chances of being ranked high in Google
19.		Domain Rating	Strength of website's domain back link profile
20.		Ahrefs Rank	Ranking based on size and quality back link profile
21.		Live & Fresh Index	List of live and dead links for the website

A total of 21 metrics are considered for the study, the data providers are mentioned along the metrics. This study uses a collective list of the metrics as KPIs for detecting spam influencer websites. The spam score is used as the criteria for dividing the data set into two for identifying the statistical significance of the metrics for subsequent analysis.

2.2 Statistical Analysis

The dataset is divided into two equal sets and 500 influencer websites each having a spam score less than 5 and greater than 5 are taken as sample for conducting a statistical t-test to identify metrics that are significantly different in the two sets. Since, the range of values of each of the metrics is considerably varied; min-max normalization is used to standardize the data to a 0–1 range. Subsequently t-test is conducted and the metrics having a p-value less than 0.05 are considered insignificant for further analysis. A list of remaining 12 significant metrics is highlighted in Table 2.

Table 2. Statistically significant metrics having a p-value greater than 0.05

Metric	P-value	Metric	P-value
Domain authority	0.038	Citation Flow	7.23E-28
Page authority	0.030	Trust Flow	0.0003
Moz rank	1.03E-15	External Back Links	0.002
Links in	0.048	Referred Domains	3.94E-32
External equity links	1.25E-05	SemRush URL Links	7.12E-28
Alexa rank	9.23E-15	SemRush Hostname Links	0.045

The final dataset for analysis thus comprises of the 13 significant attributes namely Domain Authority (DA), Page Authority (PA), Moz Rank (MR), Links In (LI), External Equity Links (ELL), Alexa Rank (AR), Citation Flow (CF), Trust Flow (TF), External Back Links (EBL), Referred Domains (RD), SemRush URL Links (UL) and SemRush Hostname Links (HL) for 2751 influencer websites. Subsequent sub-sections model the identified metrics to segregate outliers using bio inspired computing algorithms [16].

2.3 Outlier Detection

After the statistical t-test that identifies significant metrics, a hybrid bio inspired approach is used for detecting outlier influencer websites. Outlier detection is a popular approach when identifying data points that do not comply with majority of the data set based on selective metrics. There are several studies in literature that demonstrate various outlier detection approaches. An exhaustive list of outlier detection approaches with a comparison of motivation, comparison and disadvantages is highlighted with a categorization into statistical models, neural networks, machine learning and hybrid systems [17]. Chandola et al. [18] further provide an exhaustive review of the techniques by grouping the existing studies into six main categories based on classification, clustering, nearest neighbor, statistical, information theoretic and spectral. They further highlight the widespread applications of these approaches across domains encompassing cyber-intrusion detection [19], fraud detection [20], medical anomaly detection [21], image data [22], textual anomaly detection and sensor networks [23].

With the huge data influx, there are studies for outlier detection in high dimensional data [24–26]. However, these approaches are computationally intensive often NP hard and may even lead to a locally optimum solution [27]. Since the data under consideration is huge and may also be unstructured textual data. This is creates need of integrating approaches that do not converge to a local optima. The meta-heuristic approaches are known to help in reaching to a globally optimum system [28]. Further, bio inspired algorithms have been one of the most popular optimization techniques and mimic swarm behavior for optimization problems [16, 29, 30]. Tang et al. [31] thus integrate a few popular bio inspired algorithms with K-means to avoid the local convergence. This study thus utilizes the integrated bio inspired wolf search algorithm for outlier detection. We thus use the 2751 influencer websites comprising of 14 attributes including KPIs for each website for identifying these outliers.

The wolf search algorithm (WSA) is one such optimization approach that is said to overcome local optima by imitating the wolf preying behavior [31, 32]. Another similar wolf hunting approach for grey wolves is used in literature for detecting outliers integrated with k-nearest neighbor [33]. In the current study, the number of clusters is identified as 2 for normal and outlier data points. The wolf population is initialized with visual distance and escape probability. The initial centroids are assigned for the two clusters. The fitness for the centroid in each wolf is calculated and the best solution is identified. The random preying behavior of the wolf is done by selecting a companion having the best solution within the visual distance. If the fitness of the companion is better than the self fitness of the wolf the companion is selected and is thus approached. After the prey is hunted the wolf randomly selects a position beyond the visual range and the process is repeated from the new location. The centroids with the best fitness are considered as the final solution.

Further, the results are compared with the integrated bat algorithm (BA) which uses the echolocation behavior of bats to find the prey and differentiate between different insects even in the dark [31, 34]. The bat algorithm is one of the most popular algorithms used for several engineering, multi-objective and constrained optimization problems [35–37]. For the integrated bat approach along with the two clusters, the bat population, frequency factor and loudness are initialized. The initial clusters are randomly assigned or the bat population. For each bat, the initial centroids are similarly identified. The fitness of the centroids is computed and the best solutions are identified. Further, the new solution is generated by adjusting the frequency and velocity. If the randomly generated solution is greater than the defined pulse rate, a new best solution is selected from the best solutions from each of the bats. The new solutions are accepted by adjusting pulse rate and loudness for subsequent iterations. The pulse rate is increased and the loudness is decreased for the next iteration.

Thus the bio-inspired algorithms help in identifying the best cluster centroids over iterations. The formulation of centroids is mainly iteratively guided by the search agents in the mentioned approaches. Since the dataset considered for this study requires only two clusters and has a total of 14 attributes for which the centroid values need to be computed.

The $Centroid_{ij}$ is value of the centroid for i^{th} cluster and j^{th} attribute. Thus, the $Centroid_{ij} = \sum_{k=1}^{SolSpace} weight_{ki} datapoint_{kj} / \sum_{k=1}^{SolSpace} weight_{ki}$. The centroids largely depend on the weight that tells whether the data point belongs to the cluster or not. $weight_{ki} = 1$, $if\ datapoint_k \in cluster_i; else\ weight_{ki} = 0$. Once the best cluster centroids are identified for the two clusters of outliers and normal data points, a distance measure is subsequently used segregate the outliers. The subsequent section demonstrates the findings.

3 Findings

The K-means integrating WSA and BA algorithms have been used in this study for detecting outliers. The use of bio-inspired algorithms avoids locally optimum solutions. The study demonstrates the segregation of outlier influencer websites based on certain KPIs that have been extracted for a set of 2751 influencer websites using APIs. A total of 13 attributes are considered for detecting the outlier influencers for off-site web analytics. The spam score is excluded for the classification and is used for the validation. Table 3 highlights the cluster centers for the remaining 12 metrics. The table lists the cluster centroids for the authentic blogs (A) and outlier blogs (O) for both WSA and BA.

Table 3. Cluster centers for K-Means Integrated WSA and BA

		DA	PA	MR	LI	ELL	AR	CF	TF	EBL	RD	UL	HL
WSA	A	0.12	0.19	0.18	0.69	0.32	0.74	0.55	0.76	0.84	0.58	0.46	0.75
	O	0.08	0.11	0.09	0.45	0.17	0.31	0.48	0.36	0.61	0.24	0.13	0.31
BA	A	0.20	0.27	0.24	0.81	0.39	0.96	0.59	0.97	0.98	0.40	0.31	0.50
	O	0.11	0.12	0.09	0.33	0.17	0.01	0.51	0.06	0.49	0.35	0.21	0.44

The results for the two approaches used for the purpose show that the bat algorithm shows higher accuracy. Out of 2751 influencer websites, 1254 websites were identified as outliers based on their spam score and manual examination. The bat algorithm correctly identified 1218 giving an accuracy of 97.12% while the wolf search algorithm correctly identified 1203 with an accuracy of 95.93%. However, time taken to converge to the optimum solution is 22.61 s for BA while it is just 16.18 s for WSA. The Fig. 1. demonstrates the outlier plots for WSA and BA.

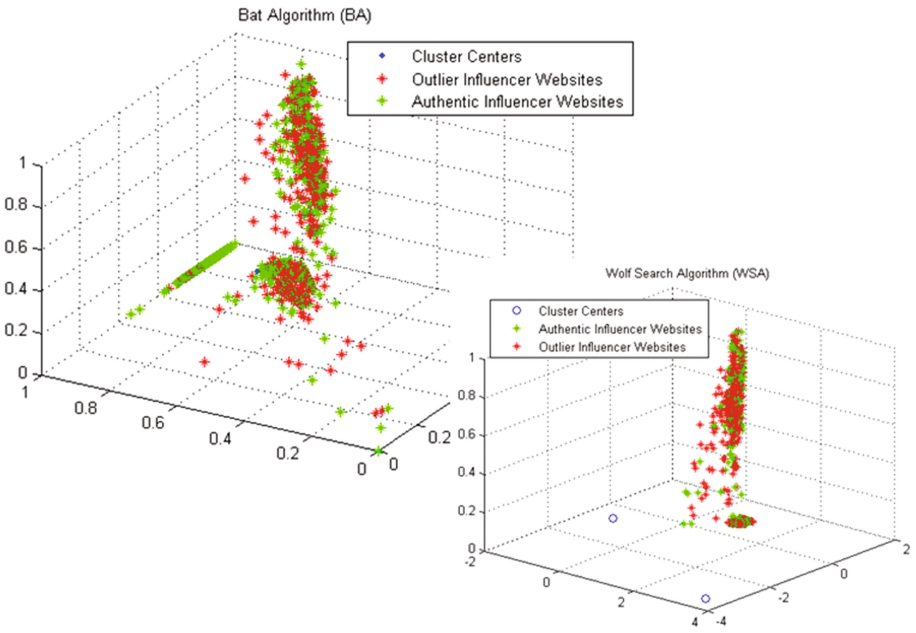

Fig. 1. Outlier plots for WSA and BA

Thus, the findings indicate that a large number (45.58%) of influencer websites are actually outliers. The reason behind this is that majority of influencer websites being categorized as outliers is because these blogs are heavily dependent on techniques like article spinning, link farming and keyword stuffing for content building and subsequent promotion. They often pick up original content and spin/manipulate the content by paraphrasing and including keywords related to the consumer domain to gain traction. These practices are often deemed unfit when it comes to digital marketing. However, the customers adopting these services are often not aware of such malpractices adopted by the websites. This has adverse effects on the consumer website in the long run and may even result in penalization. The use of KPIs in identifying such outlier influencers thus segregates these websites on the basis of publically available metrics from several service providers.

4 Conclusion

With the increased internet use and online marketing opportunities, organizations have realized the importance of web visibility and have started leveraging the power of internet to reach a larger audience for their products and services. This has opened new avenues for digital marketing especially influencer marketing where on several portals have emerged to encourage these influencers to build content for customer businesses. However, this process of content building generates a lot of spam content within these websites when done in bulk for a large consumer base and often involves techniques like article spinning and keyword stuffing for user traction. Such practices are not considered ethical as per the search engine guidelines and affect the consumers adversely. This study thus attempts to use publically available influencer website KPIs, a total of 13 attributes including Domain Authority, Page Authority, Moz Rank, Links In, External Equity Links, Spam Score, Alexa Rank, Citation Flow, Trust Flow, External Back Links, Referred Domains, SemRush URL Links and SemRush Hostname Links for 2751 influencer websites. Further, K-means integrated bio-inspired computing techniques are used for detecting and segregating outliers from the extracted data. Findings indicate that such approaches overcome local optima problems and give globally optimum solutions for such NP hard and computationally extensive data. Further, it is seen that the integrated bat algorithm gives better accuracy than wolf search algorithm as demonstrated in existing literature when the approach is used for clustering [31]. Our study re-establishes the same for the web analytics data set under consideration for outlier detection by extending the proposed approach.

5 Implications and Future Scope

This study uses KPIs and segregates outlier influencer websites that is beneficial for off-site web analytics. This may be useful for preventing consumer investments to such spam influencers that may adversely affect the websites position on search engines in the long run. Apart from the KPIs, content based analytics including keyword density, lexical diversity, meta information and topic modeling may also be incorporated in the analysis.

Future studies can be extended to using social media analytics for further validation of the results since social media platforms are utilized by consumers for raising concerns regarding the services used by them. These platforms specially Twitter and Facebook profiles of such influencer websites provide a lot of information in the form of user generated content that may be integrated with the existing metrics to reinforce the findings. An empirical validation of the results can also be done using a structured questionnaire for the consumers opting for such influencer marketing services and the short term and long term impact of the same on their visitors and web visibility. An existing study surrounding an analysis of results suggested by search engines for market share establishment can also be extended for influencer marketing [38].

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Chapter 4
Bioinformatics Database Resources

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ABSTRACT

Various biological databases are available online, which are classified based on various criteria for ease of access and use. All such bioinformatics database resources have been discussed in brief in this book chapter. The major focus is on most commonly used biological/bioinformatics databases. The authors provide an overview of the information provided and analysis done by each database, information retrieval system and formats available, along with utility of the database to its users. Most widely used databases have been covered in detail so as to enhance readers' understanding. This chapter will serve as a guide to those who are new to the field of bioinformatics database resources, or wish to have consolidated information on various bioinformatics databases available.

INTRODUCTION

The National Center for Biotechnology Information (NCBI) defines bioinformatics as: "the field of science in which biology, computer science, and information technology merge into a single discipline". Bioinformatics can be considered an amalgam of three sub-disciplines:

1. Development of new algorithms as well as statistics so that the relationship between the elements of huge datasets can be determined.

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2. Analysis as well as interpretation of biological data i.e. various types of sequences and structures.
3. Development of tools and software to ensure efficient access as well as management of biological data (Toomula, 2011).

The bioinformatics database resources focus primarily on the third sub-discipline of bioinformatics. A database can be defined as a computerized and organized storehouse of related information that provides a standardized way for searching, inserting and updating data. The data stored in these databases is persistent and organized. Database Management System (DBMS) is a software application that deals with the user, other applications, and the database itself in order to perform analysis and capture data in a systematic manner.

Bioinformatics databases or biological databases are storehouses of biological information. They can be defined as libraries containing data collected from scientific experiments, published literature and computational analysis. It provides users an interface to facilitate easy and efficient recording, storing, analyzing and retrieval of biological data through application of computer software. Biological data comes in several different formats like text, sequence data, structure, links, etc. and these needs to be taken into account while creating the databases.

There are various criteria on the basis of which the databases can be classified. On the basis of structure, databases can be classified as a text file, flat file, object-oriented and relational databases. On the basis of information, they can be classified as general and specialized databases. Most commonly, they are classified on the basis of the type of data stored in primary, secondary and composite databases (Kumar, 2005).

CLASSIFICATION OF DATABASES

Type 1

Databases can be classified on the basis of structure as Abstract Syntax Notation (ASN.1), Flat files, Object oriented databases, Relational databases, and XML. Table 1 provides a comparison of various types of databases on the basis of structure

- **ASN.1:** This format comprises of a syntax and description of how a particular data type can be represented physically in a data stream or sequential file (Buneman, Davidson, Hart, Overton, & Wong, 1995). This format has been adopted by NCBI for the representation of sequential data. It is one of the major file formats in GenBank (Cooray, 2012).
- **Flat Files:** This implementation is based on only one table, which incorporates the complete data i.e. all the attributes for each variable. Each row of the table specifies a different record. Specified delimiters are used to differentiate among records. Maintenance of data stored is a major drawback of this type of databases. Integration of two or more databases is difficult due to redundancy in data and variation in the format used.
- **Object Oriented Databases:** Object oriented databases can handle complex data types and can be easily integrated with Object Oriented Programming Languages (OOPL) (Codd, 1970). They can be defined as a collection of objects. Objects represent an instance of an entity and comprise attributes as well as methods (Hasegawa, 2008).

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- **Relational Databases:** Relational database systems can be defined as a collection of relations or tables. In a relational database, the data is organized in the form of a table where each row contains a record and each column specific an attribute of the record. The ordering of tuples, attributes or values within a tuple do not make any impact on the relation. The data is subjected to various constraints for validation (Cooray, 2012).
- **XML:** XML can be defined as an advanced flat file format. It provides greater support for representation of complex nested data structures. It contains data definitions and supports new definitions and tags upon requirement. The major advantages of this type are fast accessibility, reliability, and scalability. (Cooray, 2012)

Type 2

The databases can be classified into three categories on the basis of the information stored. They are Primary, Secondary and Composite databases.

- **Primary Databases:** Primary databases contain data that is derived experimentally. They usually store information related to the sequences or structures of biological components(Singh, Gupta, Nischal, Khattri, & Nath, 2010)(IASRI, (N.D.)). They can be further divided into protein or nucleotide databases which can be further divided as sequence or structure databases. The most commonly used primary databases are: DNA Data Bank of Japan (DDBJ), European Molecular Biology Laboratory (EMBL) Nucleotide Sequence Database, GenBank, and Protein Data Bank (PDB) (Toomula, 2011).
- **Secondary Databases:** Secondary databases contain the data that is obtained through the analysis or treatment of data present in primary databases. For instance, it can contain conserved protein sequence, signature sequence active site residues of protein families which are obtained from multiple sequence alignment of related proteins, etc. (Varsale, Wadnerkar, Mandage, & Jadhavrao, 2010; Sahoo, Rani, Dikhit, Ansari, & Das, 2009). These databases can be further classified as metabolic pathways database, protein family database, etc. The most common examples are Class Architecture Topology Homology (CATH), Kyoto Encyclopedia of Genes and Genomics (KEGG), Protein Families (Pfam) and Structural Classification of Proteins (SCOP).
- **Composite Databases*:*** Composite databases are collections of several (usually more than two) primary database resources. This helps in the lessening the tedious task of searching through mul-

Table 1. Comparison between different databases on the basis of structure

Type	Merits	Demerits	Examples
ASN.1	Implementation ease, Standardized	Not easy to integrate	CDD, GenBank, OMIM
Flat File	User-friendly	Not easy to access, integrate and validate	EMBL, DDBJ
Object Oriented	Implementation ease, Supports abstract data types	Factorization of document, Integration enhancement	MITOMAP
Relational	Implementation ease, Reliable, Scalable	Reduced performance when a large number of join operations are used	GDB, SMART
XML	Fast response, Flexible, Better accessibility	Less mature as compared to DBMS	GO, SwissProt

Cooray, 2012.

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tiple databases referring to the same data. The approach used, for instance, the search algorithm employed, differs considerably in every composite database. For example DrugBank offers details on drug and their targets, BioGraph incorporates assorted knowledge of biomedical science and Bio Model is a storehouse of computational models of the biological developments, etc. There are many composite databases which provide users with various tools and software for analysis of data. NCBI being a composite database has stored a lot of sequence of nucleotide and protein within its server and thereby suffers from high redundancy in the data deposited (IASRI, (N.D.).

NATIONAL CENTER FOR BIOTECHNOLOGY INFORMATION (NCBI)

It was developed at the National Institutes of Health (NIH) in 1988 for advancement (Wheeler et al., 2007) of science as well as health as it provides access to a large amount of biomedical and genomic information (www.ncbi.nlm.nih.gov/home/about/mission.shtml). It maintains a large scale of databases and bioinformatics tools as well as services. One of the most popular databases is GenBank. It is a nucleic acid sequence database and its data is acknowledged by the scientists all around the world. Another popular and major database is PubMed, a bibliographic database for the biomedical literature. All the databases are available online at official website of NCBI through the Entrez search engine (Wheeler et al., 2007).

Mission

The aim is to find novel techniques and methodologies for dealing with huge and complex data and provide better accessibility to analytical and computational tools.

Organization

The various branches of NCBI are Computational Biology Branch (CBB), Information Engineering Branch (IEB) and Information Resource Branch (IRB).

Options on Homepage

There are various options can be viewed and explored on the homepage of NCBI's website. They are mentioned in Table 2.

Resources

The resources that are present on this site can be divided into two major categories: databases and tools, which are then further divided as follows:

1. **Databases:**
    a. **General:**
        i. Entrez,
        ii. PubMed and PubMed Central,
        iii. Taxonomy, and

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Table 2. Various options along with their descriptions present on NCBI's homepage

Option	Description
Submit	Deposition of data
Download	Downloading data from NCBI
Learn	Users can learn about various tools and databases through documents or tutorials
Develop	New applications can be built by using Application Programming Interfaces and code libraries of NCBI
Analyse	Choose an appropriate NCBI tool for a specific data analysis task
Research	Research and collaborative projects of NCBI can be explored

iv. Protein.

b. **Gene Level Sequences:**
   i. Gene,
   ii. GenBank,
   iii. Unigene,
   iv. Homologene, and
   v. Reference Sequences.

c. **Genomic Analysis:**
   i. Entrez Genome.

d. **Analysis of Gene Expression:**
   i. Gene Expression Omnibus.

e. **Analysis of Phenotypes:**
   i. Online Mendelian Inheritance in Man, and
   ii. Online Mendelian Inheritance in Animals.

f. **Molecular Structure and Proteomics:**
   i. Structure Databases,
   ii. Molecular Modeling Database, and
   iii. PubChem.

g. Hiv-1/Human Protein Interaction Database.

2. **Tools**:
   a. BLAST.
   b. **Gene-Level Analysis:**
      i. Open Reading Frame Finder.
   c. **Genomic Analysis:**
      i. Map Viewer, and
      ii. Model Maker,
      iii. Evidence Viewer.
   d. **Analysis of Gene Expression:**
      i. Genset, and
      ii. Probe.
   e. **Tools Supporting Proteomics Blast Link (Blink):**
      i. Open Mass Spectrometry Search Algorithm (Wheeler et al., 2007).

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Entrez Global Query Cross-Database Search System

It is an integrated database search and retrieval system which is widely used (Maglott D., 2005) as it enables text searching using Boolean expressions (Schäffer et al., 2001). The data is integrated from a wide variety of sources and databases to create a uniform information model. Hence it is used for both indexing as well as retrieval (H., 2014). It aids in the availability of extensive links within and between database records (Wheeler et al., 2007). It allows users the combined access to sequential, structural and taxonomic data. Graphical representation of chromosome maps as well as the sequence is also provided. It can also aid the user in obtaining the sequences, structures or references that are related to the query entered. The users can also store their private configuration options using 'My NCBI' (Wheeler et al., 2007).

PubMed and PubMed Central

NCBI National Library of Medicine (NLM) created the PubMed database which is also the part of NCBI Entrez retrieval system. Providing users with an ease in accessing abstracts as well as references from biomedical and life sciences journals was the primary reason behind its creation. To add on, there are links provided for accessing the complete journal articles (Lindberg, 2000). The primary data source for PubMed is MEDLINE database (C. K. J. J. C. M. J., 2000). PubMed Central (PMC) enables users to access freely all the articles it contains (B. J. S. E., 2002).

Taxonomy

Taxonomy database can be accessed using the Taxonomy Browser for either viewing the taxonomic position or retrieving data depending upon the requirement of the user (Wheeler et al., 2007).

Protein

This database stores individual protein sequences in a textual format including FASTA and XML. The most common sources from which these sequences have been obtained are GenBank, NCBI Reference Sequence (RefSeq) project, PDB and SWISS-Prot/UniProtKB. Sets of similar and identical proteins determined by BLAST is also provided for each sequence (S. E., 2013).

GenBank

It is located in the USA. NCBI since 1992 has provided access to GenBank DNA sequence database through NCBI gateway server and hence is accessible freely(Schuler, Epstein, Ohkawa, & Kans, 1996). The three nucleotide sequence databases GenBank, European Molecular Biology Laboratory (EMBL) and DNA Data Bank of Japan (DDBJ) coordinate among themselves so that all three of them are updated with the latest findings (Pruitt, Tatusova, & Maglott, 2005).

A detailed structure of a nucleotide sequence file format in this database includes the following:

1. **Locus:** This can be defined as a title given by GenBank itself to name the sequence entry. It includes the following:

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   a. **Locus Name:** Similar to accession number for the sequence.
   b. **Sequence Length:** Tells the number of bases existing in the sequence.
   c. **Molecule-Type:** Identifies the type of nucleic acid sequence. The various types are mRNA (which is present as cDNA), rRNA, snRNA, and DNA.
   d. **GB Division:** Postulates class of the data according to classification criteria of GenBank.
   e. **Modification Date:** The date on which the record was modified.
2. **Definition:** This denotes the name of the nucleotide sequence.
3. **Accession:** This covers accession number, accession version, and GI number. Accession number can be defined as the unique identifier associated with each nucleotide sequence present in the database. If more than one record is created for a particular sequence then it will have the same accession number but all records will have different versions associated with that accession number.
4. **Keyword:** Defined words that were used to index the entries.
5. **The Source:** This describes organism from which sequences have been obtained. The accepted common name is mentioned first and then the scientific name is mentioned. In the end, the taxonomic lineage according to GenBank is specified.
6. **The Citation:** Includes the journal from which with the sequence was derived as initially the sequences were obtained only from published literature.
7. **Features:** These consist of the information derived from the sequence such as biological source, coding region, exon, intron, promoters, alternate splice patterns, mutations, etc.
8. **Sequence:** Contains the following:
   a. Count of presence of each nucleotide in the sequence,
   b. Whole nucleotide sequence,
   c. Beginning of sequence is determined by keyword “ORIGIN”, and
   d. End is marked as “\\”.

There are many techniques for retrieving and searching data from GenBank. The sequence identifiers can be searched in GenBank along with Entrez Nucleotide. Another approach is using BLAST search and then aligning nucleotide sequences to the query sequence. The last method is to search the appropriate link and then download nucleotide sequences. It intends to offer and reassure access of the most updated data of the nucleotide (www.ncbi.nlm.nih.gov/genbank/).

In order to maintain the confidentiality, GenBank on request, reserves announcement of new submissions for a definite interval of time. If sequences of the human genome are deposited to GenBank, it is mandatory not to include any personal information that can anyhow lead to the revelation of the identity of the individual.

Gene

It is involved in the characterization and organization of gene information about genes. Each gene record can be identified through a unique GeneID (Maglott D., 2005). Organism-specific XML files can be created by applying the organism filter (Maglott, Ostell, Pruitt, & Tatusova, 2007).

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UniGene

UniGene can be defined as a software that partitions the sequences present in GenBank into sets of non-redundant gene- oriented clusters. These collections have been employed in the creation of unique sequences for microarray fabrication in order to comprehend gene expression study on a large scale (Schuler, 1997).

Entrez Genome

Entrez Genome (Tatusova, Karsch-Mizrachi, & Ostell, 1999) provides access to a large number of complete microbial genomic sequences and an enormous number of viral genomic sequences. There are also a huge amount of reference sequences for eukaryotic organelles. It is supplemented by Entrez Genome Project database. This database provides the status of various on-going annotation, assembly and sequencing projects (Wheeler et al., 2007).

Gene Expression Omnibus (GEO)

It can be defined as a data repository as well as retrieval system for various types of high-throughput molecular abundance data. It accepts array comparative genomic hybridization (aCGH) data, chromatin immune- precipitation on array (ChIP-chip) data, gene expression data and SNP array data (Barrett et al., 2007).

Online Mendelian Inheritance in Man (OMIM)

It contains a catalog of human genes as well as genetic disorders (Hamosh, Scott, Amberger, Bocchini, & McKusick, 2005). The data comprises of disease phenotypes, gene polymorphism, genes, map locations and patterns of inheritance (Wheeler et al., 2007).

Online Mendelian Inheritance in Animals (OMIA)

It is a database that contains the genes, inherited disorders as well as traits in fauna species excluding human and mouse. It also has the links to the records that are relevant in OMIM, PubMed and Gene databases (Wheeler et al., 2007).

PubChem

PubChem can be considered as a molecular library containing relational databases which were created using Microsoft SQL servers. The major focus is on the biological, chemical and structural properties of small molecules so that they can be used as diagnostic and therapeutic agents. All of the deposited data can be accessed freely by the users. It comprises of three sub-databases which are: PCSubstance, PCCompound, and PCBioAssay which contain substance information, compound structures and bioactivity data of compounds respectively (Wheeler et al., 2007).

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Basic Alignment Local Search Tool (BLAST)

NCBI developed BLAST, a powerful tool for comparing sequences from various organisms (T., 2002). It can be defined as an algorithm to determine the similarity between biological sequences (Altschul, Gish, Miller, Myers, & Lipman, 1990). Gapped alignments having links to the database are provided in the final result (Wheeler et al., 2007). It has been reported that this tool has the capacity to search entire DNA database in less than 15 seconds. (ftp://ftp.ncbi.nlm.nih.gov/pub/factsheets/HowTo_BLASTGuide.pdf). The input is in the FASTA or Genbank format and output can be displayed in various formats like HTML, XML formatting and plain text (T., 2002). The score of each alignment is assigned an Expectation Value (E-value) which is a measure of statistical significance (Wheeler et al., 2007).

Open Reading Frame Finder

Six-frame translation of nucleotide sequence is performed by this tool. The result is location of each ORF within a specified size range (Wheeler et al., 2007).

EUROPEAN MOLECULAR BIOLOGY LABORATORY (EMBL)

It is a molecule-based biology research foundation, maintained by 21 member states and formed in the year 1974 (www.embl.fr/aboutus/general_information/organisation/member_states/index.html). It stores and makes available raw nucleotide sequences. It is situated in UK (IASRI, (N.D.)). European Bioinformatics Institute (EBI) maintains EMBL nucleotide sequence database (Garg, Pundhir, Prakash, & Kumar, 2008).

Mission of EBI

The various aims of the organization are as follows:

- To provide freely available data and bioinformatics services to all facets of the scientific community.
- To contribute to the advancement of biology through basic investigator-driven research.
- To provide advanced bioinformatics training to scientists at all levels.
- To help disseminate cutting-edge technologies to industry.
- To coordinate biological data provision throughout Europe (www.ebi.ac.uk/).

European Nucleotide Archive (ENA)

Free as well as unrestricted information access on DNA and RNA sequences is provided by ENA. This archive is created using three databases which are Sequence Read Archive, Trace Archive and EMBL Nucleotide Sequence Database (www.ebi.ac.uk/ena). The information in ENA can be extracted manually or programmatically and resultant files can be obtained in various formats like XML, HTML, FASTA and FASTQ. (O. J., 2002) Using accession numbers and other specific text queries the users can obtain individual archives (Leinonen et al., 2010).

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EMBL Nucleotide Sequence Database

It contains the high level genome assembly data of sequences and their functional annotation (Stoesser et al., 2003; Amid et al., 2011). The data is store in flat file format.

Data Classes

The different data classes of sequences are mentioned in Table 3.

Resources at EMBL-EBI

The EBI website provides link to access many services like various biological tools and databases. Some of the most common resources are listed below in the Appendix.

DNA DATA BANK OF JAPAN (DDBJ)

This biological database resource belongs to National Institute of Genetics (NIG) in Japan. DDBJ is the only nucleotide sequence data bank currently present in Asia. Although DDBJ essentially has Japanese researchers as contributors but it also accepts the data from researchers of other countries. It is an associate of the International Nucleotide Sequence Database Collaboration (INSDC). The major driving force behind DDBJ operations is the advancement of the quality of INSD as the nucleotide sequence accounts organism development more directly than other biological constituents.

Tasks

Key tasks of DDBJ Center are as follows:

1. Construction and operation of INSDC which offers nucleotide and amino acid sequence data along with the patent request.
2. Provides searching and analysis of biological data.
3. Training course and journal.

DDBJ Flat File Format

The data submitted in DDBJ is managed and retrieved according to the DDBJ format (flat file). The flat file includes the sequence and the information of who submitted the data, references, source organisms, and information about the feature, etc (www.ddbj.nig.ac.jp/ddbjingtop-e.html).

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Table 3. Summary of data classes

Data Class	Definition	Example
EST	Raw expressed sequence tags without sequence quality information	FASTA Flat file HTML XML
WGS	Genomic contigs	FASTA Flat file HTML XML
GSS	Genome survey sequence; single pass, single direction sequence	FASTA Flat file HTML XML
HTC	High throughput assembled transcriptomic sequence and optional annotation	FASTA Flat file HTML XML
HTG	High throughput assembled genomic sequence and optional annotation	FASTA Flat file HTML XML
STD	Assembled and annotated sequences	FASTA Flat file HTML XML
CON	Scaffolds build from genomic or transcriptomic contigs	FASTA Flat file HTML XML
STS	Sequence tagged site	FASTA Flat file HTML XML
PAT	Patent sequences	FASTA Flat file HTML XML
TSA	Transcriptomic contigs	FASTA Flat file HTML XML
CDS	Coding sequences	FASTA Flat file HTML XML

www.ebi.ac.uk/ena/submit/sequence-format.

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PROTEIN DATA BANK (PDB)

PDB is a universal free archive for structural data of biological macromolecules. It was established in 1971 at Brookhaven National Laboratory under the governance of Walter Hamilton and initially contained only 7 protein structures. There were two major reasons which initiated the formation of PDB. The first one was increasing assembly of datasets related to protein structure. Another reason was the availability of Brookhaven Raster Display (BRAD) that envisages the protein structures in 3-D (Meyer, 1997). It is now conserved by the Research Collaboratory for Structural Bioinformatics (RCSB). It contains three-dimensional structures of proteins, nucleic acid fragments, RNA molecules, large peptides and complex structures of proteins and nucleic acids (Berman et al., 2000).

Data Storage and Acquisition

The data for each structure is stored in a distinct file and hence the data is stored in flat file arrangement. The major source for the three-dimensional structure of proteins includes cryo-electron microscopy, molecular modeling, NMR experimentations and X-ray crystallography trials (IASRI, (N.D.)). Each structure present within PDB is given four character alphanumeric characters. The protein structure files may be viewed using the open resource. The RCSB PDB website covers an extensive list of both free and marketable molecule conception programs that includes Jmol, Pymol, and Rasmol and web browser plugins (Protein_Data_Bank, N.D.).

Atomic Coordinate Entry Format Description

The various sections of the PDB file are:

1. Title Section,
2. Primary Structure Section,
3. Heterogen Section,
4. Secondary Structure Section,
5. Connectivity Annotation Section,
6. Miscellaneous Features Section,
7. Crystallographic and Coordinate Transformation Section,
8. Coordinate Section,
9. Connectivity Section, and
10. Bookkeeping Section.

Title Section

It contains the elements which describe the experiment and biological macromolecules present in the record entered. The elements of this section along with their description are mentioned below:

- **HEADER:** It contains an idCode field which is used for unique identification, a classification, and date when the coordinates were deposited to the PDB archive for a PDB record.

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Coordinate Section

It stores a collection of atomic coordinates as well as the MODEL and ENDMDL records. The elements of this section along with their description are mentioned below:

- **MODEL:** It provides a specification of the model serial number.
- **ATOM:** It provides atomic coordinates for standard amino acids and nucleotides.
- **ANISOU:** It has anisotropic temperature factors.
- **TER:** It determines the end of a list of ATOM/HETATM records for a chain.
- **HETATM:** It is used for the representation of non-polymer or other "non-standard" chemical coordinates.
- **ENDMDL:** It is paired with a corresponding MODEL element to generate individual structures (Berman et al., 2003).

Connectivity Section

It contains information on atomic connectivity. Element of this section along with its description is mentioned below:

- **CONECT:** It determines connectivity between atoms for which coordinates have been supplied (Berman et al., 2003).

Bookkeeping Section

It has final information about the file itself. Element of this section along with its description is mentioned below:

- **MASTER:** It contains the number of lines in the coordinate file for selected record types.
- **END:** It denotes the end of the PDB file (Berman et al., 2003).

UNIPROT

It is a database of freely accessible protein sequences which contains high-quality data and functional information for the proteins. Many of the records have been obtained from genome sequencing projects. The information regarding the biological function of the protein has been extracted from the research literature. European Bioinformatics Institute (EBI), Swiss Institute of Bioinformatics (SIB) and Protein Information Resource (PIR) constitute the UniProt consortium. Each one of them is deeply engaged in protein database maintenance and annotation (Consortium, 2011)(Eck & Dayhoff, 1966). It includes four core databases: UniProtKB, UniParc, UniRef, and UniMes. It is funded by grants from European Commission, National Human Genome Research Institute, NIH, NCI-caBIG, the Department of Defense and Swiss Federal Government (Consortium, 2010)

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UniProtKB

UniProt Knowledgebase (UniProtKB) is a protein database that is partially curated by experts. It includes three databases: Swiss-Prot, TrEMBL, and PIR-PSD. The former one contains reviewed and manually annotated records whereas the latter one comprises the un-reviewed and automatically annotated entries (Consortium, 2010).

Swiss-Prot

It can be defined as a manually curated protein sequence database with high annotation level. It was created by Amos Bairoch in 1986, developed by the Swiss Institute of Bioinformatics and subsequently further enhanced by Rolf Apweiler at EBI (Bairoch 2000; Bairoch & Apweiler, 1996; Altairac, 2006). It is well known for its high annotation level, a low degree of redundancy, standardized nomenclature usage, and links to specialized databases (O'Donovan et al., 2002).

To provide a set of relevant information for a particular protein is the core aim of this database. It also aggregates data obtained from scientific literature and bio curator-evaluated computational analysis. To remain up-to-date the annotations are often reviewed periodically (Apweiler, Bairoch, Wu, et al., 2004). It has Sequence Retrieval System (SRS) that helps in searching through relevant databases like for Translated EMBL (TrEMBL) on the same site.

Each data in SwissProt that belongs to a protein sequence is considered to have a separate core data and annotation. Former includes protein sequences, related references, bibliography and taxonomy of the organism from where the sequence has been extracted. Latter includes function(s) performed by the protein, post-translational modification, functional sites, structural domain sites, secondary structure features, likenesses to other proteins and diseases that may be caused due to a mutation in diverse strains (IASRI, (N.D.)).

Table 4 describes the codes which are used in a record of Swiss-Prot.

TrEMBL

Since the sequence data were being generated at a very high rate with respect to the ability of the SwissProt in performing the annotation hence TrEMBL Nucleotide Sequence Data Library was created so as to facilitate computer-annotated data for those proteins which could not be entered in Swiss-Prot (Apweiler, Bairoch, & Wu, 2004). The records present in this database are automatically annotated and have been analyzed computationally with high quality. Automatic processing and insertion of the translation of annotated coding sequences present in the three major nucleotide sequence database are done through this database. It also takes into account the sequences from PDB, Ensembl, RefSeq and CCDS (Consortium, 2011).

PIR: International Protein Sequence Database (PIR - PSD)

PIR was developed initially at National Biomedical Research Foundation (NBRF) in the year 1984. PIR, Munich Information Centre for Protein Sequences (MIPS) and Japan International Protein Information Database (JIPID) collaborated together to form PIR-PSD(IASRI, (N.D.)) which can be defined as an integrated public bioinformatics resource to support genomic and proteomic research. It also helps in the

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Table 4. Codes along with the full-name and description as used in Swiss-Prot

Code	Full- Name	Description
ID	Identification	It is a unique identifier that related with each entry and it appears in the beginning of a record.
AC	Accession Numbers	The name of data record might change but the AC cannot be changed. Also, if there are more than one accession numbers it suggests that the record was fabricated by integration with other records.
DT	Date	It comprises date consistent with the data entry formation, alteration date of sequence and annotation respectively.
DE	Description	It contains the general details of the sequence.
GN	Gene name	It contains the name of the encoding gene(s).
OS, OG, OC	Organism name, organelle, organism classification	These have the details of name and taxonomy of the organism.
RN, RP, RX, RA, RT, RL	Reference number, Position, comments, cross-reference, authors, title, and location	These have the bibliographic information.
CC	Comments	It has the free text comments.
DR	Database cross reference	It provides cross-reference to other databases.
KW	Keywords	It contains a list of keywords that can be used in indexes.
FT	Features tables	It defines regions or sites of concern in the sequence.
SQ	Sequence headers	It directs beginning of sequence statistics and gives a short summary of its contents.

IASRI, (N.D.).

identification and interpretation of protein sequences. Since 2002, it has become a part of UniProtKB (Wu & Nebert, 2004). This database contains non – redundant data, is annotated by experts, is comprehensive in nature and uses object-oriented DBMS (Database Management System). Classification of the sequences of protein on the basis of super-family is the unique characteristic of this database. The classification criteria also takes into account the homology domain as well as sequence motifs (IASRI, (N.D.)).

The curation status of PIRSF Database can be categorized as uncurated, preliminary and full/Full (with description). PIRSF Membership can be classified as follows: full (F), associate (A) and seed (S). Full is used for proteins which share complete sequence similarity as well as common domain architecture. Associate is used for those members whose sizes are greater than the family length range. Seed is used when it is required to create family specific full-length and domain HMMs using already present full members. PIRSF Family Level are divided into the Homeomorphic family (HFam), Subfamily (SubFam) and Superfamily (SuperFam).

The members which are categorized as HFam family are homologous as well as homeomorphic. The category of subfamily delineates protein clusters within a homeomorphic family which have specialized functions and/or variable domain architecture. Superfamily level brings together a number of distantly related families and orphan proteins that share one or more domains (http://pir.georgetown.edu/pirwww/support/help.shtml).

There are various rules for writing a protein pattern and they are as follows:

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1. Usually, capital letters are used for denoting amino acid residues and "-" is inserted in between two amino acids.
2. To provide multiple amino acids as a choice in a particular position "[…]" can be used.
3. To exclude a set of amino acids "{…}" is used.
4. If a particular position has "x" then it means that any amino acid can be inserted there.
5. If an amino acid occurs more than once consecutively then this can be denoted using "(n)", where n is a number of times that amino acid has occurred.
6. On similar grounds, as the previous rule, "(n1,n2)" are employed for multiple or variable positions.
7. To match a pattern at N or C terminus, the symbol ">" is required at the beginning or end respectively.

UniParc

UniProt Archive (UniParc) stores proteins sequences from publicly available protein sequence database in a non-redundant manner (Apweiler, Bairoch, Wu, et al., 2004) and it is updated on a regular basis. Since proteins may exist in several databases and there are high chances that a single sequence is present multiple times in the same database. Hence to avoid redundancy of data, each unique sequence is presented only once in this database. The identical sequences are merged even if they belong to different species. A unique identifier called UPI is given to each sequence which enables the identification of a same protein from various source databases. The protein sequences present in this database are without any annotation. Database cross-references are provided in order to facilitate the retrieval of more detailed information from the source databases.

UniRef

Clustered sets of protein sequences from UniProtKB and selected UniParc records are comprised in UniProt Reference Clusters (UniRef).(Suzek, Huang, McGarvey, Mazumder, & Wu, 2007) The UniRef100 database is involved in combining the identical sequences and sequence fragments (from any species) into a single UniRef entry. The accession numbers of all the merged records, sequence of a representative protein and links to the corresponding UniProtKB and UniParc records are mentioned. (Consortium, 2010)

UniMES

UniProt Metagenomic and Environmental Sequences (UniMES) database has been created for environmental and metagenomic data (Consortium, 2010). In order to improve the original data through more analysis, proteins that have already been predicted are merged using InterPro. UniMES is the source containing data from Global Ocean Sampling Expedition (GOS) (Yooseph et al., 2007). UniProt Reference Clusters or UniProt Knowledgebase do not contain data of environmental sample of this database.

STRUCTURAL CLASSIFICATION OF PROTEINS (SCOP)

SCOP database was started by Alexey Murzin in the year 1994 at Centre of Protein Engineering and was later on established at Laboratory of Molecular Biology (Chandonia et al., 2007) in Cambridge University, England (Hubbard, Ailey, Brenner, Murzin, & Chothia, 1999). It is an open source database and hence

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is accessible freely (Subramanian, Muthurajan, & Ayyanar, 2008). The structural domains of proteins were manually classified using the criteria of likeliness of sequences as well as structures in order to create this database (Conte et al., 2000; Andreeva et al., 2004). Its foremost function is to categorize 3D structures of proteins in a hierarchical pattern of structural levels which include family, super-family, fold and class so as to determine the evolutionary association between proteins. (IASRI, (N.D.))

SCOP Levels

PDB contains freely available 3D protein structures which are used by SCOP for classification. The protein domain is the main element of classification of structure in SCOP (Hubbard et al., 1999). The various levels are described in Table 5.

The root of this hierarchical classification is class which has the following major types:

1. All α proteins class which contains domains comprising α-helices.
2. All β proteins class which contains domains comprising β-sheets.
3. α and β proteins class which contains individual units as β-α-β and β-sheets are usually parallel to each other.
4. α or β proteins class which contains separated α and β regions and β-sheets are arranged in an anti-parallel fashion.
5. Multi-domain proteins class which contains those folds comprise at-least two domains of different classes.
6. Membrane and cell surface proteins as well as peptides class which contains proteins excluding the ones present in the immune system.
7. Small proteins class which contains proteins that have a metal ligand, heme and/or disulfide bridges.

It can be inferred from the above table that families are more closely related than super-families. The criteria for placing various domains within a fold into the same family is that either they share a minimum of 30% sequence similarity or they share the same function with 15% sequence similarity. To support the classification of domains into super-families and families BLAST is used (Andreeva et al., 2004; Hubbard et al., 1999).

Table 5. Different levels of SCOP database

Level	Description
Class	Types of folds.
Fold	Various domain shapes contained in one single class.
Superfamily	Domains having at-least a distant common ancestor and belonging to a particular fold are clustered together.
Family	Domains sharing a more recent common ancestor in a super-family are grouped into families.
Protein Domain	Clustered domains in families.
Species	Gathering of protein domains in accordance with species.
Domain	Either an entire protein or a part of protein.

Hubbard et al., 1999.

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Methodology of CATH

The methodology adopted by this database is as follows:

1. Separation of proteins into various domains
2. Created domains are then automatically sorted into classes.
3. Clustering is performed on the basis of sequence similarity upon the created classes.
4. Groups generated in step 3 constitute the H levels of the classification.
5. Topology level is created by structural comparison of H levels.
6. Architecture level is not assigned computationally.
7. At the end, Class Level classification is performed based on the following 4 criteria:
    a. Content of secondary structure,
    b. Contacts in secondary structure,
    c. Alteration scores of secondary structure, and
    d. Parallel strands percentage(Sillitoe et al., 2015).

Search Options Provided by CATH

The database can be searched by one of the following ways:

1. Entering a text, ID or keyword,
2. Uploading a protein sequence in FASTA format,
3. Uploading a PDB structure, and
4. Browsing the hierarchy (Sillitoe et al., 2015).

Data Files Provided by CATH

The various types of data files provided by CATH along with their description are mentioned in Table 8.

Using the Online Database

The classic investigation in this database begins by tracing a single PDB structure to its function and homologues. Let us assume that a user is interested in domains that can be found in a particular PDB chain. The user has the PDBID of the desired protein. The steps to be performed are as follows:

1. In the top right corner of home page there are links to key functions performed and the 'Quick Search' box. The user can enter the PDBID into this box and then click on Enter button.
2. The result page then obtained will have a list of all records that match with the query –term. Chain, Domains, Node and PDB are the return types obtained.
3. The domain in which user is interested will have a CATH Domain code which can be defined as a PDB Chain Identifier extension.
4. If on results page, user clicks on PDB record then structures and sequences for the chains corresponding to that record can be viewed. There is also a tabular representation of corresponding chains and domains.

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Table 8. Type and description of data files provided by CATH

Type of File	Description of File
CathCathedral library	It is the library containing graphs of secondary structure of domain.
CathDomainDescriptionFile	It contains complete information of various domains in CATH.
CathDomainList	It contains a list of CATH domains which have been assigned already.
CathDomainPdb	It is a library containing PDB files which have been chopped for representative CATH domains.
CathDomall	It stores for each PDB Chain domain boundaries in "domall" format.
CathHmm	It contains HMM library file for CATH domains.
CathHmm (+unclassified)	It contains HMM library file for all CATH domains, including those which have not been classified till now.
CathNames	It contains a list of manually assigned names of CATH classification nodes.
CathUnclassifiedList	It contains a list of CATH domains that have not been classified till now.
Chains	It contains a list of PDB chains in CATH.
Domain Sequences (ATOM)	It is a FASTA sequence database created through ATOM records in PDB for all CATH domains.
Domain Sequences (COMBS)	It is a FASTA sequence database created through COMBS sequence data for all CATH domains.
Representative Domain Sequences (ATOM)	It is a clustered FASTA sequence database for CATH domains.
Representative Domain Sequences (COMBS)	It is a clustered FASTA sequence database for CATH domains.
Representatives	It has a list of CATH representative domains.

Sillitoe et al., 2015.

5. When the user goes to the pages corresponding to the query domain then it will be observe that a tab entitled 'History' has been inserted. This tab contains the actions taken by curators of this database for assignment of domains.
6. Domain recognition in structures is done using CATHEDRAL.

SSAP is a server provided by this database for pair-wise comparison of two structures (Sillitoe et al., 2015).

PFAM

A database of protein families, Pfam contains annotations as well as multiple sequence alignments generated using hidden Markov models (Finn et al., 2009; Finn et al., 2006; Bateman et al., 2004). There are 4 elements present in all the families or patterns. These are: annotation, seed alignment, HMM profile and full alignment of sequences. Using seed alignment, sequences are bootstrapped into multiple alignments and eventually family (IASRI, (N.D.)).

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Features

The user can get the information about known protein structures, multiple alignments, protein domain architectures and species distribution for each family in Pfam. It has been reported that Pfam contains minimum one match for 80% of protein sequences present in UniProt Knowledgebase. Now, the Pfam consortium is involved in the coordination of the annotation of Pfam families via Wikipedia (Finn et al., 2009).

Types

The two sub-types of Pfam database are Pfam-A and Pfam-B. The former one is manually curated. It stores protein sequence alignment and hidden Markov model for each record. Since the records in Pfam-A are unable to consider all known proteins, Pfam-B was created to serve as an automatically generated supplement. A huge number of small protein families obtained from clusters are present in Pfam-B(Heger, Wilton, Sivakumar, & Holm, 2005). When no Pfam-A families are found then Pfam-B families were used earlier but it has been discontinued from release 28.0 (Finn et al., 2009). iPfam (Finn, Marshall, & Bateman, 2005) is a database that was built on domain description provided by Pfam. It determines whether the different proteins described together in PDB are so enough to potentially interact.

Pfam 28.0

This is the latest version of Pfam. This database creates the higher-level clustering of families which are related and these groupings are termed as clans. A clan can be defined as a collection of Pfam-A records that which are related to each other by sequence, structure or profile-HMM similarity. A family in Pfam is now usually retrieved to as a Pfam-A record. Each record includes seed alignment which is curated, profile HMMs and full alignment which has been automatically generated (Finn et al., 2009).

Classification of Pfam Records

Each record in Pfam can be classified into one of four ways which are: Family, Domain, Repeat and Motifs. Family can be defined as a collection of related protein regions. Domain is a structural unit of a protein that can evolve and function independently. Repeat is a term used for a short unit which becomes stable when there are multiple copies but in isolation it is unstable. Motif is a short unit which is present outside globular domains (Finn et al., 2009).

Pfam-A Family Page

This is a page through which a user is able to view Pfam annotation for a protein family. Also, domain architectures can be sighted where information regarding a particular family is developed; it supports alignments in several formats for the family, therefore can be downloaded. To add on, for each family information such as structural details, phylogenetic, the HMM logo and species distribution are made accessible.

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Clan

A clan can be defined as a category of protein families that are triggered from the single evolutionary origin. The likeness in tertiary structure or common motif sequence of the protein indicates the evolutionary relationships. Clan alignment is the alignment of the seed alignments of all the families within a particular clan.

Criteria for Categorizing Families Into Clans

There are a several criteria used for classifying families into clans. The golden standard is the usage of structures for making the classification. Profile comparisons such as HHsearch are used in the absence of structures. Sequence that matches two HMMs in the identical region of protein sequence is considered. SCOOP is a method that takes into consideration the common matches when searched, which may thereby specify an association. Such type of information is employed in order to decide about relationship among families.

Site Organization

The major page for accessing information is the family page, as the name suggests it describes the Pfam family records. To navigate to the family pages the users can also enter the Pfam identifier or the accession number in the keyword search box. There are various tabs for specific information such as alignments, curation and models, domain organization or architectures, functional annotation, HMM logo, interactions, species distribution, structure and Trees (Finn et al., 2009).

Keyword Search

The search box in the page header of each page of Pfam website can be used for keyword search. This type of searching can be done by entering various types of queries. Some of the most common ways are: Gene Ontology IDs and terms, HEADER and TITLE fields from PDB entries, InterPro entry abstracts, sequence entry description and species fields in UniProt and text fields in Pfam entries (Finn et al., 2009).

Using Pfam

To determine the domain architecture of the protein of interest, the user needs to search that particular protein sequence against the Pfam library of HMMs. If the protein is not recognized by Pfam then the user shall paste the complete protein sequence in search page. The sequence will be searched against the HMMs present in the database and the matches will be displayed as the result. If there a large number of sequences to be searched then batch upload facility can be used. The user needs to upload a file containing all the sequences in the FASTA format. The results will be emailed back to the user usually 48 hours after submission. If there are a considerably very huge number of sequences then Pfam searches can be performed locally by the user through the use of the 'pfam_scan.pl' script. This technique requires the user to have additional data files from website, HMMER3 software and Pfam HMM libraries. Pfam Alyzer is a tool which can be used by the user to identify the proteins which contain a specific combination of domains and to specify particular species and the evolutionary distances allowed between domains (Finn et al., 2009).

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Scores in Pfam

E-Values and Bit-Scores

HMMER3 calculates E-values (expectation values). It can be defined as a count of hits expected in order to have a score which is either equal to or better than the value by chance. E-value is considered good if it is much less than 1. Since E-values are dependent on the size of the database searched, hence a second system is used for retaining Pfam models. This in-house system is based on a bit score and hence does not depend on the size of the database searched for. Bit score gathering (GA) threshold is calculated for each Pfam family and thereby is set manually in such a manner that all sequences scoring either exact or overhead this threshold appear in full alignment.

Sequence vs. Domain Scores

HMMER3 calculates two kinds of scores known as sequence score and domain score. Sequence score provides the score for the complete sequence. Domain sequence provides the score for the domain(s) on that particular sequence. The sequence score can be defined as an aggregate score of a sequence which is aligned to HMM model. In a sequence, a single domain is said to be existing when scores are the same. Therefore, the result of these multiple illustrations of domain enhances confidence thus concluding that sequence belongs to a specific family of protein.

Table 9 provides a list of most commonly used terms in Pfam's website.

PROSITE

Prosite is a protein pattern database which was created in 1988 by Amos Bairoch and belongs to Swiss Institute of Bioinformatics. It includes the basic patterns which are found in incomplete protein sequences, for instance, the specific functional or structural domains. Generally, patterns are found using multiple sequence alignment and then further processed according to the database (IASRI, (N.D.)). Protein motifs as well as patterns in this database are determined as regular expressions. Each record holds two forms of data that include patterns and relative descriptive text. A line commencing with "PA" declares the expression. References, as well as association for all the protein sequences that comprise of the pattern, are also revealed. Documentation files contain the descriptive text which is connected with the accession number using the expression data (IASRI, (N.D.)).

The data entries describe the protein domains, families and functional sites. In addition, they also have the information about the amino acid patterns as well as profiles. After manual curation by a team of Swiss Institute of Bioinformatics, the data is incorporated into Swiss-Prot protein annotation. It is involved in recognizing possible specific functions of newly discovered proteins and analysis of known proteins for previously undetermined action. It also suggests various implements for protein sequence analysis and detection of motif present within the protein sequence. It is part of the ExPASy proteomics analysis servers as well (De Castro et al., 2006; Hulo et al., 2008).

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drugs and other health-related constituents are kept in KEGG ENVIRON database. KEGG MEDICUS is a database in health information category and it takes into account the package information of all advertised drugs in Japan (Kanehisa, Goto, Furumichi, Tanabe, & Hirakawa, 2010).

Classification on the Basis of Systems Data Stored

In this category we have three sub-types which are as follows:

1. **KEGG PATHWAY:** Pathway database is one of the fundamental KEGG resources which stores computerized information on the interaction of molecular networks. It is also known as the wiring diagram database. The objective was to enable the interpretation of genome sequence data through this database. It contains KEGG pathway maps which have experimental information on different pathways present in cell or organism. Through a molecular network, the genes in genomic sequence can be linked to gene products in the pathway. It also determines the pathways that are most likely to be encoded in a genome. The pathway maps are classified into the following sections: cellular processes, environmental information processing, genetic information processing, metabolism and organismal systems. Cellular processes deal with death, growth and membrane functions of the cell. Environmental information processing considers transportation through membranes and different mechanisms of signal transduction. Genetic information processing takes into account the transcription, translation, replication and repair mechanisms. Metabolism segment has visually drawn global maps of metabolic pathways. Organismal systems include various systems in an organism like endocrine, immune and nervous system.
2. **KEGG MODULE:** It highlights the functional units present in a pathway map. For instance, it will store the sub-pathways which have been reported to be conserved among specific molecular complexes as well as organisms. The gene sets present in these modules can be linked with various specific metabolic capacities as well as phenotypic features.
3. **KEGG BRITE:** It can be defined as an ontology database that contains a categorized arrangement of various biological entities. It can have many dissimilar relationships which are in contrast with KEGG PATHWAY as it contains only molecular interactions and reactions.

KEGG Search

It accepts an entry identifier in order to save the resultant entry. The identifier may be in the form of a database-dependent prefix followed by a five-digit number. If DBGET mode is implemented, then DBGET search will be made against the entire KEGG database. MEDICUS is a default mode in the KEGG MEDICUS page. A keyword search also implemented in order to get the required information (www.genome.jp/kegg/).

CONCLUSION

The book chapter provides an overview of the most common databases on the information and analysis provided by each database, information retrieval system and formats available, along with utility of the database to its users. The diversity of databases makes it challenging to identify which database

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should be used to solve a particular problem because database nomenclature is not standardized and data formats are also varying. Hence databases struggle with data redundancy and data inconsistencies. Different strategies have been proposed to prioritize choice of a particular database on the basis of the purpose of usage.

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APPENDIX

Table 10. A list of resources that can be accessed and/or are available through EMBL-EBI

Services	Description
ArrayExpress	It contains information on experimentations related to gene expression.
BioModels Database	It contains catalog of computational models which are related to life sciences.
Chemical Entities of Biological Interest (ChEBI)	It can be considered as a database as well as ontology of molecular entities.
Clustal Omega	It performs multiple sequence alignment of nucleotide or protein sequences.
Clustal Phylogeny	It generates a phylogenetic tree based on the result given by ClustalW2 program.
Complex Portal	It stores manually curated biological macromolecular complexes from several model organisms
Ensembl project	It contains the genome databanks for eukaryotes. This is a joint venture with Wellcome Trust Sanger Institute.
Enzyme Portal	It provides detailed information for various enzymes.
Europe PubMed Central	It is a database that provides free access to biological research literature.
European Nucleotide Archive (ENA)	It provides information related to nucleotide sequencing.
Experimental Factor Ontology (EFO)	For various biomedical records, it provides an ontology of experimental variables.
Expression Atlas	This database stores the information regarding expression of genes based on different conditions.
FASTA	It is a protein sequence similarity search tool.
FingerPRINTScan	It determines PRINTS for a protein query sequence.
Gene ontology	It is an ontology of gene functions along with their processes.
GeneWise	It compares a protein sequence with a genomic DNA sequence.
GGSEARCH	It is used for searching sequences that are homologous to the desired query.
HMMER	It is a tool for protein homology search that uses profile hidden Markov models (HMMs).
IntEnz	It is an integrated relational enzyme database.
InterPro	It is a database of classification of proteins.
InterProScan 5	It searches sequences against InterPro's analytic protein signatures.
Kalign	It is a tool for multiple sequence alignment.
LALIGN	It is a tool to identify internal duplications.
MAFFT	It is a tool for multiple sequence alignment.
MEROPS	It is a database of proteolytic enzymes.
MUSCLE	It is a tool for multiple sequence alignment.
MView	It is used to reformat a multiple sequence alignment or transform a sequence similarity search into a multiple sequence alignment.
NCBI BLAST	It is a tool for local similarity search.
Patent databases	It is a database of non-redundant patent sequences.
Pfam	It has been created to assign conserved protein domains and families.
Phobius	It is a tool used for the prediction of signal peptides and trans membrane topology from amino acid sequence of protein.
PICR	It provides mapping between protein identifier name spaces.
Pratt	It is a tool for discovering patterns in unaligned protein sequences.
PROSITE Scan	It is a tool for searching protein query sequence.
Protein Data Bank in Europe	It collects, distributes and organizes 3D structural data on biological macromolecular structures and their complexes.
Proteomics Identifications Database (PRIDE)	It can be defined as a repository of protein expression data which is determined with the help of mass spectrometry
UniProt (The Universal Protein Resource)	It contains the protein sequence and functional annotation data.

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Strategies and Processes

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Developments and Diversity of Proteins and Enzymes

2

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Abstract

Proteins form an integral part of a large consortium of industrially and therapeutically important products. Thus, efficient strategies for producing high-quality proteins and enzymes at industrial scale have gained importance in the past few decades. However, the heterogeneous production of recombinant proteins at industrial setups requires remotion and optimization of certain drawbacks such as protein aggregation, contamination, unstable cultures and less productive fermentation process. Therefore, the ultimate aim is to develop bioprocess that could be utilized for efficient production of important proteins. This has led to the development of structural biology, protein engineering and bioinformatics tools for identifying and rectifying these issues at molecular level. In the postgenomic era, a huge variety of protein families are yet to be functionally characterized. In this context, the discovery of new proteins with varied functionalities can only be achieved using modern-day methodologies that incorporate sequences, structure and activity-based approaches. Later, the positive outcomes could be easily directed towards the development of stable recombinant culture and productive fermentation process alongside a cost-effective downstream process. This chapter discusses the strides in the protein/enzyme production and their biotechnological perspectives along with the limitations in scale-up. Besides, several methodologies for selecting efficient protein molecules such as directed evolution approaches as well as for studying their physicochemical characteris-

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tics such as single-molecule techniques are also described. In addition, this chapter also delineates production of therapeutic proteins and proteases and applications of chaperones in industrial production process.

Keywords

Therapeutics • Bioprocess • Directed evolution • Protein engineering • Interactions Single-molecule biophysics • Fluorescence • Atomic force microscopy • Biochemical diversity • Protease • Down-stream processing • Chaperones • Protein folding

2.1 Protein Science: Journey from Cell to Industry

The past two decades had been crucial for the development of industrial production process of recombinant proteins. Several new strategies have been developed and implemented for producing large amounts of high-quality proteins of varied commercial applications. A huge number of new proteins from a range of origins such as virus, bacteria, fungus, plants and higher animals have been produced using genetically modified organisms (GMO) (Ahmad et al. 2012; Buiatti et al. 2013). The postgenomic era has opened new vistas in identifying alternate sources of scarce proteins which were earlier found difficult to produce at small or industrial scales. These proteins/enzymes are now readily produced in forms resembling closely to the actual native proteins. This has also cut down the amount of protein and protein-based products that were earlier obtained directly from the human or animal tissues. During the past decade, the US Food and Drug Administration (FDA) has been approving 15 new recombinant proteins on an average each year (Mullard 2014). The protein production at industrial scale differs from traditional small molecules that are chemically synthesized. In this case, recombinant DNA technology plays the pivoting role along with protein expression systems directed in various living systems. Basically, successful protein/enzyme production process depends heavily upon the following five factors, viz. (a) production cost, (b) control on actual product processing such as native post-translational modifications, (c) processing time for producing protein from the gene of interest, (d) host-based nuisances in protein production and (e) control of protein aggregation (Rai and Padh 2001; Gupta and Shukla 2015).

The postgenomic boom in genetic information has led to an enormous increase in a number of innovative biological products and biosimilars that mostly comprise proteins. This has fuelled the demand of customized production cell lines with high level of productivity. Nevertheless, heterologous protein production at industrial scale still requires much optimization and differs significantly case by case. Based on widely characterized genetic architecture, *E. coli* has been a widely employed host in protein products that do not require post-translational modifications (Chen 2012). Besides safe genetic manipulations, the simplified purification strategies for producing recombinant proteins using *E. coli* at industrial scales also make them a preferred host. On the other hand, several protein products have been industrially produced using yeast as an alternative host (Celik and Calık 2012). This host is typically free from pyrogens and viral and

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oncogenic DNA and thus is a preferred for production of pharmaceutical proteins (Mattanovich et al. 2011). Apart from this, baculoviruses have evolved as popular systems for recombinant protein overproduction in eukaryotic cells (Fornwald et al. 2016). Owing to the similar cellular milieu, these insect cell lines promote protein modifications and processing similar to higher eukaryotic cells and thus act as preferred hosts for producing qualitatively pure proteins (Radner et al. 2012). These are generally employed when the product specificity is essential and aids in its clinical efficacy. Collectively, the design of heterologous protein production process depends heavily on the level of purification, stabilization and formulation required for a particular protein product.

The other major drawback in industrial protein production is attributed to protein aggregation and precipitation (Vázquez-Rey and Lang 2011). Protein folding is a complex phenomenon that incorporates two major components, i.e. foldases, that accelerate folding and chaperones that prevent formation of insoluble protein aggregates. In an industrial bioprocess, due to the presence of numerous cell stress factors such as heat shock, nutrient depletion or other environmental contaminants, the protein products tend to aggregate (den Engelsman et al. 2011). These aggregates due to their toxic nature further lead to loss in biomass and hence significantly affect the efficacy of the production process. Thus, recovery and renaturation steps are added to obtain optimized amounts of proteins/enzymes in an economically feasible fashion. Thus, several molecular techniques such as utilization of protease-deficient strains as well as bioprocess strategies such as high-temperature culturing and engineering of fusion peptides/proteins that promote protein solubilization have been widely used (Clark 2001; Rajan et al. 2011; Levy-Sakin et al. 2014). Incorporation of all these schemes into a unified bioprocess scale-up will lead to achieve the goal of obtaining high-quality proteins/enzymes in excellent quantities.

2.2 Protein Families: From Biotechnology Perspective

The biotechnological advances in recent times have been found to heavily depend upon new sequencing technologies and advances in proteomics that have enabled large-scale identification and functional characterization of new proteins and enzymes (Ideker et al. 2001; van Beilen and Li 2002; Hartmann et al. 2014). Nevertheless, the process of identification is often complicated owing to the fact that sequence similarities do not warrant similar functional characteristics. Since, a small modification or mutation in a protein could severely affect its structure and native functionality (Wang and Moult 2001). Besides, several microbes with identified functions may not essentially harbour an expected gene in their genomes. Also, there are many protein families that are yet to be discovered based on sequence-based or activity-based approaches. The newly sequenced genomes have created ample sequence information about umpteen of proteins/enzymes spread across the taxa (Loman et al. 2012). Thus, it is essential to annotate these genes and understand how these proteins function in the living cells. This would essentially result in novel protein candidates that could be used in the biotechnological perspective. Since the experimental verification requires time as well as large amount of technical infrastructure, recently several computational algorithms have been developed to partially predict the functions of unknown proteins. Although highly

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error prone, the bioinformatics approaches essentially cut down the large list and help in creating a precise catalogue of gene products (Weckwerth 2011). Thus, the discovery of new enzymes and proteins helps in cataloguing functional homologues that could serve as alternatives to the proteins that are industrially and therapeutically important. This essentially is an important prerequisite for fuelling research in protein science for identifying new therapeutics as well as commercially important proteins/enzymes.

A large number of environmental factors influence the survival of microorganisms with fitting genetic machinery that helps them sustain. Extreme environmental stress directs the evolution of thermostable, psychrophilic and halophilic proteins as well as proteins with specific functions such as degradation of xenobiotics and other chemical substances (Elleke et al. 2013). In the recent past, several databases and automatic annotation tools have been developed that include IMG-M, MG-RAST, COG/KOG, TIGRFAM, CDD and PROSITE (Kunin et al. 2008). The new protein families' characterization and the novel functionalities identification of the already existing protein families are the major outcome of an integrated pipeline consisting of biochemical, structural, genomic and meta-omics data (Thomas et al. 2012). This pipeline essentially helps in characterizing huge number of newly identified scaffolds that await functional assignment. In the coming years, these strategies would help in identifying novel proteins and enzymes with varied functions that could be developed into a wide variety of biotechnological products such as therapeutic molecules, drug delivery scaffolds, enzymes and various other commercial products.

2.3 Protein Production: Scaling Up and Limitations

Since proteins are important as therapeutics, as catalysts and as diagnostics tools, their demand has continuously increased (Tripathi et al. 2009). Therefore, the ultimate goals of the development of bioprocess and its scale-up are:

1. The production of desired proteins at minimal cost
2. Maximize the volumetric productivity, i.e. the maximum amount of protein obtained in given volume in the least period of time

Thus, nowadays, most of the proteins are the recombinant proteins obtained through heterogeneous production (Xia et al. 2015). The heterogeneous production of recombinant proteins requires a genetically and biochemically stable recombinant culture with higher yield, a high productive fermentation process and cost-effective downstream process. Various strategic choices may be used to the process for enhancing the protein production while designing the purification protocols and strategies, and these can be listed as follows:

1. Selection of right expression host for the protein(s): bacteria, yeast, insect cells or human cells.
2. Selection of suitable expression vector.
3. Selection of suitable strain(s) if bacterial expression is used.
4. Whether the expression of full-length protein is required or a fragment thereof.

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5. Whether the tagging of protein is required. If yes, which one is the best?
6. Identification of a good purification strategy and its common pitfalls.

Since every protein is in itself different, unfortunately, the answer to the each of these questions a priori cannot be fitted with every protein (Structural Genomics Consortium et al. 2008). Therefore, the strategies and the purification protocols need to be designed individually for each protein while keeping in mind of its intended use. The above given questions have already been discussed earlier in the book. After fixing all these queries, the next step is the scaling up of the process. Thus, the development of successful scaling-up process is the key factor for the commercial success of any proteins.

The scale-up and optimization of the protein production via biochemical activities of microorganisms, including bacteria, yeasts, algae and moulds, and of animal and plant cell systems require sophisticated engineering skills. To achieve the protein production at commercial level needs the increase in size of fermenter without affecting the overall production efficiency of the process. For this purpose, various fermentation parameters need to be considered which are directly linked with the biochemical activities of the culture and so the protein production as the protein is directly linked with the biochemical activities of the cells. Majorly mixing, mass transfer and heat transfer play the critical role during scale-up of the process (Schmidt 2005). Theoretically the following criteria are assumed suitable bases for the scaling up of the process (Ju and Chase 1992):

1. Constant fermenter geometry (constant height to diameter ratio; *H*/*D*)

   While selecting constant H/D as a basis for the scale-up, the surface to volume ratio declines dramatically during scale-up. It will decrease the relative contribution of surface aeration to oxygen supply and dissolved carbon dioxide removal as compared to sparging contribution. This factor can be critical when the shear-sensitive cultures like animal cells are being used for the protein production which leads to significant decrease in the volumetric productivity. In contrast, this factor will not affect the protein production from the microbial culture as in this case the surface aeration is unimportant (Shuler and Kargi 2002).
2. Constant power per liquid volume

   To minimize the cost of final protein product and to earn the maximum profit, the protein production at commercial level must be cost-effective which is directly linked with the power consumption during aeration and mixing of the system. Therefore, while scaling up, constant power per liquid volume can be an important factor. For geometrically similar, fully baffled vessels with turbulent conditions, it may be noted that if scale-up should be based on maintaining a constant power input per unit volume considering no gassing in the system, one may have the following:

$$N_1 = N_2 \left(D_2 / D_1 \right)^{2/3}$$

where N = impeller speed, D = tank diameter and subscripts 1 and 2 represent lab scale and scaled-up fermenter.

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For the gassing system,

$$N_1 = N_2 \left(D_2 / D_1\right)\left(Q_1 / Q_2\right)^{1/14}$$

where Q = volumetric gas flow rate.

3. Constant volumetric mass transfer coefficient (K_La)

   Volumetric mass transfer coefficient is an important criterion for an aerobic fermentation. Most of the protein production is carried out under the aerobic condition. During the scale-up of a process for the aerobic fermentation, K_La needs to be increased in the way which it can fulfil the oxygen demand of the biomass during protein production. In taking constant K_La as basis of scale-up criteria, the following equation can be used during the scaling up of fermenter for the protein production:

$$N_1 = N_2 \left(D_2 / D_1\right)^{13/21} \left(Q_2 / Q_1\right)^{5/42}$$

4. Constant impeller tip speed

   The impeller tip speed is important not only for the well mixing of the reactor content but also for the culture protection from shear damage. If the animal cell culture or the bacterial cells are the source for the protein production and as these cells are sensitive to the shear damage, this factor needs to be optimized carefully while scaling up the process; otherwise, it may lead to the less protein production due to the loss of active biomass. Therefore, the equal impeller tip speed in both the laboratory and full-scale plant reactor is one of the key scale-up criteria. The typical impeller tip speed ranges from 5 to 7 m/s:

$$N_1 = N_2 \left(D_{i2} / D_{i1}\right)$$

where D_i = impeller diameter.

5. Constant mixing quality (constant Reynolds number)

   Constant Reynolds number in other words indicates the constant mixing quality. The constant mixing quality for the optimum protein production is important as it affects both the mass and heat transfer in the system which may lead to be a limiting factor for the biomass production and so protein production. Therefore, constant Reynolds number can also be used as the basis criteria for the scale-up:

$$t_{m2} = t_{m1} \left(D_2 / D_1\right)^{11/18}$$

where t_m = mixing time.

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6. Constant mixing rate number

Minimum mixing time is desirable for creating the homogenous environment in the reactor. Mixing time is often used as scale-up criteria. Mixing time (t_m) can be defined as the minimum time required for the homogeneous distribution of a small volume of pulsating masses in the bulk of the liquid. It is important to adjust the proper mixing conditions in the large vessels during the scale-up. However, the use of mixing time as a scale-up criteria basis has its own limitations as to maintain the t_m constant in both the vessels increases the power expenditure significantly which is not suggestible as it increases the production cost significantly. Thus, as a whole, it can be understood now that the major limitations of scale-up are the mass, heat and momentum transfer deficiencies with the increase in size of the bioreactors which affect the overall production of the protein (Palomares and Ramírez 2003). Mass transfer becomes more important when the nutrient or chemical inducers like IPTG are to be added while the fermentation is on run. With the increasing size of reactor, mixing time increases significantly (Junker 2004). For example, mixing time in large bioreactors containing animal or plant cell culture (10,000 l) can be in the order of 10^3 s. Thus, approximately 17 min would be required for the homogenous distribution of nutrient or inducer in the reactor under the specified conditions. However, it can be solved by adding these chemical inducers or nutrients though multiple ports to the reactors (Ozturk 1996).

Other important mass transfer limitation is related to the oxygen supply to the cells in aerobic culture system due to low solubility of oxygen in water (Shuler and Kargi 2002). The problem gets aggravated with the increase of cell densities due to higher oxygen demand for supporting the cell growth as compared to the oxygen supply. The effective mixing in reactor to generate homogenous environment is necessary to enhance the volumetric productivity of the protein; otherwise, it may lead to the alcoholic or acid fermentation in bacteria, yeast and animal cell cultures (Palomares and Ramírez 1996; O'Beirne and Hamer 2000). Therefore, during scaling up of the process, the bioreactor should be designed to have a higher K_La to increase the oxygen transfer rate (OTR) as much as possible. In general, the dissolved oxygen tension (DOT) should be higher than 20% (with respect to air saturation) to support the growth of the culture. The limitation of oxygen transfer in bulk liquid to the cell may also be due to diffusion through additional resistances, such as cell aggregates or pellets and immobilized cells. In such cases, a 50% DOT in the bulk liquid may be required to sustain the growth of aggregated or immobilized cells in the reactor (Yegneswaran et al. 1991).

As a whole, the primary limitations of the scale-up are gas supply and heat removal. For geometrically similar tanks, shear, mixing time and K_La are impossible to maintain identically simultaneously in both the large and small tanks. Thus, scale-up is difficult as various gradients such as DO gradient, substrate gradient, temperature gradient, pH gradient and CO_2 gradient do occur in the large reactor which led to the induction of multiple physiological responses by the cells. Thus, such oscillating environment in large reactors leads to a heterogeneous cell growth. Consequently, biomass, productivity and yield get lowered

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significantly, and the by-product formation gets enhanced as compared to small-scale reactors (Bylund et al. 1998; Enfors et al. 2001; Käß et al. 2014). Therefore, a successful conversion of lab scale process to commercial scale requires a lot of time and efforts which is the major limitation for the rapid development of a successful scaling-up process (Neubauer et al. 2013).

2.4 Directed Evolution Approaches

Native proteins many a times are required to be modified and altered to an extent that they meet the industrial demands. Directed evolution has been long proven as an effective approach for enhancing the properties of proteins for commercial and therapeutic applications (Cobb et al. 2012; Goldsmith and Tawfik 2012; Porter et al. 2016). This technique relies on evolution of proteins in laboratories through the manifestation of diverse environmental strains. This is followed by screening and identification of protein variants with desired properties (Kumar and Singh 2013). During the course of evolution, iterative mutations and natural selection have helped organisms to survive in the changing environments. To direct useful phenotypes by providing artificial environmental constraints forms the base of directed evolution approaches. This artificial selection process has been utilized since long for selective breeding of crops as well as domestication of animals. Thus, directed evolution has been established as a highly effective and broadly applicable methodology for obtaining modified gene products. This technique basically mimics the natural evolution process and has been hence termed as 'directed evolution' or 'in vitro evolution' (Zhao and Zha 2004) (Table 2.1).

Earlier, the traditional genetic screens utilized physicochemical agents that randomly modified genomic DNA. This methodology was called random mutagenesis that relied upon agents that mainly included several chemical compounds such as ethyl methanosulphonate (EMS), nitrous acids, 2-aminopurines and even ultraviolet (UV) radiations (Kaur and Sharma 2006). These artificial mutagenesis agents actually augment the rate of mutations during the DNA replication process that result in modified gene products. Later, due to relatively lower mutation rates and lack of controls, in vivo random mutagenesis strategies were employed which are still in infancy (Ravikumar et al. 2014). Further, several workers reported the use of error-prone PCR (epPCR) that utilizes DNA polymerases with mutational bias resulting in a large mutational scope (Leung et al. 1989; Camps et al. 2003). Another important methodology that was developed later included DNA shuffling (Stemmer 1994). This was the first homologous recombination method that involves digestion of particular gene by DNases followed by the reassembly of fragments by PCR. Although the fragments reassemble based on sequence homology, the entire gene also incorporates recombinations during the crossover events (Coco et al. 2001). Owing to high rate of point and deletion mutation, a library of mutants could be generated for screening new mutants. Later, a modification to this technique was developed that utilizes recombination of a family of related genes from various species (Crameri et al. 1998). This was termed as family shuffling and involved

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Table 2.1 Comparison of different direct evolution approaches

Approach	Methods	Advantages	Disadvantages
Chemical mutagenesis	Ethyl methanesulphonate (EMS), nitrous acid, UV radiation, etc.	Mutations are dose dependent	Chemical hazard, low and uneven mutations
Mutator strains	Phage-assisted continuous evolution (PACE), XL1-red *E. coli*, etc.	Comparatively simple	Low and uneven mutations
Error-prone PCR (ep-PCR)	Taq polymerase with varying dNTPs and divalent ion (Mg^{2+}, Mn^{2+}) concentrations, etc.	High and even mutation rate	Non-even sampling of codons
Homologous recombinations	DNA shuffling, family shuffling, StEP, RACHITT, NExT, etc.	Ease of identification of useful or futile mutations Sequence reshuffling for attaining functional diversity in protein families	Overdependence on sequence homology
Nonhomologous recombinations	ITCHY, SHIPREC, NRR, overlap extension PCR, etc.	Ease of shuffling poorly related sequences.	Poor general applicability

StEP Staggered extension process, *RACHITT* random chimeragenesis on transient templates, *NExT* nucleotide exchange and excision technology, *ITCHY* incremental truncation for the creation of HYbrid enzymes, *SHIPREC* sequence homology-independent protein recombination, *NRR* non-homologous random recombination

naturally occurring homologous genes. The technique was found effective in producing improved enzymes as well as structurally stable proteins using a single recombination-selection cycle. More recently, focussed mutagenesis approaches have been developed that utilize synthetic DNA oligonucleotides which contain one or more degenerate codons for targeted sites (Acevedo-Rocha and Reetz 2014). These mutation-inducing oligonucleotides are incorporated into a gene library using restriction digestion or gene assembly protocol. This results in simultaneous saturation mutagenesis that has higher probabilities of recombination and an increased ability to produce a large library of mutants that could be screened of desired property.

With further advent of technology, random chimeragenesis on transient templates (RACHITT) was developed which was an improved version of the DNA shuffling technique (Coco et al. 2001). In this case, fragmented DNA anneals directly to a transient polynucleotide scaffold which is further digested. This helps in increasing number of fragment recombinations as well as crossover frequencies. Further modification to this technique in the form of nucleotide exchange and excision technology (NExT) has been proposed that incorporates treatment with uracil-DNA-glycosylase (UDG) and piperidine or apurinic/apyrimidinic lyases leading to higher frequency of recombinations and larger library sizes (Müller et al. 2005). Further, several nonhomologous recombination methods have also been devised that help in shuffling genes with significantly lower sequence identity. The major

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technique is the incremental truncation for the creation of hybrid enzymes (ITCHY). Here, the domains from two parent enzymes are randomly fused to generate chimaera library that is screened later for novel activities. The technique involves exonuclease III for the controlled digestion of DNA to generate truncated fragments of parent genes in maximum numbers which further undergoes blunt-end ligation to form chimaeras (Ostermeier et al. 1999).

Several screening procedures for directed evolution approaches have been also developed alongside. Spatial separation screening involves expression in model unicellular organisms such as *E. coli* or yeast followed by screening as colonies against environmental constraints. Besides this, spatial separation technique has also been recently utilized for screening individual mutants. Several workers have utilized fluorescent readouts, high-performance liquid chromatography (HPLC), nuclear magnetic resonance (NMR), gas chromatography as well as mass spectroscopy for directly monitoring substrate utilization or product formation in colonies (Cobb et al. 2012). Apart from these, earlier fluorescence-activated cell sorting (FACS) had also been used for screening mutant colonies (Fulwyler 1965). The technique relies on a non-diffusing fluorescent reporter (fluorescent-labelled antibodies or tags) for the identification and isolation of cells containing desired gene variants from heterogeneous cell mixture. The current directed evolution protocols have been effectively utilized for enhancing solubility, substrate affinity, catalytic efficiency, thermostability and activity for multiple substrates in a large variety of proteins.

2.5 Single-Molecule Studies of Proteins

Force represents a crucial functional and structural parameter that defines the role of biological macromolecules in their native environment. This has made nanomechanical single-molecule experiments as important tools for probing variety of biomolecular events such as protein folding, protein-ligand interactions, DNA-protein interactions, molecular motors and enzyme catalysis (Mehta et al. 1999; Deniz et al. 2008). These experimental tools amalgamate material sciences with molecular sciences for precise measurement of miniscule regulatory forces that determine function in the life forms. The outcome gives important insights into the intra- and intermolecular interactions that influence biological macromolecules. Looking at the historical perspective, earliest reported single-molecule experiments were the patch clamp-based conductance measurement of ion channels (Sakmann and Neher 1984). However, this technique has its limitations in the choice of systems that could be studied. In due course, spectroscopy provided a more versatile and convenient means to study single molecules (Joo et al. 2008). The commercial availability of sensitive optical detectors made it easier to monitor molecules that emit photons upon excitation. Besides, this also helped in precise observation of photon emission events with high sensitivity and time resolution. Thus, single-molecule fluorescence-based studies became more relevant with the advent of better imaging and biomolecule labelling techniques (Tian et al. 2017; Chen and Ting 2005; Peterman et al. 2004). Later, owing to its functional operation at biomolecular length

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Table 2.2 Comparison of single-molecule techniques used for studying biomolecules

Method	Principle technique	Force (nN)	Resolution (nm)	Applications
Single-molecule FRET	Fluorescence	None	2–10	Protein folding and interactions
Magnetic tweezers	Electromagnet and magnetic bead	0.001–100	1–10	Stretching and deformations in DNA and proteins
Optical tweezers	Infrared laser and microbead	0.1–150	0.1–5	Molecular motors, actin assembly
Microneedles	Optical fibre	1–1000	10	DNA and protein deformations
Atomic force microscopy (AFM)	Cantilever and piezoelectric surface	5–1000	0.1–1	Protein folding, interactions, DNA super structures, DNA unwinding
Biomembrane force probes (BFP)	Lipid vesicle and suction pipette	0.01–1000	10	Protein-ligand and protein-lipid interactions

scales, atomic force microscopy was also widely employed in single-molecule-based studies. Currently, several techniques exist that can take into account a wide range of biomolecular forces. These include optical tweezers, glass microneedles, magnetic beads and biomembrane force probes (BFP) (Table 2.2). Thus, single-molecule study has gradually emerged as an important tool for investigating structure-function correlation of biomolecules.

2.5.1 Single-Molecule FRET

Current understanding of protein folding phenomenon has taken an interesting turn with the advent of single-molecule fluorescence techniques. Single-molecule FRET (Förster resonance energy transfer) represents a very precise and controlled methodology to understand the folding of individual protein molecules (Haran 2003). The relaxation rates observed during the folding kinetics of proteins give only the theoretical steps defining the folding states of a protein (Michalet et al. 2006). Considering a protein exhibiting simple two-state folding behaviour, it can be assumed that the measured spectroscopic property (during unfolding/refolding) is a linear combination of averaged values that demarcate conformational states populated by folded and unfolded states at different time points. On the other hand, theoretical studies provide direct information about the behaviour of single protein molecule under the same experimental condition (Snow et al. 2005). Thus, the single-molecule FRET experiments are aimed at direct visualization of folding events that directly correspond to an individual protein moiety. The methodology involves the attainment of trajectories of FRET efficiency or the distance versus time plot during the time scale of transition between unfolded and folded states or vice versa (Lee et al. 2005).

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Unlike other spectroscopic techniques, FRET provides quantitative details of the variation in intermolecular distances. Thus, FRET is sometimes called the 'spectroscopic ruler' in the areas of biophysical studies on biomolecules (Piston and Kremers 2007). Nevertheless, doubts on preciseness of this distance calculation as well as efficiency in multiple experiments remained. This incertitude was dealt in detail by the works utilizing polyproline as spacer between donor and acceptor chromophores. It was observed that the average FRET efficiency at shorter distances was slightly lower than theoretically calculated by Forster theory and way much higher for the longer distances (Watkins et al. 2006). The plausible explanation to this divergence could be the negligible information about orientational averaging during donor lifetime as well as the requirement of interchromophore distance longer than the sizes of chromophores. This early evidences paved way for the development of more accurate single-molecule FRET methodologies. Recently, more precise calculations indicated that molecular simulations could be used in alignment with the FRET-based measurements (Reif and Oostenbrink 2014; Best et al. 2015).

A classical single-molecule protein folding experiment monitored by FRET identifies photon bursts from freely diffusing protein molecules under increasing denaturant concentration. The major advantage of this simple experiment is that it is free from any artefacts that may arise from surface interactions. Each subpopulation of unfolded, partially folded and folded protein moieties slowly interconvert, and the FRET efficiency distribution displays peaks corresponding to the mean efficiency of each subpopulation (Haran 2003; Forman and Clarke 2007). Basically, the peak numbers in the FRET efficiency distribution precisely show the number of thermodynamic states during this simple protein refolding/unfolding experiment. In most efficiency distribution experiments consisting of slowly refolding and unfolding rates, only two major peaks are obtained at an intermediate denaturant concentration. These two peaks represent the unfolded and folded subpopulations of the protein. Similarly, several protein systems have been studied that include cold shock protein (CspTm) (Nettels et al. 2007), Acyl-CoA-binding protein (ACBP) (Laurence et al. 2005), Chymotrypsin inhibitor 2 (CI2) (Deniz et al. 2000), RNase HI (Kuzmenkina et al. 2006) and immunity protein Im9 (Tezuka-Kawakami et al. 2006). Further, workers have also utilized other applications such as microfluidic devices in association with single-molecule FRET measurements to elucidate the protein folding phenomenon more precisely (Lipman et al. 2003).

2.5.2 AFM-Based Force Spectroscopy

Biomolecular interactions are majorly regulated by multiple weak but specific forces that define the affinity of interacting partners. Single-molecule studies have identified topological features and mechanical characteristics of these forces and have thus provided mechanistic insights into numerous biological interactions. With the advent of scanning probe microscopy (SPM) and later the atomic force microscopy (AFM), force spectroscopy emerged as a new tool for studying biomolecular systems (Liu and Wang 2011). The AFM utilizes a sharp tip of a flexible cantilever

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that probes the mechanical characteristics as well as numerous other parameters of a sample (Carvalho and Santos 2012). Most current day AFM machines rely upon computer-controlled piezoceramic stage that holds the sample and the cantilever that moves over the sample. The deflection force acting between the sample surface and the cantilever is utilized to precisely calculate topological and mechanical features of the sample. This deflection is generated due to lateral (XY) and vertical (Z) displacements of the sample with respect to probe (Dufrene 2002). The sensitivity and resolution of the calculated force depend on the spring constant of cantilever and the laser power that monitors the movement of cantilever. There are two general modes of cantilever motion, 'tapping' mode and the 'contact' mode. In 'tapping' mode, the cantilever is oscillated above the sample surface near its resonance frequency, whereas the 'contact' mode majorly involves constant approach-retraction cycle of cantilever close to sample surface (Garcia and Perezb 2002).

The cantilever motion is utilized to calculate the force, and thus a typical force versus displacement (FD) curve is generated. The variation of force in an FD curve describes the movement of probe towards the sample surface. The movement of probe close or away from the surface is equated with the elastic force of the surface that defines the interaction of the probe and the sample (Anczykowski et al. 1999; Butt et al. 2005).

This interaction is defined on the basis of Hooke's law:

$$F = -k\mathrm{d}$$

where F is the force acting on the cantilever, k is the spring constant of the cantilever and d is deflection.

The cantilever force constants are calibration dependent and vary with different materials used to prepare the probes. Basically, the probe/sample separation affects the different forces that act on the cantilever. Several complex phenomena such as receptor-ligand, protein-protein, DNA-ligand and DNA-protein interactions have been analysed using single-molecule force spectroscopy measurements (Churnside et al. 2012). The biotin/streptavidin interaction is a classical ligand/receptor interaction that has been studied in detail using AFM-based force spectroscopy. The unusually high affinity of the pair as well as the availability of structural information of the interaction has aided in precise calculation of forces acting between them (Grubmuller et al. 1996; Yuan et al. 2000). Several groups have studied the variation in these forces by using mutant protein as well as different analogues of biotin. Besides, this intermolecular force measurements involving protein/protein interactions have been greatly studied using numerous antigen/antibody interactions (Carvalho and Santos 2012). In this case, owing to the diversity in protein pairs, there were tremendous variations in the force measurements. The resulting information provided ample information about the acting forces in different protein scaffolds and molecular pairs and their correlation with their physiological functions.

Another complex phenomenon studied using single-molecule force spectroscopy is the protein folding/unfolding. Several research groups have utilized AFM to study the stretching of single- or multi-domain proteins (Fisher et al. 1999; Besta et al. 2003). In these cases, the FD curves were correlated with the enthalpic and

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entropic parameters associated with protein folding. In most cases, the proteins generate initial entropic stretching that further leads to domain-wise unfolding generating continuous cycles of deflections. This cycle of deflections is followed by entropic stretching everytime a new domain is unfolded. The compilation of entire entropic and enthalpic cycles is used to define folding/unfolding pathway of the protein.

2.5.3 Optical Tweezers

Optical tweezers form another important tool for single-molecule studies of proteins. Basically, optical tweezers utilize the force of laser radiation pressure to trap small particles. Following this, other associated techniques are used to manipulate the trapped particles and study the variation of forces (Novotny et al. 1997; Curtis et al. 2002). Initially, this methodology was used for manipulating and studying micron-sized dielectric particles. Nevertheless, now optical tweezers have been implemented in studying biological systems to a good extent. Mainly, the ability to manipulate single molecules at nanometre scale and to measure forces on these molecules has made this technique an important biophysical tool. In general, the radiation pressure is defined as a force per unit area on a molecule due to change in the momentum of light. All light is composed of photons having a consistent momentum (p). And if there is a change in momentum of light due to refraction with a molecule, the difference between the momentum flux entering and leaving the object can be used to define the total force. Thus, force due to refraction of light can be used to trap and manipulate molecules and helps in making quantitative measurements (Smith et al. 2003). Conformational changes in molecules can generate change in these measurements and thus can provide opportunity to demonstrating their conformational space under particular physicochemical condition. In other words, these measurements can be used to study structural transitions in molecules, define presence or absence of intermediates or even predict the presence of an alternate pathway. Moreover, the wealth of kinetic and thermodynamic information can be obtained that include rates of transitions, free-energy calculations, identification and calculation of energy barriers and even the full energy landscape showing the conformational dynamics of a protein (Wang et al. 1998).

Recently, many workers have used optical tweezers to obtain insights into the conformational paradigm of intrinsically disordered proteins (IDPs). The technique has helped in probing the low-energy fluctuations and marginally stable structures of IDPs. A very important example is the study of α-synuclein, an IDP that is associated with the pathophysiology of Parkinson's disease (Neupane et al. 2014). Several transient metastable structures of this protein have been identified and studied using optical tweezers. This has helped in showing quasi-equilibrium fluctuations in α-synuclein structure that are short-lived and very unstable that may be attributed to the previously predicted molten globule-like conformation. Besides, several groups have also studied transient states of proteins in their heterogeneous mixtures such as during misfolding and aggregation (Stangner et al. 2013; Heidarsson et al. 2014;

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Mashaghi et al. 2014). Recent work on dimeric prion protein has shown the presence of multiple intermediates with comparatively slower diffusion rates that indicates a rugged or rough energy landscape of misfolding (Yu et al. 2015). Similarly, other studies involving optical tweezers have shown the presence of misfolded intermediates in case of slow refolding luciferase enzyme and have helped in correlating calcium concentration and misfolding of neuronal calcium sensor-1 (NCS-1) (Heidarsson et al. 2014). Overall, optical tweezers form an interesting tool to study the dynamics and function of proteins under both physiological and non-physiological conditions.

2.6 Proteases in Biotechnology

Proteases form one of the largest family of enzymes that constitute about 2% of the human genome and account for more than 60% of the total enzyme market. In general, proteases are enzymes that perform proteolysis in a specific or non-specific manner. These proteins mainly hydrolyse peptide bonds and are commonly found associated with protein catabolic pathways. These catabolic pathways in turn form a part of variety of important physiological processes such as cell division, apoptosis, signal transduction, food digestion, blood clotting, etc. Besides, several disease aetiologies are found associated with variety of proteases playing a part in growth and progression of pathogens including the replication of viruses (Neurath and Walsh 1976). Thus, these proteins harbour a diversity of structural and functional features that help them carry out critical purposes inside and outside the cells. Despite several evolutionarily linked diversifications, all proteases essentially function to cleave the amide bond by a nucleophilic attack on the carbonyl group that results in hydrolysis. These proteases naturally exist as inactive precursors called zymogens. These zymogens get converted to their active forms by particular environmental triggers. These triggers could be a variety of factors such as pH, salt, ions, small molecules, peptides or specific ligands that induce specific conformational changes in the protein (Anwar and Saleemuddin 1998; Gupta et al. 2002).

Owing to the huge demand of industrial proteases, sources other than plants and animals have garnered much interest in the scientific and industrial community. This increased interest has led to the discovery of numerous microbial proteases as an alternative source. Basically, the broad biochemical diversity of microbial enzymes as well as their high yield has led to their high acceptability and success at the commercial scale. Additionally, protein engineering approaches to modify the cleavage specificities, solubility and stability of proteases have further broadened their commercial landscape (Eijsink et al. 2004; Bansal et al. 2012). These engineered next-generation proteases are tailored to increase substrate selectivity as well as lend multiple substrate hydrolyzing capabilities. Besides other industrial applications, proteases are also advantageous therapeutic agents that have been employed in the treatment of several diseases such as cancer, AIDS, cardiovascular disease and other infections (Rao et al. 1998; Chanalia et al. 2011).

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2.6.1 Classification of Proteases

Proteases are broadly classified based on their site of action and by the nature of active site residues. The Enzyme Commission (EC) classifies proteases into group 3 (hydrolases) and subgroup 4 (peptide bond hydrolases). On the basis of site of action, proteases are further categorized as endopeptidases and exopeptidases. The exopeptidases specifically attack on the peptide bonds proximal to the start or end of protein substrate, i.e. either at the amino- or carboxy-terminal. Thus, based on their N- or C-terminus specificity, these enzymes are further divided into aminopeptidases or carboxypeptidases. Besides, the endopeptidases cleave peptide bonds inside the polypeptide chain mainly away from the C- or N-termini.

Further, these endopeptidases are classified into six major groups based on the nature of active site residues involved in their catalytic mechanism (Garcia-Carreon and Del Toro 1997). These are called aspartate, glutamate, cysteine, serine, threonine and metalloproteases. The serine, cysteine and threonine proteases involve nucleophilic attack on the substrate and produce covalently linked acyl-enzyme intermediates. On the other hand, aspartate, glutamate and other metalloproteases activate water molecules that act as nucleophile for breaking the peptide bond. Additionally, based on pH optima, proteases are also categorized as acidic, neutral or alkaline proteases.

2.6.2 Protease Sources

Proteases are ubiquitously found in all forms of life and play a variety of physiological functions. Owing to their large presence in the living milieu, initially, these proteases were commercially obtained from several plant and animal sources directly. However, due to low agricultural facilities specifically for industrial production of proteases, plant sources are limited. Similarly, animal origin proteases such as trypsin, pepsin and rennins are extracted directly in bulk quantities from animal sources (Gupta et al. 2002). Nevertheless, their production also depends on livestock availability and ethical and operational limitations. Thus, low production from plant and animal sources and increasing industrial demands led to identification of other alternative sources of proteases (Table 2.3).

Thus, owing to their huge biochemical diversity, microbial sources are slowly becoming commercial generators of various proteases. With the advent of new protein engineering approaches, it has become easier to optimize and regulate microbial growth and hence enzyme production. Besides the ease of bulk production, the other major advantage of using microbial enzymes is their similar characteristics compared to original animal and plant enzymes.

2.6.3 Engineered Proteases

The proteases have been commercially utilized in several applications and are often required to work under extreme and non-physiological conditions such as high temperature, pH, presence of chaotropes, chelating agents and detergents (Gupta et al.

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Table 2.3 Few important commercial proteases and their source of production

Product	Company	Protease type	Source
Protex 30L	Genencor/DuPont	Serine protease	*Bacillus subtilis*
Neutrase 0.8L	Novozymes	Protease	*B. amyloliquefaciens*
Protex 6L	Genencor/DuPont	Serine protease	*B. amyloliquefaciens*
Ronozyme ProAct	DSM/Novozymes	Alkaline serine protease	*B. licheniformis*
Esperase 8.0L	Novozymes	Protease	*Bacillus* spp.
FNA	Genencor/DuPont	Serine protease	*B. amyloliquefaciens*
Versazyme	Novus	Keratinase	*B. licheniformis*
Arazyme-One-Q	Insect Biotech Co.	Metalloprotease	*Serratia proteamaculans* HY-3
Alcalase 2.4	Novozymes	Subtilisin	*Bacillus* spp.
Savinase	Novozymes	Subtilisin	*Bacillus* spp.
Porperase 1600L	Genencor/DuPont	Serine protease	*B. alcalophilus*
Allzyme FD	Alltech	Serine protease	*Aspergillus niger*

2002). This leads to lowered efficacies and degradation of proteases in industrial setups. Thus, proteases with improved stability and functions have been produced using modern-day genetic engineering, protein engineering and directed evolution approaches. Beside this, the proteases have also been used as therapeutics as they are capable of cleaving various physiological substrates. However, very few proteases have been used as therapeutics because of narrow substrate specificity, stability and activity. The development of high-throughput, bacterial and yeast-based methods has facilitated the redesigning of proteases to the modified one with novel specificities, lesser toxicities and higher stability (Guerrero et al. 2016).

In leather and detergent industries, proteases with high thermostability are required for optimal activity and yield. In general, high temperatures affect the native fold of proteins leading to aggregation and loss of activity. Protease engineering approaches have been successful in enhancing thermostability of proteases to a good extent (Mitrea et al. 2010; Zhao et al. 2016). These approaches mainly rely on availability of thermostable homologue of particular enzyme/protease that is used to identify crucial residues and interactions. These critical residues are then engineered into the mesophilic protein scaffolds to mimic their thermostable counterparts. Another widely used approach is the introduction of non-natural disulphides in the protein structures to confer more stability. The addition of extra-stabilizing disulphides helps in lowering the entropy of the protein and thus keeping the native and active scaffold of the protein intact. An important example is the production of engineered thermostable subtilisin E that incorporates an unnatural disulphide based on structural comparisons with a thermophilic subtilisin-type protease, aqualysin I (Bryan 2000).

Similarly, metal binding sites in many enzymatic proteins have been found to stabilize and help increase the activity. Introduction of calcium-binding pockets by substituting Gly131 and Pro172 by Asp residues in subtilisin increased electrostatic interactions and stabilized the protein (Pantoliano et al. 1988). On the contrary, industries such as detergent and laundries require proteins to function under highly chelating conditions. Thus, proteins with high stability aided with better catalytic function in absence of metal ligands have been produced by a combination of

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protein engineering and directed evolution. A subtilisin variant Sbt88 with 1000 times greater stability was characterized based on deletion of calcium-binding loop followed by improvement of activity by directed evolution (Strausberg et al. 1995). Also there are several industrial applications that require proteases to function in organic solvents. Several methodologies that mainly include error-prone PCR and directed evolution have been utilized to screen proteases with improved activity in organic solvents.

Besides other industrial applications, proteases have also been extensively used in wide range of therapeutics and have been engineered to suit particular application. Engineered factor VIIa (FVIIa) with improved pro-coagulant and anti-fibrinolytic activity by residue mutations and increasing its enzymatic efficacy by increased localization affinity are such few examples (Persson et al. 2001). Another important aspect of engineering therapeutic proteases has been to reduce their non-specificity and thus the side effects. On these lines, bifunctional thrombin represents an excellent example where the protein not just acts as an activator of multiple pro-coagulant substrates but also acts as an anticoagulant agent (Hanson et al. 1993). Further, thrombin has also been engineered to produce a more efficient protein having higher anticoagulant function. An engineered double mutant thrombin (W215A/E217A) with compromised pro-coagulant activity and very slow (>2000-fold) fibrinogen cleaving activity has been developed that specifically activates protein C in the presence of thrombomodulin (Gandhi et al. 2009). Another important factor associated with therapeutic proteases or proteins in general is their half-lives under physiological milieu. Several factors such as protease digestion and endogenous inhibition have been attributed for their short half-lives in organismic environment. Among several examples, designing inhibitors of tissue plasminogen activator (t-PA) has been shown to prevent systemic activation of plasminogen and helped in promoting thrombolytic property of t-PA (Madison et al. 1989). Furthermore, reducing immunogenicity of therapeutic proteases has also been a subject of interest to increase their overall clinical efficacy. Thus, novel protein engineering approaches along with modern-day computational biochemistry and synthetic biology have helped in channelizing the development of better and high-quality proteases with improved commercial and industrial applications (Table 2.3).

2.6.4 Production Process

The animal- and plant-based enzymes are directly produced from the animal tissues and extracts. Initially, the tissue and organs are processed in an enzyme-extracting solution to obtain the crude proteases. Later, several steps of extraction and concentration are involved to get proteases of typical potency (Jaswal et al. 2008). Nowadays, most major proteases and enzymes are obtained at commercial scales using microbial and fungal strains. These protease-producing strains are screened using plate assay method, and their production capability is estimated quantitatively. At the next stage, media design and optimization are done to help in inducing the production of particular enzyme/protease. The optimization process involves

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find application in other basic science protocols such as general protein digestion, removal of affinity tags, tissue extraction and separation and several cell culture methodologies. The rise in engineered proteases in recent times has brought down the cost of production in major industries such as pharmaceuticals, bakery, detergent, leather and food. Protein engineering helps in incorporating desirable characteristics such as heat stability, pH range, substrate specificity, increased activity and storage time. Proteases from various sources such as bacterial, fungal and viral have been engineered to produce suitable application-based enzymes.

2.7 Chaperones in Biotechnology

Molecular chaperones have been an area of growing interest in the field of medical, pharmaceutical and industrial biotechnology (Henderson et al. 1996; Arakawa et al. 2006). Chaperone function has been found critical in both normal and stress conditions in all living cells. The term chaperone dates back to 1978 where it was used to describe the function of a nuclear protein called nucleoplasmin that helps in chromatin assembly by preventing nonspecific interaction of histone proteins with DNA (Schlieker et al. 2002). Later, these were categorized as a class of proteins that assist in post-translational modification of other proteins. The current understanding of chaperones describes them as a highly conserved protein family that primarily functions to assist folding of nascent polypeptides and prevent their misfolding and aggregation (Hartl and Hayer-Hartl 2002). This stabilizing function of chaperones has been responsible for protecting proteins under variety of stress conditions including heat, chemicals, toxins, free radicals, radiations, etc. Chaperones binding to exposed hydrophobic sites in polypeptides help in preserving their correct scaffold thereby preventing their aggregation. Their role in aggregation prevention has been probed and studied in several neurodegenerative and systemic disorders such as Alzheimer's, Parkinson's, diabetes, etc. (Henderson et al. 1996; Barral et al. 2004). Besides, the role and application of chaperones in folding proteins of therapeutic and industrial importance have been areas of intense research.

The chaperoning function is not just associated with protein-based chaperones but has also been successfully achieved using certain chemical scaffolds and co-solvents too. These co-solvents include several osmolytes and small molecules such as arginine that help in raising the osmotic pressure against environmental water stresses and result in protein stabilization (Arya et al. 2014; Dandage et al. 2015; Srivastava et al. 2015). The well-characterized genetic architecture as well as the ease of fermentation has made *E. coli* as an important industrial organism for the production of proteins of various origins. It has been shown that chaperones can help in improving the refolding process obtained from inclusion bodies and may also be expressed in *E. coli* to reduce the formation of inclusion bodies (Thomas and Baneyx 1997). Thus, in vivo overexpression of chaperones along with protein of interest has been utilized as a successful strategy to obtain proteins of industrial and commercial interest with high yields (Villaverde and Carrio 2003; Ventura and Villaverde 2006). Besides, there had been several other strategies where the yields

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of industrial proteins have been raised by addition of chemical chaperones at different steps of purification process (Mannen et al. 2001; Rajan et al. 2011).

Moreover, several studies have also demonstrated that chaperones coexist and cooperate with each other during the refolding process in vivo (Hartl and Hayer-Hartl 2002; Genevaux et al. 2007). Hence, there has been a rise in newer strategies that involve expression of a combination of chaperones rather than a single chaperone. However, there are several limitations associated with chaperone overexpression, and hence including more steps in the in vitro refolding and purification process has been favoured in the recent years (Hoffmann and Rinas 2004; de Marco et al. 2007). This has led to utilization of protein chaperones as well as chemical and pharmacological chaperones in the industrial setups. Besides, it has been also found that immobilization of chaperones has been also identified as an important tool for retaining and reutilization of chaperones for longer usage. As a whole, chaperones have been identified as crucial tools for improving recombinant production of therapeutic and industrial important proteins that are aggregation prone.

2.7.1 Chaperone-Assisted Protein Folding

Molecular chaperones bind selectively to nascent polypeptides and partially folded protein intermediates and help them fold into their native and active structure. Thus, chaperones effectively demarcate folded and unfolded polypeptides based on their hydrophobic features (McHaourab et al. 2009). Although the primary sequence contains inherent information on protein folding, the crowded cellular milieu makes a nascent polypeptide very prone to misfolding and aggregation. At this stage, chaperones play a crucial role in stabilizing and assisting the initial protein scaffold to correctly fold into its active form. Besides, molecular chaperones are often involved in compartmental translocations, proteolytic degradation and removal of misfolded and aggregation-prone proteins (Young et al. 2003; Young et al. 2004).

In general, chaperones are found in both prokaryotic and eukaryotic systems and are similar in their basic structural features. The major differences occur in quaternary organization involving the number of subunit, monomer associations and their active oligomeric states. Nevertheless, all chaperones function in a similar fashion and bind to aggregation prone and partially folded protein intermediates to prevent their aggregation. Out of several identified systems, the best characterized chaperone system considers a chamber-based folding of a nascent polypeptide. The GroEL-GroES chaperonin system represents the best example of this chamber-based protein folding (Mayhew et al. 1996). Here, the GroES molecule acts as the lid of the folding chamber in the form of GroEL and helps in creating an isolated environment for a nascent polypeptide. The folding is assisted in the presence of ATP, and the phenomenon is explained via *cis*- or *trans*-mechanism (Hayer-Hartl et al. 2015). The folding mechanism in most chaperone systems is ATP dependent and is considered highly efficient and error-free. The protein folding funnel describes large number of protein conformations with very high entropy at the top. During the folding process, the entropy slowly decreases owing to the number of unstable states receding into native or near-native conformations (Baldwin and Rose 2013).

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Here, it is worth mentioning that smaller proteins generally undergo spontaneous folding and large proteins mostly require chaperone assistance for correct folding.

Chaperone assistance actually helps in reducing the population of unfolded conformers that represent different energy levels. Thus, a chaperone-assisted channelization of the energy funnel helps the protein population to attain native structure. In most cases, along with the main chaperone, several co-chaperones smaller in sizes are also present. A major example is the DnaK chaperone system that involves formation of ATP-bound DnaJ complex with DnaJ co-chaperonin (Rosenzweig et al. 2013). The process follows ATP hydrolysis by water and addition of another subunit GprE that releases both ADP and DnaJ. This propagates the release of folded protein from the chaperone complex. Besides these in vivo chaperone systems that have been utilized for recombinant protein production, several chemicals and solvents have been also used to refold proteins in vitro (Bruzdziak et al. 2013). This group of chemical chaperone consists mainly of osmolytes and non-osmolytic small molecules. Chemical chaperones also function by sticking and stabilizing the exposed hydrophobic patches of partially folded proteins and hence facilitate their folding (Rajan et al. 2011). Thus, they form a key step in obtaining correctly refolded proteins in industrial setups. Osmolytes augment the thermodynamic stability and thus aid in protein folding. Besides, solvent additives like arginine also help in recovering active protein during large-scale production of bacterially expressed proteins.

2.7.2 Classes of Chaperones

Molecular chaperones are categorized into two major classes, viz. group I type chaperones found in bacteria, mitochondria and plastids and the group II type chaperones found only in archaeal and eukaryotic cytoplasm (Johnson and Craig 1997). Besides, there is another group of co-chaperones that assist chaperones in selecting protein targets and regulate their association and dissociation. Based on function and mechanism of action, molecular chaperones have been further classified into three subclasses. The 'folding' chaperones (e.g. DnaK and GroEL) depend on ATP-driven conformation change for polypeptide substrate refolding. The 'holding' chaperones (e.g. Hsp 31 and IbpA) bind to the partially unfolded protein intermediates until the 'folding' chaperones are available during stress conditions. Besides, the third class of chaperones (e.g. ClpB) acts on already aggregated forms of proteins and helps their resolubilization. On the other hand, there are two separate classes of nonbiological chaperones that include 'chemical chaperones' consisting of mainly osmolytes (e.g. trehalose) and 'pharmacological chaperones' that include mainly protein-stabilizing ligands and small molecules (e.g. arginine).

2.7.3 Aspects in Industrial Protein Production

The well-characterized genetics as well as fermentation technology of *E. coli* has made it the most commonly used organism for the heterologous production of proteins from various sources. However, the major bottleneck with *E. coli*-based

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Table 2.4 Some important chaperones expressed in specific host cells for assisting protein folding

Chaperone	Host
GroEL/ES	*E. coli*
BiP	*Insect cells*
DegP	*E. coli*
Peptidylprolyl *cis-trans* isomerise	*Insect cells*
DnaK	*E. coli*
ClpB	*E. coli*
Hsp 70	*Insect cells*
HtbG	*E. coli*
Calnexin	*Insect cells*
Human protein disulphide-isomerase (PDI)	*CHO cells*
Polyubiquitin	*Kluyveromyces lactis*
DegP	*E. coli*

protein production is the formation of insoluble inclusion bodies (IB). Although IBs help in greatly increasing the overall yield of the recombinant protein, the process of obtaining the protein in its function form is often problematic (Ventura and Villaverde 2006). The exact mechanism behind the formation of these depositions is not known, but it is assumed that eukaryotic nascent polypeptides generally have higher exposure of hydrophobic sites and thus have higher affinity for aggregation (Fahnert et al. 2004). The other important factor is the inefficient protein chaperoning and stabilization system in the bacteria. This led to large number of reports supporting the usage of chaperone overexpression as an immediate solution to this problem (Georgiou and Valax 1996; Thomas and Baneyx 1996; Carrio and Villaverde 2002) (Table 2.4).

Molecular chaperones like GroEL/ES or DnaK have been co-expressed with desired proteins to obtain considerable yields (Chen et al. 2003; Gupta et al. 2006). Nevertheless, it was found that expression of single chaperones does not have significant increase in the amount of soluble protein. Further, it was found that large chaperones actually require small co-chaperones that function in consort to 'hold' and 'refold' the protein. It was shown that application of bi-chaperone systems such as ClpB and DnaK could be a better resort in obtaining soluble protein in significantly higher yield as compared to their individual co-expression (Mogk et al. 1999; Mogk et al. 2003). The eukaryotic counterparts of both these proteins (Hsp70 and Hsp40) have been also shown to improve refolding of recombinant proteins as compared to co-expression of large chaperones such as Hsp90 alone (Glover and Lindquist 1998; Genest et al. 2013). Molecular chaperones are currently utilized in biotechnology industry for their ability to prevent as well as reverse the protein aggregation. Several complex systems such as the *E. coli* DnaK-DnaJ-GrpE system have been utilized to suppress protein aggregation and effectively perform disaggregation (Zolkiewski 1999).

On the other hand, owing to their complex mechanism of action, the precise calculation of aggregation kinetics as well as affinities of chaperone systems (bi-, tri- or more) to different aggregate types are not yet characterized. This fall back has led to several model propositions for defining the actual phenomenon. Two major

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models are widely accepted that explain the mechanism of action of multiple chaperone systems. The DnaK/ClpB system (chaperone/co-chaperone system) has been studied in detail and has been utilized to develop these models (Mogk et al. 1999). According to the first model, ClpB makes initial contacts with the protein aggregates and later gets attached to DnaK. This model is based on the finding that DnaK has relatively lower binding affinity of binding to smaller protein aggregates. On the other hand, the second model suggests that the ClpB/DnaK complex directly attaches with the protein which is solely determined by specificity of individual chaperone components. Nevertheless, at present, there is still a dearth of significantly active chaperone systems that could be applied in the industrial setups effectively.

2.8 Therapeutic Proteins

There has been a surge in protein-based therapeutics during the past few decades. The major reason behind this surge is the critical role of proteins in cellular machinery and elucidation of mechanisms of their function in great detail. This led to the development of an entirely new class of biotherapeutics that is produced from living systems or their products (Carter 2011). Protein-based biotherapeutics extensively accounts for monoclonal antibodies, recombinant proteins, fusion proteins and peptides. Owing to their broad-spectrum specifications, therapeutic proteins have been successfully utilized in treating cancers, cardiovascular diseases, diabetes, anaemia, haemophilia, etc. (Leader et al. 2008). Nevertheless, these proteins have their own demerits and limitations such as low oral stability due to enzymatic degradation, low physiological half-life and poor shelf life. Thus, the area of protein therapeutics is continuously being researched upon to make them better and more efficient. Next-generation protein therapeutics relies heavily upon protein engineering that helps in modifying these proteins of different origins to suit human immunological response. Currently, these emerging new pharmaceutical products account for more than 200 commercial products that mainly include therapeutics, diagnostics and vaccines (Pavlou and Reichert 2004) (Table 2.5).

2.8.1 Classes and Source

Protein therapeutics have been broadly classified based on their pharmacological activity. They can be used as replacement to abnormal or deficient protein and as delivery systems for certain drugs, effectors or toxins, for enhancing a particular metabolic pathway, adding a new function or activity, and interfere or inhibit certain pathological molecule or an organism (Caravella and Lugovskoy 2010). Besides this function-based categorization, they have been also grouped based on molecular type such as blood factor, antibody, anticoagulant, enzyme, scaffold, fusion protein, growth factors, etc. Overall, protein-based therapeutics is an ever-growing field that relies on producing newer, engineered, efficient and immunologically less-reactive protein-based pharmaceuticals.

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protein-based therapeutics and has greatly revolutionized their clinical usage. Engineered natural proteins, fusion proteins and PEG conjugated and antibody-based therapeutics are only few examples that have been widely utilized for producing effective therapeutics (Carter 2011). Insulin is the first therapeutic protein produced through recombinant DNA technology that was commercialized. This synthetic counterpart (Humulin, Eli Lilly Inc.) was approved by the US Food and Drug Administration (FDA) in 1982 for the treatment of diabetes mellitus (Johnson 1983). The two major advantages were its rapid action after meals and also maintenance of low levels of insulin between meals. The engineered insulin incorporating stabilizing amino acid mutations was similar in action to the endogenous insulin in the body. Later, several companies modified and produced more efficient insulin analogues that had better physiological half-lives, reduced risk of hyperglycaemia and ease of administration. These rationalizations were employed in commercialization of several other natural proteins such as erythropoietin and tissue plasminogen activator (tPA) and different cytokines such as interferon-α (Andersen and Krummen 2002).

Several other protein-based therapeutics have been produced in mammalian cells with additional glycosylation sites that help in augmenting the in vivo half-life. For example, engineered darbepoetin (Aranesp) is administered to anaemic patients for enhancing the production of RBCs (Egrie and Browne 2002). Similarly, epoetin-α has been also produced to contain extra N-linked glycosylation sites for better physiological half-life. Besides this, the advent of fusion proteins has opened a new era of protein-based therapeutics. Fusion proteins are created to combine properties of two or more different proteins and have been commercially successful in countering many diseases such as cancer and multiple sclerosis (Dingermann 2008). An excellent example is the fusion of Fc region of immunoglobulins to target proteins that help in increasing their serum retention and half-life. Apart from increasing half-lives, conjugation with Fc region enables high-throughput purification and increased solubility and stability of therapeutic proteins. Important examples of Fc-fusion proteins that have been approved after clinical trials include etanercept (Enbrel) incorporating a TNF receptor 2 and romiplostim, a thrombopoietin (TPO) receptor agonist that is composed of peptide-Fc fusion (Bibila and Robinson 1995; Chapman et al. 1999).

Other than this, polyethylene glycol (PEG) conjugation has also been shown to improve clinical efficacy of therapeutic proteins. This has given rise to an entirely new engineering technology called 'PEGylation' that has been employed in improving efficacy of several proteins (Ginn et al. 2014). PEGylated proteins have higher molecular volume that prevents their early renal clearance leading to an increased half-life. Several PEGylated proteins have been commercialized successfully as efficient therapeutic proteins that include analogues of interferon-α, interferon-β1a, erythropoietin, human GCSF (granulocyte colony-stimulating factor) and L-asparaginase, etc.

Moreover, there has been a rise in production of 'engineered protein scaffolds' that act as alternative to antibody-based therapeutics since they recognize specific protein targets (Gebauer and Skerra 2009). These scaffolds are produced as a library

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of small and highly soluble moieties and later screened using phage or yeast systems against specific protein targets. A number of these scaffolds are now increasingly adding up into the next-generation therapeutics (Skerra 2000; Lofblom et al. 2011). Several examples include avimer (based on LDLR-A modules), Adnectins (based on type III fibronectin domains), affibodies (based on synthetic Z domain of staphylococcal protein) and DARPins (based on ankyrin repeat proteins). These scaffolds owing to their small sizes are now utilized for creating multi-targeting and multivalent next-generation protein-based therapeutics. Thus, the clinical success of protein-based therapeutics has revolutionized the clinical development of several new, engineered and efficient protein drugs against several pernicious diseases.

Conclusion

The postgenomic era has paved new pathways into the discovery and development of novel proteins and protein/enzyme-based products. This huge information base has aided protein engineering and later bioprocess to emerge as more efficient and product oriented. The molecular details of protein functions have been elucidated using modern-day single-molecule studies. Utilizing this functional information along with structural biology, several new modifications in industrial protein production have been implemented. In this context, traditional methodologies including directed evolution approaches are now aided with highly curated sequence information as well as more precise molecular biology tools. Besides, the industrial bioprocess setup for commercial proteins/enzymes now includes chaperone-based methodologies. Both at the in vitro as well as in vivo levels, protein recovery is greatly enhanced using biological and chemical chaperones. Overall, the present scenario in protein and enzyme production at industrial scale looks highly competitive and exacting due to increasingly high stimulus of information on sequence, structural and functional aspects of proteins.

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Acronyms

AES	Advanced Encryption Standard
ANP	Analytic Network Process
ANS	Autonomic Navigation System
API	Application Programming Interface
BAN	Body Area Network
BI	Business Intelligence
CADS	Continuous Authentication on Data Streams
CCAF	Cloud Computing Adoption Framework
CI	Computational Intelligence
CIA	Confidentiality, Integrity, and Availability
CMED	Cloud based MEDical system
CPU	Central Processing Unit
CS	Cloud Server
CSA	Cloud Service Architecture
CSP	Cloud Service Providers
DCTP	Data Collection based on Trajectory Prediction
DDOS	Distributed Denial of Service
DEMATEL	Decision-Making Trial and Evaluation Laboratory
DES	Data Encryption Standard
DNA	Deoxyribo Nucleic Acid
DoS	Denial of Service
DSA	Digital Signature Algorithm
DSMS	Data Stream Management System
ECG	Electrocardiogram
e-CLV	Electronic Customer Lifetime Value
E-commerce	Electronic Commerce
EDOS	Economic Denial of Service
e-Governance	Electronic Governance
EHR	Electronic health Records
ELS	E-commerce Logistics System

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E-RS	Enhanced Reed-Solomon
GB	Gigabyte
GDP	Gross Domestic Product
GPS	Global Positioning System
GSM	Global System for Mobile communication
HMM	Hidden Markov Model
IA	Information Accountability
IaaS	Infrastructure as a Service
ICT	Information and Communication Technology
IoT	Internet of Things
IoV	Internet of Vehicle
ISG	Information Security Governance
IT	Information Technology
ITSC	Intelligent Traffic Control System
MCDM	Multi criteria Decision Making
MD	Message Digest
MDP	Multi-Dimensional Password
ML	Machine Learning
MLA	Multi-level Authentication Scheme
MLC	Multi-level Cryptography
MOLA	Multi Objective Learning Automata
P2P	Peer to Peer
PaaS	Platform as a Service
PARAMO	PARAllel predictive MOdelling
PB	PetaByte
PCC	Predictive Cloud Computing
PccP	Preserving Cloud Computing Privacy
PHMS	Patient Health Monitoring System
PIoT	Predictive Internet of Things
PMC	Predictive Mobile Computing
POR	Proof of Retrievability
PPCA	Probabilistic Principal Component Analysis
PRDC	Permission-based RFID Data Collection Algorithm
PTT	Prediction of Trigger time
PoD	Prediction of Distance
QoS	Quality of Service
RBAC	Role Based Access Control
RBE	Role Based Encryption
RC	Rivest Cipher
RDIC	Remote Data Integrity Checking
REF	Reference
RFID	Radio Frequency Identification
RPM	Remote Patient Monitoring
RSA	Rivest Shamir Adleman
SaaS	Software as a Service

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SAMOA	Socially Aware and Mobile Architecture
SBA	Seed Block Algorithm
SDG	Stochastic Gradient Descent
SecCTP	Secure Cloud Transmission Protocol
SHA	Secure Hash Algorithm
s-Health	Smart Health
SLA	Service Level Agreement
SOAP	Simple Object Access Protocol
SQL	Structured Query Language
SSL	Secure Socket Layer
SWF	Smallest Window First
TB	Terabyte
TLS	Transport Layer Security
TPA	Third Party Auditor
TTP	Trusted Third Party
UML	Unified Modeling Language
V2V	Vehicle-to-Vehicle
VANET	Vehicular ad-hoc network
VM	Virtual Machines
VPN	Virtual Private Network
Wi-Fi	Wireless Fidelity
WSDL	Web Services Description Language
WSN	Wireless sensor networks
XML	eXtensible Markup Language

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Chapter 1
Introduction to Predictive Computing

1.1 Introduction

The existing computing techniques are becoming more challenging to compete with the global development. However, the modern computing techniques have more focus on interdisciplinary approaches to perform complex tasks and development to satisfy human needs. The computing techniques designed to strengthen communication among the living and nonliving objects, to reduce energy consumption and time by applying smart methods for predicting navigation paths, prediction of health diseases and monitoring, weather prediction, etc., can be classified under predictive computing techniques. Further, the computing techniques like Green Computing, Ubiquitous Computing, Internet of Things (IoT), Human–Computer Interaction, and Intelligent Transportation are considered as a few major techniques which perform computations in real time or near real time. Table 1.1 presents the evolution of computing paradigm and from which we observe the shift of programming paradigm that was completely based on desktop computing since 1960–1990. During this period, the procedural languages [1–8] like ALGOL [4, 5], FORTRAN [6, 7], Pascal [7, 8] and C [7] were the common programming languages for designing and developing computer programs. As the advancements in technology have taken place, the evolution of other programming languages like functional programming [2, 3], and declarative programming languages [2, 3] like LOGO, PROLOG [9, 10] and ASP [11] has taken over the procedural programming languages. With the significant technological change after 1990 and emerging of object oriented programming languages [2] like Java, C#, etc., the computing scenario has changed completely and new methods are being introduced. With the use of Internet technology, significant developmental changes have taken place with the help of web-based and scripting languages [12] in the market for designing of websites and Internet-based systems. Web-based computing has changed the way of use of computer systems and this has led to the development of applications that can work parallel or concurrent [13–17], agent-based

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Table 1.1 Evolution of computing paradigm

S. no.	Computing paradigm	Programming language	Era of use
1.	Procedural/Imperative programming [1–3]	ALGOL [4, 5]	1958–1968
		FORTRAN and its variants [6, 7]	1950–till now
		Pascal and its variants [7, 8]	1970–2012
		C and its variants [7]	1972–2011
2.	Functional [2, 3]	LISP and its variants	1958–2013
		ML or MIRANDA	1985–1989
3.	Declarative [2, 3]	LOGO or PROLOG and its variants [9, 10]	1972–1995
		Answer set programming (ASP) [11]	1993–1999
4.	Object oriented [2]	C++	1983–till now
		JAVA and its variants	1995–till now
		C# and its variants	2000–till now
		SMALLTALK and its variants	1972–1990
		EIFFEL and its variants	1986–2009
5.	Scripting [12]	VBScript and its variants	1996–till now
		JavaScript and its variants	1995–till now
6.	Parallel/Concurrent [13, 14]	Ada [15]	1982–till now
		Erlang [16]	1986–till now
		RUST [17]	2010–till now
7.	Agent based [18, 19]	AgentSpeak [20]	1996–till now

environment [18–20]. These significant changes in computing and communication have eased down the connectivity of the devices and data processing could become possible in real time to predict new findings like prediction of change detection in ground images, prediction of shortest navigation path of a vehicle by using existing driving habits and prediction of health status, etc. These changes and advancements in computing field have opened the doors to information security related issues and problems. The use of sensor technologies, Internet technologies, virtualization and real-time computation all along the way has introduced new bugs and vulnerabilities in the designed system. However, a variety of information security techniques are proposed over the period of time which can be used to make communication secure.

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In [21], Bartels has proposed a new kind of computing where convergence of innovations in software architecture, backend operations, communications and to various client devices connected to the network lets advance computing technology work together to find and solve the complex business problems in innovative manner that could not be addressed by the last generation computing techniques. Seed of '*innovations*' adds new capabilities to existing technologies for real-time situational awareness and automated analysis. Researchers and software developers are introducing this seed to their software, hardware and communications to solve the complex business problem smartly.

1.2 Definitions

The term 'Predictive Computing' is tossed with the advancements in computing field and with the evolution of computing techniques like cloud computing, pervasive computing, IoT, big data, etc. Predictions from these computing techniques are based on explanatory models and a good predictive model can be turned into a machine. In this section, we have presented the general definition of computing, and few definitions related to the concept of predictive computing and Predictive Analytics.

- Computing
  Over the period of time, a wide range of definitions has been given related to terms '*Computing*' and '*Predictive Analytics*'. Comer et al. [22] have stated that '*computing is the systematic study of algorithmic processes that describe and transform information: Their theory, analysis, design, efficiency, implementation, and application*'. In [23], Denning has stated that 'computing is a natural science' as the term '*computation*' and '*information processes*' are existing in the literature long ago even before the invention of computers. In [24], Shackelford et al. stated, '*computing is any goal-oriented activity requiring, benefiting from, or creating computers and includes designing and building of hardware and software systems for a wide range of purposes; processing, structuring, and managing various kinds of information; doing scientific studies using computers; making computer systems behave intelligently; creating and using communications and entertainment media; finding and gathering information relevant to any particular purpose, and so on*'.
- Predictive Analytics
  Today's businesses use variety of business models which in turn are driven by data analytics which provides useful methodology for exploring available data and for developing significant models to serve the purpose of an entity [25]. A variety of terms can be found related to analytics like business analytics, academic analytics, learning analytics, predictive analytics, etc. In [26], Matt has stated that analytics means different things to different peoples and is not a one-size-fits-all endeavour. In [27], Eckerson stated that '*Predictive analytics is*

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a set of business intelligence (BI) technologies that uncovers relationships and patterns within large volumes of data that can be used to predict behavior and events. Unlike other BI technologies, predictive analytics is forward-looking, using past events to anticipate the future'. In [28], IBM stated that '*Predictive analytics connects data to effective action by drawing reliable conclusions about current conditions and future events*'. According to SPSS '*Predictive analytics is both a business process and a set of related technologies that leverages an organization's business knowledge by applying sophisticated analysis techniques to enterprise data*' [29].

- Predictive Computing
  According to Nadin [30], '*Predictive computation is the path that leads from reaction-based forms of computing to anticipatory forms of computing*'. 'To predict' means to state something about next step or next sequence. The predictive value could be find with respect to time, space, words, expression in language, degree or significance whereas, '*Predictions can be time-independent (extenders), pertinent to simultaneous occurrences (portents), or can infer from data describing a previous state or the current state of the world to a future state*'. In [31, 32], Frost & Sullivan have stated that IoT market will continue its growth in future and architecture of IoT 2.0 will enable self-healing events in the connected system. IoT 2.0 is supposed to react to various events, to using *sentient tools and cognition or* '*predictive computing*'. Thus, a definition of predictive computing can be proposed here:

> *Predictive computing presents an algorithmic approach that processes collected data of living and nonliving entities periodically from different sensor nodes in the network to develop an effective prediction model where the next step, or next sequence, or the future state of the system/user activity can be represented effectively.*

Here, we have used the term 'model' in general sense which refers to abstraction of system that can derive some knowledge after processing the collected data. We can realize the existence of predictive computing from the following scenario (Fig. 1.1) that represents the growing trends of business transactions over use of computing.

1.3 Pillars of Predictive Computing

In [33], Stankovic has represented that by using the techniques like pervasive computing, Internet of Things, wireless sensor networks (WSN), mobile computing and cyber-physical systems, the world can be transformed into smart world. These computing techniques provide the basis for predictive computing. The author has

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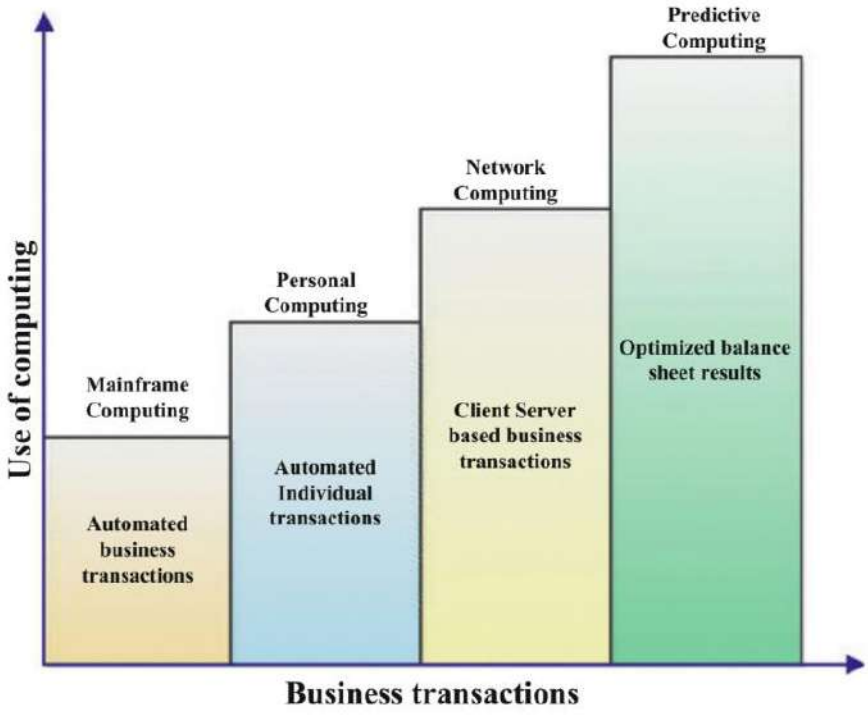

Fig. 1.1 Role of predictive computing in business transaction

also focused on the major research problems like security, privacy, massive scaling, architecture, and robustness, etc., for creating smart applications that can make predictions to make our lives easier and comfortable. Figure 1.2 represents the six core computing techniques that can act as six pillars for predictive computing.

– *Predictive Computing and Internet of Things*—also known as predictive internet of things (PIoT). The architecture of IoT 2.0 will enable self-healing events and is supposed to react to various events related to living and nonliving objects in the network by making use of predictive computing [31, 32]. Connected IoT nodes in the network are used to collect the information related to the object which is further stored in the database or clouds.

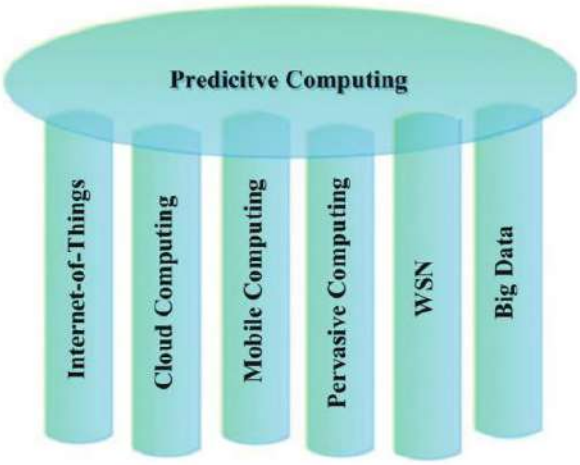

Fig. 1.2 Six pillars of predictive computing

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- *Predictive Computing and Cloud Computing*—also known as predictive cloud computing (PCC). The major objective of PCC is to develop and provide a smart allocation and deallocation of servers by combining ensembles of forecasts and predictive modeling to determine the future origin demand for website content [34]. PCC distributes the load evenly over various virtual machines located in clouds and also ensures the security of data by using various PCC security frameworks and techniques.
- *Predictive Computing and Mobile Computing*—also referred as predictive mobile computing (PMC). In contrast to traditional telephony, the mobile computing can communicate by voice, video and data wirelessly over diversified devices and systems by making the use of mobile communication standards and protocols. The mobile applications are distributed among various mobile nodes and use centrally located information. However, the predictive mobile computing has application-aware adaptation and has an environment-sensing ability. Mobile devices are considered as smart objects and are equipped with smart applications which use predictive frameworks that continuously monitor user's activity on the devices and send information to various servers for its further processing and making predictions [35, 36].
- *Predictive Computing and Pervasive Computing*—also known as smart computing and considered as a successor of mobile computing and ubiquitous computing. As pervasive computing embeds the computational capability into day-to-day objects to make them effectively communicate, predictive pervasive computing makes devices and objects smart and intelligent that can take or provide decisions on the basis of available information without any user intervention. Devices involved for smart computing are computers, laptops, tablets, smart phones, sensors, wearable devices, etc. [36].
- *Predictive Computing and Wireless Sensor Network (WSN)*—wireless sensor network is the backbone for implementing the predictive computing techniques and frameworks. The advancements in computing world have only become possible because of WSN, which Wireless sensor networks consist of geographically distributed autonomous devices using sensor to monitor physical and environmental conditions. The sensors used in WSN are one of the smart objects that continuously monitor and forward the information between user and data centres.
- *Predictive Computing and Big Data*—The sensor nodes used in WSN generate heavy volume of data. In some cases, daily collection of data reaches up to gigabyte (GB) and terabyte (TB). This collection of data supports creation of huge database called big data and demands cost effective, innovative forms of information processing that enable enhanced insight, process automation and decision-making [37]. By deploying predictive models over this big data, people are trying to use the insights gained from big data to uncover new opportunities for their businesses. The big data plays an important role in improving the accuracy of predictions and can be used in health care, tourist, agriculture, social networking, environment monitoring, etc. [38].

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1.4 Horizons of Predictive Computing

The existence of predictive computing could be in every major sector as shown in Table 1.2. Here, it can be observed that predictive computing plays a vital role everywhere, from smart home to healthcare sector. The integration of IoT, cloud computing and wireless sensor networks has made it possible to find the predicted result in real time for different areas. The predictive computing consists of various smart objects connected via wireless sensor network for collection of the data which gets stored in clouds for further its processing. Possibilities of predictive computing span over health care, transport, travel, sales, smart home like other many sectors (Table 1.2).

According to Gartner's hype cycle of 2015 [13], for emerging technologies IoT, mobility, digital business and analytics will play a lead role in growth of opportunities and provide the new experiences to the customers and organizations. This megatrend of hype cycle is shown in Fig. 1.3.

There will be a significant growth in the area of digital marketing and digital business. The current marketing trends will be replaced and reinvented with predictive applications solutions. These applications will be able to analyse the human behaviour from the existing data and will provide the solutions intelligently and effectively.

1.5 Role of Information Security and Techniques

The role of information security is becoming vital at each level of communication, storage and user access. Integration of technologies like IoT, cloud computing and wireless sensor networks involves billions of nodes and devices generate data that need to be stored with virtual machines located in cloud, communication between these devices and user requires access control mechanism and communication mechanisms are intact.

Figure 1.4 represents the major security-related challenges associated to these areas and application security framework. On the basis of object identification in predictive computing technology, system level characteristics could be categorized where predictive parameters can be identified, and communicated with each other. Based on this consideration, the research areas like computing and communication techniques, interconnected systems and distributed intelligence have been identified. Devices enabled with smart computing must be able to identify, perform computing and communication with each other. RFID (Radio Frequency Identification) technique is becoming more popular for identification of objects, whereas low-power research communication techniques are being used in sensor networking [39, 40]. In future, low-power and low-cost communication technologies will be considered for communication purpose among smart objects for prediction purpose. Interconnected systems play the important role in implementation

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Table 1.2 Horizons of predictive computing

	Areas	Uses					
Predictive computing	Smart home	Entertainment	Security	Kitchen	Home appliances		
	Transport	Navigation	Parking	Logistics	Traffics	Emergency services	
	Community	Factory	Retail	Surveillance	Business intelligence	Smart metering	Environment
	National	Infrastructure	Smart grid	Weather forecasting	Defence	Remote monitoring	Population
	Industries	Location	Security	Surveillance	Audit		
	Policy makers	Health	Water	Electricity	Population	Education	Goods and services
	Personal user	Handheld devices	Desktops	Banking			
	Health care	Patients monitoring	Emergency	Records	OPD		

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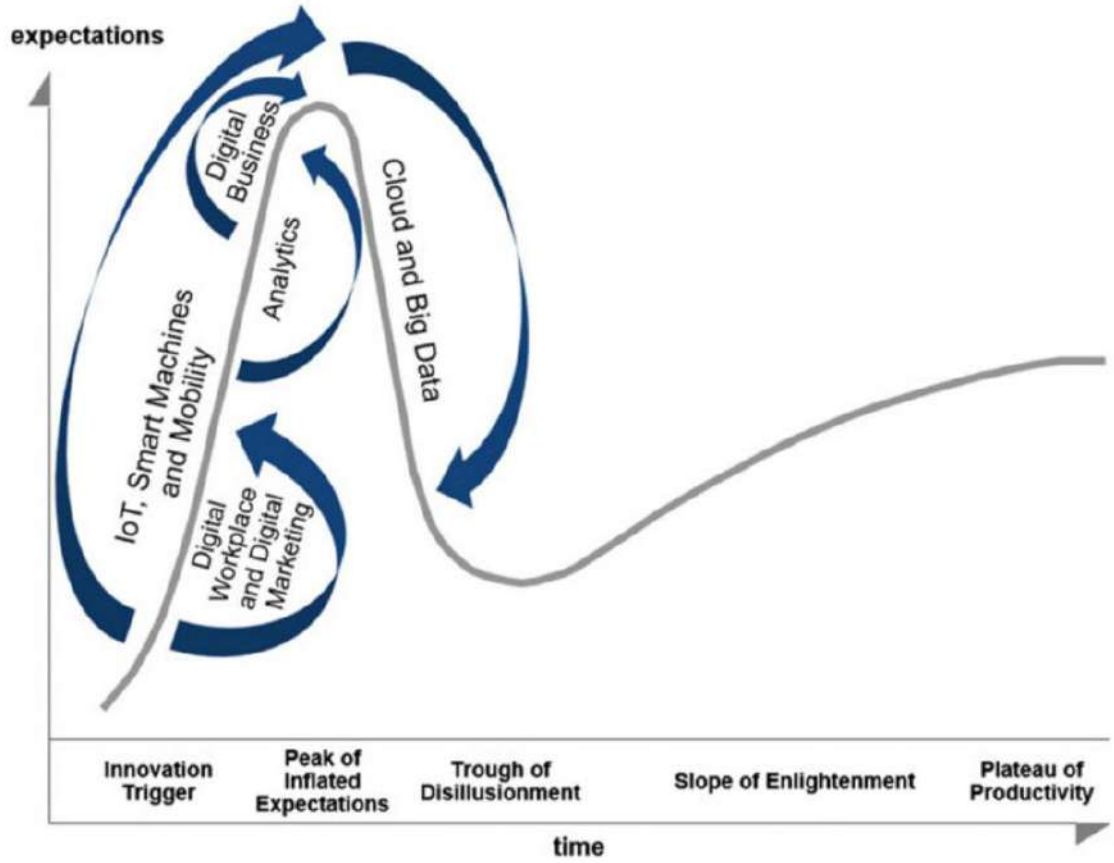

Fig. 1.3 Megatrends of significant technologies [13]

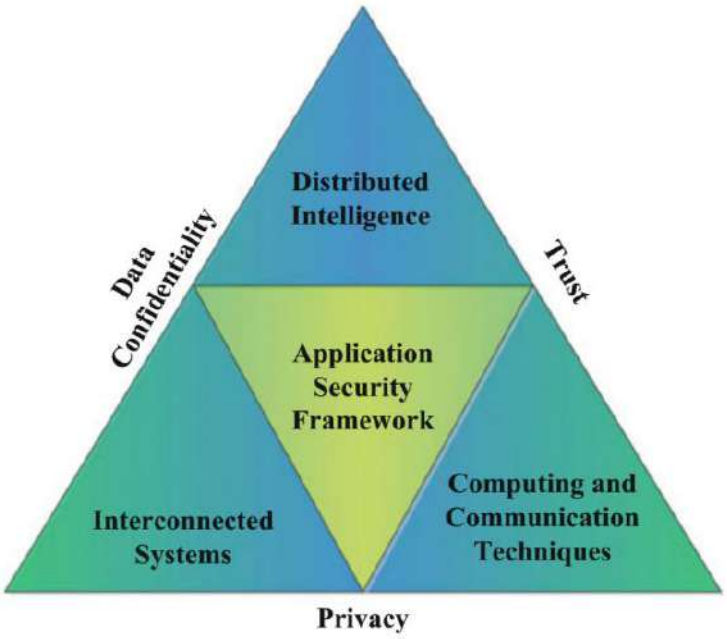

Fig. 1.4 The potential security challenges to smart computing

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Chapter 19
Biofuel Policy in Indian Perspective: Socioeconomic Indicators and Sustainable Rural Development

Anuj K. Chandel, Latika Bhatia, Vijay Kumar Garlapati, Lakshmishri Roy, and Anju Arora

Abstract Biofuels are regarded as one of the most promising options to fulfill the higher energy requirement in future and simultaneously decarbonize the environment caused by excessive usage of fossil fuels. Technologies for the production of biomass based fuels particularly bioethanol and biodiesel are rapidly developing. However, successful commercialization of biofuels is still far due to high capital and operation expenditures and technical immaturities at large operations. Biofuel policies from major biofuels supporting nations might capitalize rural economic development and sustainable agricultural growth after strongly promoting biofuels. India has a biofuel policy, which foresees biofuels as potential candidates stimulating rural development by generating employment opportunities, together with environmental and economic benefits. The biofuel industrial sector has shown promising results and could serve as a potential source of substantial employment in near future. However, for the successful incorporation of biofuel policy, sustainable key indicators encompassing social and economic factors need to be evaluated properly in different scenarios. This chapter discusses the biofuel policies, key sustainable indicators, socioeconomic aspects of biofuels in Indian perspective.

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1 Introduction

The rapid pace of industrial developments and burgeoning urbanization have called for environmentally sustainable energy sources like clean transportation liquid and gaseous fuels, wind and solar energy, and others [1]. Liquid transportation fuels such as ethanol made from first generation sugars (first generation ethanol) and cellulosic sugars (sugars derived from cellulosic biomass), biodiesel, bio-hydrogen, solar and wind energy provide unique environmental, economic strategic benefits and can be considered a safe and the cleanest renewable energy alternative to fossil fuels [2]. Significant advances have been made in last 2 to 3 decades towards the development of renewable energy. However, there are still several technical challenges and economical barriers, which play a pivotal role in making the renewable energy program unsuccessful at commercial scale.

The attention on sustainable biofuel production worldwide is growing rapidly. The profitability of biofuel production is significantly linked with the policies of multiple sectors such as agriculture, food and feed processing, research and development, industry and commercial trade. The uncertainties in oil prices mandating the serious evaluation of opportunities for the production and consumption of biofuels. Furthermore, because of the price instability in crude oil and overdependency on import, governments are showing keen interest in development and promotion of biofuels even leveraging the subsidies to make biofuels commercially viable. The paramount challenges of today such as energy security, concerns about trade balances, greenhouse gas (GHG) emissions, rural livelihoods, and domestic farm commodities are important for pushing biofuels in near term [3]. Biofuels are also considered as a potential contributor in the socioeconomic development of rural areas, and could play a substantial role in alleviation of poverty via creation of new employment opportunities—impacting directly or indirectly the multiple millennium development goals [4–6]. For example, sugar and ethanol industry provides direct and indirect employment to an approximately 12% of the rural population in Brazil. Moreira [7] observed that sugarcane crop in Brazil employs one million workers at various levels. In fact, this industry is very important for rendering socioeconomic services to the rural community such as improvement in infrastructure, opening of schools, colleges, hospitals, among others in the sugarcane growing countries like Brazil, India, China and others.

Cultivation of bioenergy crops on unused or degraded forest land and wastelands is advantageous for the restoration of green land [7]. Biofuels sector may provide substantial employment in India, as the country is basically rich in agriculture. Biofuels sector covering second generation ethanol, biodiesel and associated products from biorefinery may create new employment opportunities. Sugarcane cultivation and sugarcane processing industries for sugar and ethanol production are the

primary agro-industrial sector in the country providing the livelihood of 50 million farmers and their dependants, (approximately 7.5% of the rural population). The sugar industry based employment further helped to save substantial foreign exchange, enabling India to strengthen infrastructural facilities with improvement in Gross Domestic Productivity (GDP). Moreover, it will reduce the dependency on the Organization of the Petroleum Exporting Countries (OPEC) countries and open a path for self-reliance in petroleum requirements.

Socioeconomic and environmental indicators (such as social wellness, energy and food security, external and internal trade, profitability, conservation of natural reserves) are the key elements to measure the sustainability of renewable energy options [8]. A balanced evaluation of sustainability indicators is imperative for commercial biofuel producers to make decisions about cultivation of biofuel crops, transportation, processing and conversion, and logistic of fuel blends concerning with the future or retrospective measures [8, 9]. For the long haul, it is very important to understand bioethanol production technologies in terms of their economic viability, environmental feasibility and empowering employment opportunities before implementing a fuel ethanol policy. The choice of the best technology for economically viable renewable fuel production directly depends on the overall economics (lowest cost), environmental benefits (lowest pollution), and least energy consumption (higher efficiencies). Correct measurement of economic viability with the right scale is essential to estimate renewable fuel production costs with precision. Critical analysis of key parameters such as (i) capital expenditures (CAPEX) constituting total capital investment, equity and leverage, interest rates, life cycle of plant machineries and their maintenances and (ii) operational expenditures (OPEX) embedding raw material, auxiliaries, residue management, (iii) fixed OPEX (operation, personnel, insurances, and servicing), and (iv) revenues from by-products are imperative for accurate economic analysis of renewable fuel production.

In this chapter, we review the biofuel implementation policies from major countries who are the strong advocates of biofuel usage and socioeconomic indicators in those countries. However, particular emphasis is given to renewable biofuel development, key sustainable and socioeconomic indicators in Indian context.

2 International Biofuel Policy Scenario

In the current scenario, when the world is developing not only industrially but also technologically, the concerns like global warming and depleting oil reserves have profound impact on setting up right biofuel policies in international arena. In fact, these problems act as driving force worldwide to explore the bio based materials which can be potentially used as feedstock for first and second generation biofuel production [10]. The interest in biofuel production got momentum due to unprecedented price hike in crude oil prices in 1970's, originally because of supply

restrictions imposed by the Organization of the Petroleum Exporting Countries (OPEC) cartel. High uncertainty in oil prices and negative environmental impact on environment using oil and gas catalyzed the search for alternatives, save or replace oil with economically feasible options such as biofuels. As per the analysis by British Petroleum (BP), energy consumption is expected to increase by 34% between 2015 and 2035. Oil and gas will hold the dominant place in supply energy. However, renewable energy in the form of liquid biofuels are also growing rapidly at 6.6% per year [11]. In 2015, world ethanol production has increased by 4.1% while biodiesel decreased by 4.9% [11].

With an increased environmental concern in the 1980's and 1990's, the use of biofuel gained further popularity, as a result of which biofuel production experienced sharp hike. High oil prices, benefits to agriculture and rural areas. and diversification of sources of energy might have also contributed to this hike. Along with all these issues, biofuel production also gained momentum by the concern of various government policies such as mandates, targets, and subsidies which cover the grounds of energy security and environmental considerations. Biofuel policies not only play a major role in the development of the energy sector but also provide thrust for innovation, research, and development. The key profitability indicators of biofuel production are primarily influenced by the policies of various sectors such as agriculture, research, industry, and trade. But this optimism with respect to biofuels took a pause when the concerns were raised by the global food crisis in 2007–2008 and the policy makers were in a dilemma on food security issues generated by first generation biofuel [12].

2.1 Global Biofuel Policies

This section deals with biofuel policies in four main biofuels markets, i.e., European Union, the USA, Brazil, and India. It is based primarily on the studies from the references from [13–16]. An overview of these government biofuel policies from major biofuel producing countries is shown in Table 19.1 [17].

2.1.1 Brazil

The only mature, integrated biofuel market in practice in the world is Brazil's cane-based ethanol market. The sugarcane -based ethanol/electricity cogeneration system became a competitive energy provider at USD$35 per barrel of crude oil prices [18]. Brazil has been the world leader in the mandated blending of biofuels for over 30 years, primarily under its National Alcohol Program (Portuguese: 'Programa Nacional do Álcool') or "*Pró-Álcool*" program [19].

It was a government intervention as a response to the petroleum shortage caused by the 1973 oil crisis that initial promotion of ethanol policies took place in Brazil

Table 19.1 Government biofuel policy of various countries

Features	Brazil	USA	EU	India
Mandatory/ Indicative targets	Mandatory blend of ethanol in Gasohol: 20–25%	– Mandatory use under the Renewable Fuels Standard (RFS). Rising to 28.1 billion liters in 2012 – Specific blend requirements being implemented at State level	Indicative blending target was 5.75% by 2010. Mandatory 10% blending target by 2020. Trend towards mandatory requirements in many member states	E5 blending program in some states recently extended E10 country wide by 2017
Tax credits/ excise duty reductions	Ethanol attract a lower rate of value added tax as against gasohol	If the cellulosic ethanol qualifies for alcohol fuel tax credits, the credit amount is reduced to $0.46 per gallon	Excise duty reductions allowed until 2010, then revision. Applied in many member states ranging from small reduction to complete removal. Trend towards declining tax support	Some tax exemptions provided in the Union Budget 2007
Import tariffs	No tariff	USD 0.14/l +2.5% of the value	Very high tariffs. EUR19.3 hl for un-denatured and EUR 10.2 for denatured ethanol	198.96% ad valorem (as a percentage of the customs value of the import) on CIF value (cost, insurance, and freight) for un-denatured and 59.08% ad valorem on CIF value for denatured
Feedstock supports	No	No specific support to biofuels but possible in 2007 Farm Bill	Yes With the CAP reform set-aside land can be used for energy crops production for which farmers receive a EUR45/ton premium (maximum 2 mln hectares)	Not directly Indirectly through minimum cane pricing

Source: Jolly [18] (modified from PowerPoint presentation) Government Biofuels Policy and Sugar Crops Policy Crops Outlook, International Sugar Organization

[19]. The *Pró-Álcool* program was started in 1975, as a strong support for ethanol demand and supply and to enhance the share of domestically produced fuel. The government initiated the bioethanol development of the industry through low-interest loans and enlisted a state-owned enterprise, Petrobras [20], to incorporate the product into gasoline. Through beneficial tax treatment, ethanol was available at a price that made it competitive with gasoline, and automobile manufacturers were persuaded to produce cars that were able to use the fuel at levels above traditional gasoline-powered vehicles. The 1990s observed the termination of this government supported *Pró-Álcool* program but market regulation and tax incentives of the program continued to be supported [20, 21]. Transition phase to a full liberalization took place between 1996 and 2000. Hebebrand and Kara [22] found that the blending mandate has been met by supporting policies, including local distribution requirements, subsidized credit for ethanol storage and tax preferences for vehicles. Currently, various incentives supporting demand is maintained without direct control on ethanol production and trade.

Currently, anhydrous ethanol blending is 18–25% for gasoline. This mandate is not relevant for pure hydrous ethanol which is sold at filling stations for use in flex fuel vehicles. Ethanol–gasoline blends up to 85% of anhydrous ethanol or on up to 100% hydrous ethanol fuel can successfully run these flex fuel vehicles. The mandatory blend of ethanol (18–25%) replaces the existing gasoline dependency (50%) and showcases the success of flex-fuel vehicles allowing ethanol fuel consumption in Brazil for transport. All gas stations are required to sell both gasohol (E25) and pure ethanol (E100). Figure 19.1 shows the competitiveness in



Fig. 19.1 A gasoline filling station from Piracicaba, São Paulo state of Brazil showing ethanol and gasoline price in August, 2016

ethanol (*etanol comum*), gasoline (gasoline *comum*) from one of gasoline station in Piracicaba-São Paulo state.

Biodiesel, though not a major product in Brazil, is blended with regular diesel (B5) at 5% rate [22]. In 2013, Brazil introduced biodiesel blending targets of 5%. The Brazilian federal and state governments grant tax reductions and exemptions to reach these obligations based on the agricultural producer's size and developmental level of region. Flex fuel vehicles get the privilege of lower taxes than those on petrol-powered vehicles, and similarly, ethanol is also bestowed with favorable tax treatment at the pump relative to petrol. The Common External Tariff of Mercosur (an economic and political agreement between Argentina, Brazil, Paraguay, and Uruguay) also protects Brazilian domestic biofuel production with ethanol duties of 20% and biodiesel duties of 14% which could be eliminated under the Doha and/or the EU-Mercosur trade negotiations with non-tariff barriers on Brazilian biofuels imports. Foreign investments in ethanol distillation plants and sugarcane production, especially from Europe and the USA, provide an important explanatory factor in the growth of the ethanol sector in Brazil. International investors are motivated by lower costs for ethanol production in Brazil which is an outcome of low prices of raw materials and the high technological level of the whole production process.

The drivers for biofuels vary according to local circumstances, specific domestic policies and initiatives. These issues drastically differ between countries. Brazil is the only country where production cost of ethanol and biodiesel is competitive with petroleum sources because of some inherent advantages like land availability, quality of land for sugarcane cultivation, rain, sunlight, soya production, and availability of knowledge and skilled professionals. Ethanol attracts a lower rate of value-added tax against gasohol. Over the medium term, the ethanol–sugar interface will remain centered in Brazil. In long term, some other countries will also start producing ethanol from sugar crops, which could be triggered by the correlation between sugar and energy prices. Brazil will continue to be the key player of the oil–ethanol–sugar interface. In the years of global sugar deficit, the world market can "buy-back" ethanol from Brazil.

2.1.2 USA

US Corn-based ethanol is an integrated and fully evolved system. The main drivers for increased biofuel demand in the USA are high energy prices and incentives provided by the Energy Policy Act of 2005 (EPACT05). The EPACT05 requires a minimum of 7.5 billion gallons (approximately 28.7 billion liters) of renewable fuels (ethanol and biodiesel) to be used in the nation's motor fuel.

The main issues those motivated the USA to form biofuel policies in 1970 were the concern for country's economy, environment and domestic farm commodities, which could be a prospective source of raw material for biofuel. Dependency on imported fossil fuels and increasing greenhouse gas emission were troubling country's economy and environment respectively [23]. Energy Tax Act of 1978

introduced the tax exemptions and subsidies for the blending of ethanol in gasoline. A subsidy of 4 cents per gallon of gasohol (E10), equivalent to 40 cents per gallon of pure ethanol, was introduced in the Energy Policy Act of 1978, through a partial exemption from the federal gasoline excise tax. Tyner [24] attributes the launch of the ethanol industry to this policy. The level of ethanol subsidy has varied over the years but presently stands at 45 cents per gallon, operated through a volumetric ethanol excise tax credit (VEETC). Biodiesel blenders receive a tax credit of $1.00 per gallon. Most of the states have tax exemptions and credits for use of ethanol along with the federal tax credit. The range of programs that exist for individual states is a testament to the strength of the lobbying effort of proponents of alternative fuels and vehicles that make use of those fuels. It also illustrates the difficulty of creating an effective notification mechanism for governmental assistance [25].

It took almost 2 decades for biodiesel to have subsidies implemented on it, on the platform of Conservation Reauthorization Act in 1998. Though the US fiscal incentives and mandates differed from state to state they were complemented by those at federal level. The US biofuel policies targeted specifically on mandates in volumetric terms as a part of the Renewable Fuel Standard (RFS) program, introduced under Energy Policy Act of 2005. This act framed the policies on mandates on consumption of biofuels. This act declared purchase objective of 4 billion gallons and 7.5 billion gallons of biofuel in 2006 and 2007 respectively. With the addition of biodiesel mandates, RFS program was expanded in The Energy Independence and Security Act (EISA) of 2007. According to this act, nine billion gallons of renewable fuel will be blended into transport fuel, and this horizon will expand to 36 billion gallons in 2022. To avoid the stress on first generation grain-based ethanol, the major share of this 36 billion gallons blending fuel will be covered by advanced second or higher generation biofuels (about 60%). The 2022 mandate for biodiesel is 1 billion gallons. Output-connected measures, support for input factors and consumption subsidies are the three principal instruments for current US biofuel policies. Largest direct subsidies are the tax credits whereas indirect subsidies are mandates and it does not provide direct support for price. Tariffs on ethanol are much higher as compared to that on biodiesel (24% in former and 1% in later in ad-valorem equivalent). This high tariff on ethanol limits its import from Brazil.

Ethanol producers significantly benefit from tax credits based on biofuel blended into fuels. Fuel consumers profit from the blender's tax credit as well—in the form of a lower fuel price—when the tax credit is combined with a binding blend or consumption mandate. Fuel consumers do not benefit, however, when the tax credit is the only binding policy. In this case, the consumer fuel price does not depend on the level of the tax credit, as shown by Gorter and Just [26]. The Volumetric Ethanol Excise Tax Credit and the Volumetric Biodiesel Excise Tax Credit provide the largest subsidies to biofuels while there are some smaller additional subsidies connected to biofuel outputs both on the state and federal levels.

2.1.3 European Union (EU)

Germany is the major producer of biodiesel in EU, where tax exemptions promote it. EU ethanol production capacity in 2006 was 2.1 billion liters which quadrupled about 8.5 billion liters in 2013. In EU, wheat, corn and sugar beet derivatives are main sources for bioethanol production. Germany, France, Hungary and the Czech Republic are the major countries in EU in 2015 and 2016 for bioethanol use. In 2016, consumption of biofuels in Germany is expected to increase because of the mandates in biofuels mandates to save GHG emissions.

In Europe, biodiesel production is growing more rapidly than ethanol production. World's largest biodiesel production occurs in EU. Biodiesel represents about 80% of the total transport biofuels market. Domestic consumption and competition from import are the two major driving forces for biodiesel production in EU. In 2014, biodiesel production increased by 11%, mainly in Germany, Spain, and the Benelux because of substantially lower imports and higher domestic consumption. In 2016, biodiesel production capacity in EU is expected to be 25.2 billion liters, with a 2% reduction from 2014.

The EU Biofuels Directive (BFD) has revised the total transportation fuel consumption profile and supporting biofuels and other renewable fuels in the EU. Almost 25% greenhouse gas (GHG) emissions are caused by the gasoline consumption. The goal was set to reduce the contribution in GHG emissions (based on energy content) to 5.75% and 10% by the end of 2010 and 2020 respectively. European Parliament and Member States [30] is reviewing these goals and will decide based on the 2020 results. Most the EU countries have not met the goals of 2010 to reduce 5.75% gas emissions [27].

It was need of the hour for EU to design its biofuel policy in order to fulfill its commitment to the Kyoto targets of Green House Gas (GHG) emission as concern for rising environmental issues from the EU population. It is not a single document, but a collection of a number of records which captures the EU biofuel policy. These documents are issued by different parts of the EU governance structure [28]. There are additional national aids for the production of "ethyl alcohol of agricultural origin" and occasional tenders for surplus crops to be converted to bioethanol. EU introduced Biofuel Directive 2003/30, which targeted at the use of 2% and 5.75% of biofuel in transport sector by 2005 and 2010 respectively at the EU level. It was only Germany and Sweden that exceeded 2005 target as they respectively used 3.86% and 2.11% of biofuel in total fuel consumption.

Germany's biggest drive on renewable energy by "Energiewende" (Energy Transition), with massive energy infrastructure investments is a big push in this direction and a good example for several countries. Among the EU nations, Germany is among the top users of renewable technologies in transport, heating, and power sector. In Germany, 12.2% of energy consumption, 20% of electricity consumption, 10.4% of heating, and 5.6% of transport consumption comes from renewable sources. Germany is also strongly advocating the use of biofuels in aviation sector also [29].

To execute the strategies on biofuel consumption EU Renewable Energy Directive (2009/29) established a "20-20-20 Policy" in 2009. Under this policy, various targets are set to be accomplished by the year 2020, which includes 20% reduction of total energy consumption in the EU-27, 20% reduction in Greenhouse gas emission and the share of renewable energy is set at 20% in the total EU energy consumption. Some agreements such as Cotonou Agreement, the Euro-Med Agreements and the Generalized System of Preferences Plus (GSP+) provides duty-free access to biofuel market of EU. These free access opportunities highly benefit some countries like Guatemala, South Africa and Zimbabwe.

Common Agricultural Policy (CAP) launched in 1992 supported the bioenergy drive in the EU. This policy brought energy-crop-premium of EUR 45/ha on a maximum of 2 million ha of set-aside land. This first pillar of reformed CAP proved itself unsupportive for bioenergy production. The second pillar of CAP comprising Rural Development Policy reinforced several measures that supported bioenergy development through the modulation instrument. Promotion of renewable energy production from perennial energy crops, agricultural and forest biomass was supported by enabling investment in infrastructure.

The EU trade policies have a big impact on domestic biofuel production, reduction in production incentives, and export opportunities for foreign biofuel producers. For biodiesel, the most-favored-nation duty is 6.5%. For un-denaturated ethanol and denaturated ethanol, the ethanol tariff barriers are on the higher level, EUR 19.2/hectoliter and EUR 10.2/hectoliter, respectively. Non-tariff barriers affect the trade of biodiesel considerably. For instance, even in the situation if tariffs for biodiesel are reduced, trade would have impact due to more restrictive non-tariff barriers in the form of quality and environmental standards [23]. Excise duty reduction was effective until 2010, followed by a gradual reduction to complete removal. Under the CAP reform, set-aside land can be used for energy crops production providing a premium of EUR 45/ha to the farmer.

EU passed a legislation in 2008 to use biofuels in transportation. Adopting the "Climate Change Package" in Directive for Renewable Energy (DRE) by EU in 2009, it was mandated that in EU, 10% of the transport energy should be from renewable sources by 2020 and 20% of the overall energy requirement should come from renewable sources [30].

2.1.4 India

According to International Energy Agency [31], global oil demand is projected to be increased by 60%, i.e., 7700 billion liters in 2030 with 68% increase in China and India alone. India is the fifth largest primary energy consumer and fourth largest petroleum consumer in the world. India spends over 45% of their export earnings for importing energy [32]. Biofuels have received considerable attention in India to curb the oil dependency [33].

Food security is primary concern for India to provide food to huge population while controlling the price elevation for food commodities and improving

agricultural productivity. Therefore, Indian government cannot allow the use of arable land, which is used for food and feedstock production, for the cultivation of biofuel crops. Food security is a grave concern for India as it is already one of the largest importers of vegetable oils in the world. Further, productivity of food grains like wheat, corn, rice and coarse cereals has been quite slow in recent years causing scarcity of food grains.

Water scarcity problems are also one of the major issues that India is already suffering from and this issue will only worsen as their food demand continues to grow with a rise in populations and incomes. India is exploring the possible implementation of a controversial multibillion-dollar project of inter-basin water transfers, to meet future demands [34].

The Government of India introduced Ethanol Blended Petrol Program (EBPP) in January 2003 with a vision of blending ethanol with petrol. National Policy on Biofuels formulated by the Ministry of New and Renewable Energy (MNRE) in 2009 recommended the blending at least 20% biofuels with diesel and petrol by 2017. Ethanol blending will increase the bioethanol requirement to 3.4 billion liters by 2020 [35]. As the present requirement of ethanol for the potable and chemical sector is fulfilled solely by molasses, to suffice the above need of blending there is a need to cultivate 20–23% more sugarcane (to generate molasses) than what is the present requirement of the sugar industry. However, to grow biofuel crops more land and water will be needed. To produce 736.5 million tons of sugarcane, to meet the molasses demand, an area of 10.5 million hectares will be required which seems impossible as it will deprive the production of food crops [36, 37]. Hence crop-based biofuels will exert pressure on water and land resources that already are heavily exploited or overexploited [34].

Considering pro-poor dimension as prime focus to harness the potential of biofuels sector in India, biofuel policy of India should address these concerns for the sustainable development. Subramanian et al. [38] stated that endeavor should be to produce ethanol from various feedstocks or organic matter we should not rely solely on molasses or food crops. India is blessed with abundant renewable energy resources. Provisions are being planned to encourage their use in every possible way. The Indian approach to biofuels, in particular, is somewhat different from the current international approaches which could lead to conflict with food security. It is based solely on non-food feedstocks to be raised on degraded or wastelands that are not suited to agriculture. The issue of fuel versus food security is not relevant in the Indian context. Policy support mechanisms to promote alternative feedstocks that will benefit all the stakeholders in the bioethanol supply chain in the long run while meeting the mandated requirements. In future too, it would be ensured that the next generation of technologies is based on non-food feedstocks.

In 1948, the Power Alcohol Act heralded India's recognition of blending petrol with ethanol. The main objective was to use ethanol from molasses to blend with petrol to reduce dependence on petrol imports, trim wastage of molasses and to bring down the price of sugar. *Jatropha curcas* was identified as the most suitable tree borne oilseed for biodiesel production by the National mission in April 2003 by the Government. Blending mandate was made optional in October 2004 because of

scarcity of ethanol during 2004–2005. Blending mandate was resumed in October 2006 in 20 States and 7 union territories in second phase of EBPP. In December 2009, the government introduced the comprehensive national policy on Biofuels after a series of policy changes. The final policy was framed by MNRE which called for at least 10% biofuels blending with diesel and petrol by 2017 [13].

2.1.5 Salient Features of National Policy on Biofuels, 2009

- The Policy aims at mainstreaming of biofuels and, therefore, envisions a central role for it in the energy and transportation sectors of the country in coming decades. The national indicative target of 5% blending by 2012, 10% by 2017, and 20% after 2017 has been recommended in the policy. The goal of the policy is to cater biofuel demand by ensuring the availability of a minimum level of biofuels in country.
- Nonedible oilseeds crop plantations on waste/degraded/marginal lands would be encouraged while the plantation on infertile irrigated lands would not be supported. In the context of the International perspectives and National imperatives, it is the endeavor of this policy to facilitate and bring about optimal development and utilization of indigenous biomass feedstocks for production of biofuels. The policy also envisages the development of the next generation of more efficient biofuel conversion technologies based on new feedstocks.
- A Minimum Support Price (MSP) to be announced for farmers producing nonedible oilseeds used to produce biodiesel. MSP with the provision of periodic revision for biodiesel oilseeds would be announced to provide a fair price to the growers. The Minimum Purchase Price (MPP) for the purchase of bioethanol by the oil marketing companies (OMCs) would be based on the actual prices of bioethanol production and import price of bioethanol. For biodiesel, the MPP should be linked to the prevailing retail diesel price.
- Financial incentives for new and second generation biofuels, includes a National Biofuel Fund. Bio-ethanol already enjoys concessional excise duty of 16%, and biodiesel is exempted from excise duty. No other central taxes and duties are proposed to be levied on biodiesel and bio-ethanol. Custom and excise duty concessions would be provided on plant and machinery for production of biodiesel or bio-ethanol, as well as for engines and that run on biofuels for transport, stationary and other applications, except those that are not manufactured indigenously.
- "Declared goods" would include biodiesel and bioethanol for ensuring unrestricted movement of biofuels within and outside the states. According to the policy, biodiesel would be exempted from taxes and duties. Inter-Ministerial National Biofuel Coordination Committee under the Chairmanship of the Prime Minister and a Biofuel Steering Committee under the Chairmanship of the Cabinet Secretary, Government of India are proposed to set up to address these issues in India. The Government is also considering the creation of a National Biofuel Fund for providing financial incentives like subsidies and

grants for new and second generation feedstocks cultivation; advanced technologies and conversion processes and production units. Hundred percent foreign equity would be allowed for biofuel technology and projects when the fuels produced are utilized domestically only in order to attract foreign direct investment (FDI). Vision, medium term goals, strategy, and approach to biofuel development are therefore set out by the policy. It also proposes a framework of technological, financial, and institutional interventions and enabling mechanisms.

- National Biofuel Coordination Committee under the Prime Minister for a broader policy perspective and implementation.
- Under this policy a Biofuel Steering Committee was set up under the Cabinet Secretary to oversee policy implementation. Several ministries are currently involved in the promotion, development and policy making for the biofuel sector.

  Overall policies for the development of biofuels and research and technology development for its production are made by the Ministry of New and Renewable Energy (MNRE), Government of India. Marketing of biofuels and developing and implementing a pricing and procurement policy is under the purview of Ministry of Petroleum and Natural Gas. The role of Ministry of Agriculture has promoted research and development for the production of biofuel feedstock crops. The Ministry of Science and Technology supports biotechnological research in biofuel crops, specifically in the area of biotechnology. A National Biofuel Coordination Committee (NBCC) headed by the Prime Minister was set up to provide high-level coordination of multiple departments and agencies and policy guidance/review on different aspects of biofuel development, promotion, and utilization. NBDB is developing a definite road map for use of biofuels in stipulated time frame to measure the policy issues.

The other main concern of this policy is the state independence. States are given the liberty to have biofuel policy and set targets of their own. This has resulted in a varied response in different states. States such as Karnataka and Rajasthan have taken off with a good start, and at the same time, there are states which are yet to make a landmark. "National Mission on Biodiesel" was launched in 2003 to address socioeconomic and environmental concerns. Two phases were proposed: Phase 1 by 2006–2007, demonstration project and by 2011–2012, Phase 2-self-sustaining expansion. Biodiesel purchase policy issued on 1st January, 2006 looks at biofuels as a potential tool to stimulate rural development by creation of employment opportunities to reap environmental and economic benefits. Biofuels promotion also outlines research and development, capacity building, sales and distribution of biofuels. India's current ethanol production allows blending of only ~3% in gasoline [39, 40]. Hence, the target set to make India energy independent turned out to be "highly unrealistic." A solution for reducing the dependence on foreign fuel in the perspective of changing global climate can be the promotion of advanced second and third generation biofuels.

3 Rural Development, Benefits to Indian Farmers and Daily Wagers

Biofuels are advantageous in that they would promote sustainable development, supplement conventional energy sources in catering to the transportation fuel demand and meeting the rural populations energy demands. Biofuels are bound to satiate the ever increasing energy needs in an ecofriendly manner and minimize the dependence on imports of fossil fuels and consequently providing a high degree of national energy security. Biofuel growth across the globe has been promulgated by energy security and environmental concerns, a wide range of market mechanisms, incentives and subsidies that have been put in place to facilitate growth. Figure 19.2 presents socioeconomic indicators of biofuels implicated for sustainability of biofuels for designing sustainable systems. Developing countries like India, apart from these considerations, also view biofuels as a potential means to stimulate rural development and create employment opportunities.

The Indian Government's vision 2020 states that cultivation of Jatropha on 10 million ha would create 7.5 million tons of fuel a year and consequently create year round jobs for people. But despite ambitious programs, targets are likely to be missed owing to the high costs of Jatropha-based fuel and red tape [41].

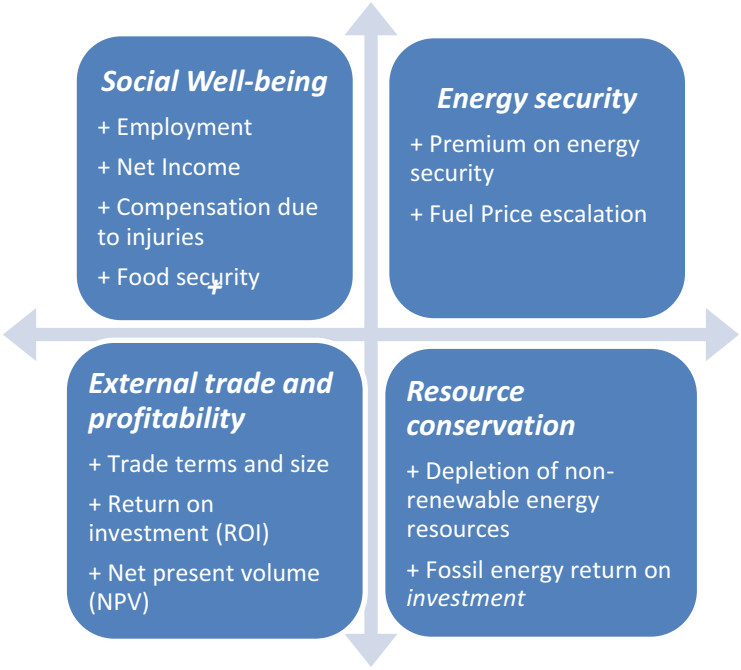

Fig. 19.2 Socioeconomic indicators of biofuels implicated for sustainability of biofuels for designing sustainable systems. These indicators have been modified for socioeconomic sustainability of bioenergy from algal biofuels systems [8]

Thus national policy of biofuels encourages biodiesel production from nonedible oilseeds, plants growing on waste, degraded, and marginal lands. This would encourage various agricultural producers to undertake plantations that provide feedstock for the biofuel industry. Over 400 species of trees are recognized in India that bear nonedible oil seeds. All of the recognized species would be evaluated for their exploitation as biofuel industry substrates by assessing their techno-economic viability. Plantations of trees bearing nonedible oilseeds will be taken up on government/community wasteland, degraded or fallow land in forest and non-forest areas. Minimum support price mechanism as proposed in the policy is also likely to promote contract farming on private wasteland. While plantations on agricultural lands would be discouraged, the corporates would be encouraged to undertake plantations by contract farming in consultation with panchayats where necessary. The employment created and provided in plantations of trees and shrubs of nonedible oilseeds would be covered under the National Rural Employment guarantee program (NREGP) [42] by Government of India. Seedlings from certified nurseries of recognized institutions identified by states would be distributed to the growers and cultivars.

The Ministry of Rural Development is specially promoting Jatropha plantations on wastelands and marginal land. Several programs nationwide have encouraged the planting of biofuel crops as well as procurement of seeds and cultivating. In this initiative, Ministry of Agriculture provides a subsidy through National Oilseeds and Vegetable Oils Development (NOVOD) Board to the farmers, ongovernmental organizations (NGOs), and individuals for the production of Tree Borne Oilseeds (TBOs) which include biofuel crops. Under this scheme, 30% credit linked subsidy is provided, with 50% term loan from the bank, and 20% beneficiary share in the form of land, labor, etc. The Ministry of Rural Development has provided financial aid of INR 490 million to 9 identified states in 2005–2006 and INR 495 million to 15 states in 2006–2007 for the plantation of *Jatropha*/*Pongamia* seedlings. Department of Rural Development of Chhattisgarh state is planting the TBOs under Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS). Plantation of biofuel crops is also in progress by the initiatives of several Joint Forest Management Committees (JFMCs) on forest land in the Chhattisgarh state [43]. The Chhattisgarh Biodiesel Development Authority (CBDA) provides *Jatropha* seedlings at highly subsidized rates for the promotion of planting in waste and forest lands. The authority is also encouraging the private investors to enter into contracts with local farmers for Jatropha cultivation.

Setting up of processing units by industry for bio-oil expelling/extraction and transesterification for the production of biodiesel is encouraged in the national biofuel policy. Gram/Intermediate Panchayats are also encouraged to create village level facilities for bio-oil extraction with corresponding sale to biodiesel processing units. Priority plantation of nonedible oil bearing plants, the setting up of oil expelling/extraction and processing units for production of biodiesel and creation of any new infrastructure for storage and distribution are declared as a priority sector for the purposes of lending by financial institutions and banks. National Bank of Agriculture and Rural Development (NABARD) would provide refinancing

towards loans to farmers for plantations. Indian Renewable Energy Development Agency (IREDA), Small Industries Development Bank of India (SIDBI), and other financing agencies as well as commercial banks would be actively involved in financing various activities under the entire biofuel value chain, at different levels.

National Biofuel Policy will also provide support for creation of awareness about biofuels and its potential and opportunities in upgrading the transportation infrastructure to support the rural economy. Various educational institutions will be encouraged to introduce suitable curricula to cater the trained manpower in all segments of the biofuel sector. Moreover, efforts will also be directed to enhance and expand the consultancy capabilities to fulfill requirements of biofuel sector. Intensive R&D work would be undertaken in the biofuel feedstock production based on sustainable biomass through nonedible oilseed bearing plantations on wastelands.

An instrumental factor of this policy includes providing a Minimum Support Price (MSP) for oilseeds and also having a thorough check on periodic revision which will ensure a fair price to the farmers and growers. The implementation of the MSP mechanism will be worked out carefully in consultation with concerned government agencies, states, and other stakeholders. For smooth working, Biofuel Steering Committee has to be set up in accordance with the National Biofuels Co-ordination Committee under this Policy. The farmers are getting the MSP of INR 6/Kg of *Jatropha* seeds from the governmental seed procurement agencies, while private companies buy at higher price of INR 7–10/Kg. The local farmers feel that decentralized value-addition options can provide a big change in their livelihood [44].

The Government of Odisha believes in revolving fund under the coordination of Odisha Renewable Energy Development Agency (OREDA) and Odisha Forest Development Corporation (OFDC) for providing subsidies of 50% to local communities like *Pani Panchayats* and self-help groups. and 33% directly to farmers above poverty line and 50% to farmers as groups. The policy also promotes the potential interlinkage between the biofuel program and various institutions like Swarna Jayanti Gram Swarozgar Yojana, MGNREGS, Integrated Tribal Developmental Agency, Compensatory Afforestation, Backward Regions Grant Fund schemes.

The government of Andhra Pradesh introduced a biodiesel policy in the year 2005 to facilitate investors and farmers to grow oil-bearing trees, mainly *Jatropha*, *Pongamia,* and *Simarouba*. Originally, the policy has proposed a three-way partnership program between government, industry, and farmers. In this program, the provision of buy-back arrangements for seeds and credit disbursement for farmers will be moved through industries. Plantations are promoted on forest lands under contract farming arrangements between private entrepreneurs and farmers [45].

Tamil Nadu government is also promoting the planting of *Jatropha* seedlings on wastelands. Primary agricultural cooperative banks in the state are enabling subsidized loans to farmers for *Jatropha* cultivation. According to the industrial policy of Tamil Nadu, 50% subsidy is given for *Jatropha* plantation and other biofuel crops and this subsidy is extended to the agro-processing industries. The state has

promoted the *Jatropha* cultivation for private companies like D1 Mohan Bio Oils Ltd., AGNI NET Biofuels Pvt. Ltd., AHIMSA, for the contract farming to farmers. Additionally, other services like training and extension support and provision of agricultural inputs are also being offered. These companies are offering buy-back arrangements with a certain market-linked price in the range of INR 5–10/kg for *Jatropha* seeds [46]. Biofuel policy of Tamil Nadu aims to bring a sustainable development and promotion for the cultivation, production and usage of biofuels crops and thus biofuels in state.

4 Socioeconomic Indicators and Governing Implementation Issues

With 4% of the world's energy consumption, India is the fifth largest consumer of energy after the USA, China, Russia, and Japan [47]. India consumes 4.4% energy resources (524.2 million tone oil equivalent (mtoe) of the world total (12,000 mtoe). In the world, primary commercial energy consumption in terms of using natural reserves (coal, oil and natural gas, nuclear and major hydro) has grown at 2.6% in the last 10 years. The growth rate of energy demand in India has grown approximately 6.8%; however, the supply has increased with a compounded annual growth rate (CAGR) of only 1% [48]. Therefore, India needs energy badly. Oil and gas constitutes about 45% share in the total energy consumption in India [48]. However, India is heavily dependent on crude oil imports, with petroleum crude accounting for about 34% of the total inward shipments (Ministry of Commerce and Industry, India). The imports have been ever-increasing, leaving the country with a growing balance of payment deficits. This necessitated India to work towards renewable and alternative fuels for energy security. Oil imports during April–February, 2014–2015, valued at US $130,848.36 million (Ministry of Commerce and Industry, India), were 12.24% lower than the oil imports in the corresponding period last year.

Though some alternatives like ocean water power, geothermal energy, wind energy, and solar energy are being explored, bioenergy is considered as a strong source of renewable energy in the coming years. The advantage of biomass is that the production of biomass for energy generation can contribute not only to climate change mitigation and energy security but also to rural development and employment generation [49].

The Government of India (GoI) approved the National Policy on Biofuels to encourage the use of renewable energy resources as alternate fuels to supplement transport fuels (gasoline and diesel for vehicles) and proposed a target of 10% biofuel blending (E10) by 2017. India produces conventional bioethanol from sugar molasses and production of advanced bio-ethanol is still in the research and development phase. However, taking the leads from R&D and process development unit, Praj Industries, Pune [50] is in the process of setting up the only one of its kind

demonstration facility for cellulosic ethanol production close to Mumbai. This facility is poised to use multiple feedstock (sugarcane bagasse, corn cobs, corn stover) for cellulosic ethanol production with low CAPEX and OPEX, with low wastes generation and reduced energy consumption. Recently, India Glycols Ltd., Kashipur has also successfully demonstrated the first cellulosic ethanol production process from lignocellulosic biomass with a capacity of 10 t/day. This facility has been built with the financial support from Department of Biotechnology (DBT), Ministry of Science and Technology and its Public Sector Undertaking—Biotechnology Industry Research Assistance Council (BIRAC). DBT believes that this technology which has lowest capital and operating costs may provide cellulosic ethanol at competitive price [51].

4.1 Elements of Energy Security

The Asia Pacific Energy Research Centre (APERC) defines energy security as "the ability of an economy to guarantee the availability of energy resource supply in a sustainable and timely manner with the energy price being at a level that will not adversely affect the performance of the economy" [52].

Several factors affect the security of energy supply of a nation—the availability of new and renewable energy resources, the accessibility of these sources regarding political and economic factors, the affordability of development and utilization of these resources, and the acceptability of these resources on environmental sustainability.

4.2 Availability of Resources

Oil contributes 40% of the world's primary energy demand [52]. India is the third largest oil consumer, utilizing 3.7 million barrels a day and accounted for about 4.2% of global oil consumption in 2013 [53]. The uncertainty of existing reserves and fluctuating crude oil prices have led to political instabilities in several countries. The reliance on foreign countries for oil and competition over energy sources are being considered as the major threats to a nation's energy security. Controlled pricing of petroleum products is yet another issue faced by the Indian oil sector [54]. Moreover, the world oil production is projected to peak in the next 10–15 years [52].

The national energy policy of India is planned by the Association of Southeast Asian Nations (ASEAN) which focuses on sustainable development [55]. India's energy policy integrates measures including the enhancement of energy efficiency and saving, exploration of domestic energy reserves, strategic reduction of energy poverty, and responding to the issues of climate change and sustainable development [56]. The development and utilization of nonconventional sources of energy is

getting utmost importance. Biomass, an abundant but underutilized resource, makes up 26% of India's energy resources [57]. Biomass can be used for combustion, gasification, pyrolysis, anaerobic digestion, fermentation and transesterification for the production of heat, electricity and as a substitute for petroleum for use as a transportation fuel [58]. To enhance biomass productivity and ensure biomass availability, biomass Research Centers (BRCs) have been set up in nine of the different agro climatic zones in India with an aim to develop packages of practices for fast growing, high yielding and short rotation fuel-wood tree crops suitable for degraded wastelands [59]. Development of processes for the production of the significant amount of biofuels without threatening food production needs special mention. The so-called "next generation biofuels" can tackle the "food-vs-fuel debate" and can open new avenues for promoting energy security. Several nations have implemented biofuel policies with the aim of securing future energy supplies [52]. Modernizing biomass technologies is a viable option. Also, concerted and continuous support from policy makers to have policies are a major challenge in the path towards a clean and green future.

4.3 Accessibility and Affordability of Resources

In order to attain the sustainable development goals of poverty alleviation, achieving food security, employment generation, and assumed access to affordable, reliable, sustainable, and modern energy for all, India has to significantly increase its energy availability [39, 60]. Besides availability, accessibility of resources economically is another challenge in ensuring a nation's energy supply. India, being the world's 7th largest economy [61], needs to maintain its annual growth rate at 8% to achieve its goal of energy security for sustainable development [56, 62]. However, the relatively higher energy prices result in a slow paced economic growth of the deficient energy economy of India [63]. Production and utilization of energy require both capital and labor. In order to make the inputs affordable, costs of nearly all goods and services in the economy need to be reduced, which can be affected only by lower energy prices. Indian transport sector is the largest and the fastest-growing consumer of petroleum, with 39% of petroleum products consumed [64]. The uncertainty of crude oil prices requires the transportation sector to explore new alternatives against the emerging economic challenges posed by a volatile oil market.

Renewable energy, which accounts for only ~1% of India's energy sources, is being promoted through public-private collaborations, as envisioned by the Ministry of New and Renewable Energy, GoI [57, 64]. The ministry provides budgetary support for research, development, and demonstration of renewable energy technologies, besides facilitating institutional finance and promoting private investment through fiscal incentives [64]. However, the high initial capital makes the renewable energy sources limited in access [52]. So, financial subsidies and policies are required to encourage investors. Also, transfer of technology from developed

economies to developing economies is recommended to increase developing economies' accessibility to renewable energy [52]. The SAHYOG Project (Strengthening Networking on Biomass Research and Bio-waste Conversion—Biotechnology for Europe India Integration) aims to actively link research activities implemented within EU research programs and related programs by Indian national institutions [65].

4.4 Acceptability of Resources

Biofuels are envisioned for their ability to contribute to energy security via supplementing transport fuels and combating climate change. However, ineffective transportation and production technologies may result in the requirement of more energy for production than the energy that can be supplied [39]. However, non-food crop based biofuels, with a smaller carbon footprint can significantly reduce dependence on fossil fuels [66]. Interestingly, reports show that production costs of biofuels have decreased over time, thereby lowering the efficiency costs of biofuel policies in the long run [66, 67]. An integrated biofuels strategy is required for meeting the imbalances between demand and supply in the energy sector. Cost competitiveness is a major challenge in this sector. To make renewable energy affordable in the future, investments in R&D and technology transfer are recommended [52]. Risks associated with all these factors and their impacts on national political, economic, social, and cultural security need to be considered to envisage a nation's energy security.

5 Biofuel Policy Implementation: Employment Creation and Rural Development

5.1 Employment Index in Indian Sugar, Ethanol, and Other Biofuel Industries

Sugar industry serves as a good example for how ethanol and biofuel industries could drive employment scene and impact rural society. The sugar industry is the second foremost agro-based rural industry that accounts for nearly 8% of industrial investment and provides employment for about 7.4% of the industrial working force by providing direct employment to 4 lakh people and about 35 lakh people are indirectly connected with this industry. A sugar mill of 1250 tons crushing capacity per day creates an employment potentiality of around 300–350 permanent workers and an equal number of seasonal workers. Besides this, for harvesting sugarcane, 5000 male and female workers are required to be engaged during the crushing

season. Likewise, around 100 tractors and 1000 bullock carts are given employment during the crushing season [68].

The Indian Sugarcane industry has more than 50 million farmers and their families' dependent on it for their livelihood. Direct and indirect employment generated out of the sugar industry caters to an estimated 12% of rural population. In addition to farmers, an estimated 0.5 million workers are directly employed as agricultural labor involved in cultivation and harvesting. Diversified ancillary activities and skills supporting local economy are also supported by the sugar industry [67].

Sugar mills have been working successfully, they have rendered considerable socioeconomic services to the rural community such as opening of schools, colleges, and hospitals. Besides, they provided numerous other facilities to the farmers in general. These activities and services are more evident in Maharashtra and Gujarat. The sugar mills have brought about a far reaching social, economic, and political transformation in the rural areas by providing various facilities like the modernization of agriculture, extension of the irrigation, employment, infrastructural facilities, education, health and recreation facilities, changing cropping pattern, and have promoted dairy and poultry activities. Thus, the sugar mills have acted as a catalyst for the socioeconomic development and these activities lead to the betterment of the economic conditions, not only of the farmers but also of landless laborers and other people in the areas.

5.2 Social Security

Employees feel insecure for many reasons such as inadequate wages, layoff and retrenchments, accidents and injuries in the course of employment, occupational hazards, sickness, old age, and total or partial disability. These factors cause anxiety and fear in their minds. Thus, the measures adopted to provide such protection to employees are known as social security measures. These measures protect workers and their families through various benefits such as compensation, maternity, sickness, and other benefits. Under Workmen's Compensation Act 1923, compensation is payable by the select sugar mills to workmen for all personal injuries caused to them by accident arising out of and in the course of his employment which disable him for more than 3 days. If the workman dies, the compensation is to be paid to his dependants. Under Employee State Insurance Act 1948, an insured person in the select sugar mills is entitled to receive benefits such as medical benefit, sickness benefit, maternity benefit, disablement benefit, dependants' benefit, funeral benefit, etc. The Employee Provident Funds and Miscellaneous Provisions Act, 1952 has made schemes for three types of benefits, viz., provident fund, family person and deposit linked insurance. Under the Payment of Gratuity Act, 1962 gratuity is payable to an employee of the sugar mill on the termination of his employment after he has rendered continuous service for not less than a 5 years. The completion of continuous service of 5 years is, however, not necessary where the termination of

the employment is due to death or disablement. The Maternity Benefits Act, 1961 applies to women in factories, mines and other establishments. In the select sugar mills, married women employees having not more than 2 living children are eligible for maternity leave as per the provisions of the Maternity Benefit Act, 1961. Employees Family Pension Scheme, 1971 seeks to provide some monetary relief to the family members of employees in the select sugar mills, who die in service, that is, before superannuation. In the event of an employee's death, his family gets a pension on a graded scale depending on the employee's last salary grade [68].

5.3 Human Resources Working in Public and Private Sector

The sugar industry provides employment to a large mass of population in India. Approximately, sugar industry provides livelihood of 6 million agricultural and 0.5 million skilled and semi-skilled industrial workers. Additionally, this sector generates significant employment in ancillary and allied activities. In India, sugarcane is grown approximately of 5-million-hectare land which is roughly 3% of the gross cultivable area in the country. In reality, sucrose-alcohol manufacturing sector is one of the largest agro-based industry in the country. The annual turnover of the sugarcane and sugar related segment is in the range of INR 80–85 thousand crores. A significant portion of this turnover around INR 55–60 thousand crores accrue to the sugarcane farmers of the various states in the country [67].

5.4 Number of Sugar and Alcohol Mills in India

Sugarcane cultivation and processing is major employment in ten states and union territories. Uttar Pradesh and Maharashtra are major sugarcane growing and processing states in India. However, other states like Andhra Pradesh, Karnataka, and Tamil Nadu are also contributing considerably in sugarcane production and processing. Sugarcane processing mills are widespread in Uttar Pradesh and Maharashtra. Sugarcane mills of every size, however, mostly do sugarcane processing of 2500–5000 TCD (ton cane/day). This capacity is expanding up to 10,000 TCD. Tropical and subtropical sugarcane producing belts in India has the capacity of 12–16 million ton white sugar production per season. In Gujrat and West Bengal, two standalone sugar refineries produce refined sugars (5000 MT capacity) from imported and indigenous raw sugar. These sugar processing units aims to augment the refined sugars production particularly when sugar production is low in country in order to ensure the sugar security in the country [68].

Globally, sugar market is passing through with the transformational changes and so Indian market is also being affected severely. For example, Brazil, the largest producer of sugarcane (~673 million ton) and thus producing largest sugar (~35 million ton) and second largest producer of ethanol (~30 billion liters), in

2014–2015 faced severe crisis. In last couple of years, more than 70 sugarcane processing units got bankrupted. Since 2010, around 50% drop in revenues was observed with cutting of thousands of jobs. However, the sucro-energy sector in Brazil is looking for regain due to heating up and competitiveness in fuel market along with the perspective of bigger profits in the various links which are encouraging to industries to invest in the renewal of sugarcane cultivation and eventually in sucro-alcohol processing units. In addition to the conventional, sucro-alcohol products, sugarcane sector is also looking for cellulosic ethanol production at commercial level from sugarcane bagasse and leaves. In Brazil, Granbio, Raizen and Abengoa has set up 80 million liters/year, 40 million liters/year and 65 million liters/year respectively [69]. Centro de Tecnologia Canaviera (CTC)-Piracicaba has also set up a demonstration facility of 100-ton bagasse processing/day (~3-million-liter ethanol per year) at Usina de São Manoel in São Paulo state.

India has in total 690 registered sugar mills and amongst them, 93 sugar mills are almost on the stage of permanent closure, as these sugar mills are not in production during the last five sugarcane processing seasons. However, some new projects are coming up in Maharashtra and Karnataka with the collaboration with existing sugar mills integrated with the planning for cogeneration and distillation facilities. Figures 19.3 and 19.4 show the total 642 sugar mills in India map. Maximum sugar and ethanol mills in India are privately owned and only few are governed by state governments. Privately owned sugar mills have higher cane crushing capacity than cooperative sugar mills. For instance, out of the operational per day cane crushing capacity of 22.24 Lac TCD, the private sector owns 13.74 Lac TCD while the cooperative sector owns 7.77 Lac TCD and remaining 0.73 Lac TCD is processed by public sector undertakings (29 sugar mills). Cooperative sugars are lagging in terms of fetching upcoming projects.

Indian Sugar Mills Association [67] provided the global and domestic data on sugarcane and its byproducts and domestic agricultural market intelligence with

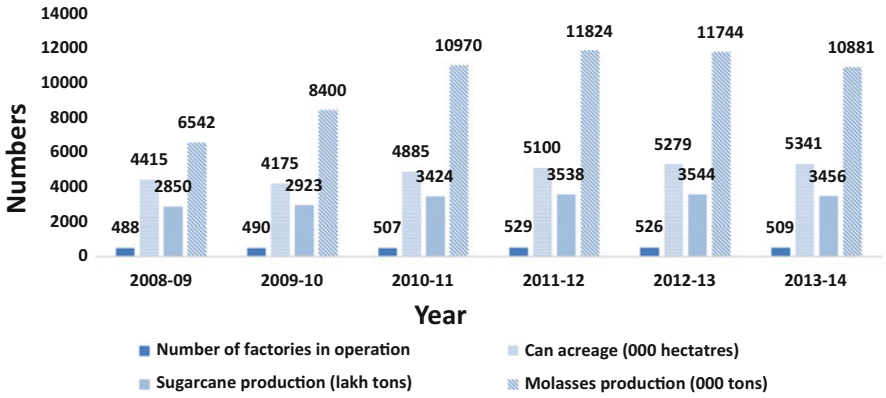

Fig. 19.3 Statistics of sugarcane production and sugarcane processing in India (Source: [67], http://www.indiansugar.com/SugarMap.aspx)



Fig. 19.4 Atlas of sugar mills in India (Source: [67], http://www.indiansugar.com/SugarMap.aspx)

Table 19.2 State wise of Indian ethanol production in 2015–2016 (adapted and modified from: [67], http://www.indiansugar.com/PDFS/List-ethanol_producers-2015-16.pdf)

Indian states	Number of Industries	Total installed capacity	
		KLPD (Kilo liter per day)	KLPA (Kilo liter per annum)
Bihar	6	335	90,450
Uttar Pradesh	35	2414	635,250
Punjab	1	60	16,200
Andhra Pradesh	11	500	144,900
Tamil Nadu	8	320	86,400
Maharashtra	68	3093	790,950
Gujarat	10	340	91,800
Karnataka	17	1225	294,300
Telangana	3	150	40,500
Other states (Uttarakhand + Sikkim + Haryana)	3	135	38,250
Grand total	162	8572	2,229,000

broad overview, key performance indicators and outlook analysis. ISMA report presents the current factual scenario of Indian sugarcane production, acreages, harvesting and crushing reports, sucrose-alcohol production, stock position and policies in states and the country [68] (Table 19.2).

6 Current Social Status and Improvement in Future

Development of villages have prominent role in holistic development of India as a large part of India's population lives in villages. Economic development in villages have a large gap than cities in India. Large rural population still do not have sustainable employment throughout the year because of poor infrastructure, non-connectivity with roads for transportation, inadequate electricity supply. Generally, for the daily routine activities and livelihood activities, rural population have to rely on polluting energy sources which have a harmful effect on the environment and their own socioeconomic development and health. Agricultural productivity has a profound impact in economic development in India. Agricultural products, byproducts and their management play a central role in renewable energy developent in India. Renewable energy development in rural areas can provide the following benefits:

- Facilitates access to drinking water;
- Allows lighting which increases security and enables the nighttime use of educational media and communication at school and home;
- Minimizes indoor pollution caused by the use of conventional fuels.

Rural population faces lack of access to affordable energy services. Biofuels produced from the raw materials grown locally in rural areas is likely to witness and aid in the alleviation of problems associated with poor standards of living. It is likely to mitigate the health issues faced by the rural population due to the traditional practices adopted to meet their regular fuel demands and also ensure energy security to the rural population.

The wasteland available in the country will be developed and utilized for cultivation of ethanol and biodiesel producing crops and will fulfill the basic requirement of fuel, fodder and food. By-products of the sugarcane ethanol industry contain valuable nutrients that have immense potential to be exploited as organic fertilizers.

The biofuels sector has the potential to serve as a source of substantial employment. Sugar industry in the major backbone of ethanol production industry in India. The sugar industry is the source of the livelihood of 50 million farmers and their dependants, comprising 7.5% of the rural population. Another half a million people are employed as skilled or semi-skilled laborers in sugarcane cultivation. This will reduce import burden to save substantial foreign exchange, enabling our country to strengthen infrastructural facilities with increased GDP. This will reduce the dependency on OPEC countries and open a path for self-reliance in petroleum requirements.

Sugar industry is likely to emerge as a significant contributor of the biofuel industry sector in catering to the energy needs of the country. This role would lead to a phenomenal transitional shift of the sugar mill into the energy complex. It is likely to meet around 20–25% of the total motor fuel requirements of the country in the near future. This would result in reduction of foreign exchange outgoing, attain

energy security along with satiating the traditional demands of chemical and potable alcohol based industry. All of this is likely to open up huge employment opportunities in the near future.

Today, Government of India through National Institute for Transforming India (NITI) Aayog is also trying to deploy methanol or wood alcohol as a promising source to curb carbon emissions while savings foreign exchange via reducing imports crude oil. Currently, India annually spends INR 4.5 lakh crore on purchasing crude petroleum. Chemistry of methanol is excellently support to be blended it with petrol while dimethyl ether can be a good and cleaner alternative to diesel [70].

6.1 SWOT Analysis

In general, SWOT matrix entails the strategic planning to evaluate the Strengths, Weaknesses, Opportunities, and Threats of any business venture. Here, we do the SWOT Analysis of biofuel production and its impact on socioeconomic status in Indian context (Fig. 19.5).

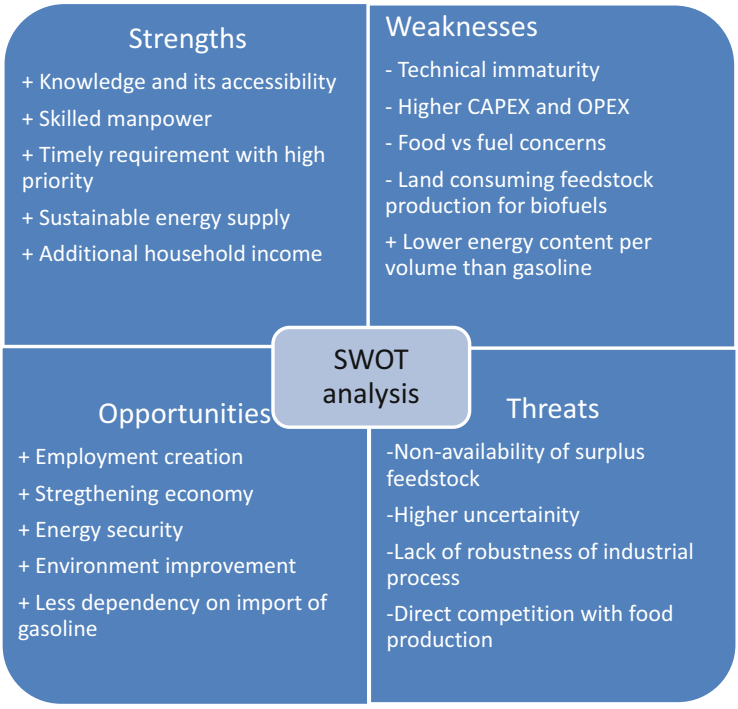

Fig. 19.5 SWOT analysis of biofuels in India

India ranks among one of the fastest growing markets for biofuels and renewable energy in the world. The Indian Government is making efforts to diversify the renewable energy portfolio, particularly in solar energy, small hydro and biomass. India has now over 8% annual economic growth rate. To maintain this growth rate, energy demand is projected to double by 2020. Therefore, India needs to harness all of the resources to get the power. Indian Government is making policies to bring foreign investment on renewables development in India. According to the HSBC estimate, India's "climate economy" will grow fivefold over the next decade, from $23 billion in 2009 to about $135 billion in 2020, roughly a 17% compound annual growth rate over that period [70]. In the last decade, private and public capital from national and international sources is flowing in through various national and international banks like International Finance Corp. and the Asian Development Bank.

7 Conclusions

Non-food crop-based biofuels, with a smaller carbon footprint, can significantly reduce dependence on fossil fuels. In the biofuel sector an integrated strategy is becoming imperative to meet the imbalances of demand and supply. Sugar industry is the emerging industry for catering to the ever increasing energy demands of the country by generation of electricity and bioethanol. These renewable energy sources hold the potential of converting the sugar mills into energy mills in due course of time. The biofuel sector has the potential to serve as a source of substantial employment. The national biofuel policy would also aid in the awareness creation of the role and importance of biofuels in the domestic market. It is also likely to promote wide dissemination of information pertaining to the potential of biofuel in upgrading the transportation infrastructure and supporting the rural economy. Substitution of petrol and diesel for transport with biofuels would witness accelerated development and promotion of cultivation of feedstock crops and production and use of biofuels. Increased utilization of biofuels in stationary and other applications and contribution to energy security, climate change mitigation, and creation of new employment opportunities is also likely to happen. By-products generated during the first and second generation biofuel production have the potential to bring down the cost of biofuels. However, constraints such as high operational expenditure (OPEX) and capital expenditure (CAPEX), and inefficient by-product and effluent management practices should be fixed in near term for sustainable development of biofuels.

This is imperative to set the biofuel policy by visualizing the situations in future using land-use pattern, alterations in crop mix, and the subsequent impact on food production. Biofuel crops could be even grown on fertile lands if oil prices keep skyrocketing. Certainly, promotion of biofuel development is highly judicious in India because of its potential of creating employment at each level, women empowerment, rural development, and augmenting entrepreneurships.

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Deployment Consideration on Secure Computation for Radix-16 Scalar Multiplication

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Abstract

An Elliptic Curve Cryptography (ECC) algorithm is one of the most powerful with respect to better security and performance than RSA algorithm. Most of applications prefer to implement this approach due to the use of shorter key sizes, low computation costs and most probably the discrete logarithmic problem is hard to achieve. In addition to it, with the support of hardware most of computation costs have been reduced in the general observation and widely available the reduction of pre-computed operations using strategies is playing one of the concerns in research gap creation. In the manuscript, we analyzed the proposed Radix-16 scalar multiplications without pre-computation for ECC and considered to be one of advanced approach technique, which is counted in the form of reduced complexity costs, reliable and secure computing. It also consists in relation to the more appropriateness for low memory devices and reduced instruction set computing, therefore a possible deployment is considered.

Keywords

ECC **PKC** **Scalar multiplication** **Radix-16** **Complexity**

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Deployment Consideration on Secure Computation for Radix-16 Scalar Multiplication

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Abstract. An Elliptic Curve Cryptography (ECC) algorithm is one of the most powerful with respect to better security and performance than RSA algorithm. Most of applications prefer to implement this approach due to the use of shorter key sizes, low computation costs and most probably the discrete logarithmic problem is hard to achieve. In addition to it, with the support of hardware most of computation costs have been reduced in the general observation and widely available the reduction of pre-computed operations using strategies is playing one of the concerns in research gap creation. In the manuscript, we analyzed the proposed Radix-16 scalar multiplications without pre-computation for ECC and considered to be one of advanced approach technique, which is counted in the form of reduced complexity costs, reliable and secure computing. It also consists in relation to the more appropriateness for low memory devices and reduced instruction set computing, therefore a possible deployment is considered.

Keywords: ECC · PKC · Scalar multiplication · Radix-16 · Complexity

1 Introduction

Cryptography is one of most important technique used to hide the original information when it hangs in between the medium. It is considered to be a science with respect to the secret information to be safe, where algorithms are playing crucial role responsiveness. In a modern day applications, cryptography is a mixed resultant of the three disciplines such as mathematical approach, make it programmable through the use of computer science and finally make it applicable to end users support on electronically implementable. In all these respects, the major attention to protect information from discloser, secure transmission in unsecured environment, authenticity, and integrity purposes [1].

Diffie and Hellman [2] were the first two authors who enlighten public key cryptography (PKC). After that variety of PKC algorithms are in propositions, but Elliptic Curve Cryptography (ECC) in all of them is attracting the most attention from the research community. A number of proposed algorithms have been showing the

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appropriate security need, but the major problem is the use of higher key lengths. Due its increased overhead for computation doesn't a suite for low memory containing devices in the fast growing world, where ECC is able to give the almost equal level of security strengths on comparatively shorter key sizes, as recommended by the National Institute of Standard Technology (NIST). According to the NIST-2012 guideline, the differences in key size ratio (in bits) between RSA & ECC algorithm and a comparative protection strength from attack on relative is presented in Table 1:

Table 1. Differences in security strength of RSA vs. ECC

RSA	ECC	Key size ratio	Protection from attack
1024	160–223	1:6	Until 2010
2048	224–255	1:9	Until 2031
3072	256–383	1:12	Beyond 2031
7680	384–511	1:20	…
15360	512+	1:30	…

The difference is an abstract idea to implement in manufacturing devices and acting as a key role makes. If RSA algorithm is in used on 1024 bits, for the same level of security and strength ECC works on minimum of 160 bits. The report available on NIST considered to be secured on the given subsequent periods. The major attraction appears in speedup enhancement on ratio of key sizes. The use of ECC is releasing so many benefits in terms of faster computation costs, bandwidth consumptions, most efficient key generations, almost be safe on little higher lengths of the key, etc. In general, the computation cost is reduced with the development of the new and/or modifications in the proposed approaches. What so ever is evolved for ECC, but from the research point of view it is still an excess been considered and improvements in the same is possible issue with respect to the current computations [3].

Discrete Logarithmic Problem (DLP) is playing important role responsiveness in establishing the secure computation and is one of the major concerns in ECC, for ECC named by ECC-DLP. ECC-DLP is working on two elliptic points as an assumptions (P and Q) on the standard cubic curve equation, to determine the secret key used as k, that follow $Q = kP$, which is the heart of ECC in PKC and its building block for security issues [4]. It is based on algorithms on repeated point doubling (DBL) and point addition (ADD) operations on used scalar. DLP is one of the hearts of cryptography, where secret keys are full responsible for the same. The big significance releasing here from the research point of view is to do the computations costs with the reduced DBLs and ADDs operations and it is showing a motivations. The algorithms are playing a pivotal role for security guarantees and determining for the same in effective implementation. A low mark has been observed on the used algorithms if it is not with the appropriate satisfaction and convincing. Where, in the other ways, performances with faster algorithms are leading with high performance and high-speed in the growing field of computing and communication systems. If the assumptions proceeds in the

forward direction but behaves like negligible to revert back of used scalar k, is a major intention of the algorithms and scalar multiplication.

The three approaches are the basis for the smooth conduct of ECC operations. The first approach is its underlying operations on finite basis and either the operations based on binary field or prime fields arithmetic assumptions. The next approach is the used algorithm, the scalar representation, which decides their computational complexity costs. Here are some of the existing methods that are in the forms of Most Significant Bit (MSB) algorithm, Least Significant Bit (LSB) algorithm, Nonadjacent form (NAF), Window Method, Sliding Window Method, Width Nonadjacent Form, Frobenious Map and Radix-rNAF (r-NAF) [5–10]. Third approach uses both of the previous two approaches with the support of hardware utilizations that are effectively utilizing in reduction of pre-computation operations, and/or using in generalization of parallel operations [11–13] or/and pipelining approaches [14].

In this manuscript, the first and second approaches are combined to the third approach for dependability and likely safety measures are managed sufficiently in secure computing. The overall scenario is considered for an efficient scalar multiplication for the proposed ECC. The below following points are reflecting throughout in this presentation:

- An extended work from radix-8 to radix-16 scalar multiplication is available, that illustrates on how dependency varies from one existing platform to new platform and how measures of deployment varies.
- To analyze the security strength at various levels for its deployment i.e., power analysis, safe-error fault attacks, side channel attacks, computations costs, and in some generic considerations.

We have set the deployment of our proposed strategy is secure, stronger and efficient in comparisons to known approaches in reference to the ECC scalar multiplication algorithms. The difficult is on cryptanalysis for the cryptographers to find the used secret. In relation to the same our contribution is a deployment specification with respect to performance enhancement and security validity.

Our manuscript is organized as follows. Section 2 presents dependency on interrelated existing algorithms. In Sect. 3, the deployment perspective has been considered with the security related analysis that highlights the advantages of proposed strategy against the side channel attacks (SSCAs) and in general considered objective. Finally, we summarized our manuscript the same.

2 Dependency of Scalar Multiplication on Existing Algorithms

ECC is based on consistent operations, organized in hierarchy, and well designed on its interrelated four levels as like to be shown in Fig. 1. The top level keeps the used algorithms of ECC, which depends on scalar multiplication kP, where it depends on group operations, such as point doubling and point addition, and further these are considered in group operations based on arithmetic operations such as multiplication, subtraction, addition, inversion and squaring. Each level of operations consists in the

form of costs, where reduction in costs using the proposed methodology is one of the research gaps. A reference from [15] is tested on Star core 41000 series processor reporting a cost for one doubling is 14,000 clock cycles and for one addition is 13,617 clock cycles.

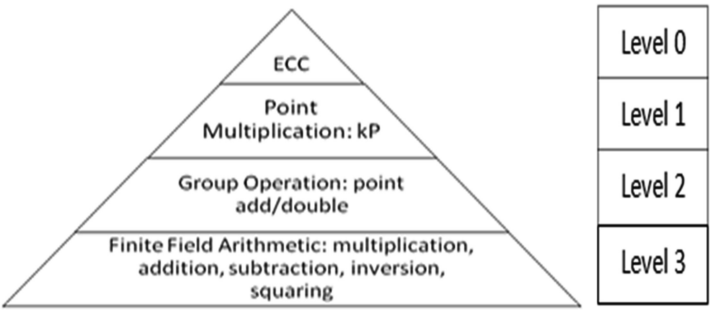

Fig. 1. Hierarchy of ECC

The most motivational concern in ECC is reduction in the computational costs. The architectural behavior of ECC is tested on the various algorithms for its better performance and is treated in the forms of advanced algorithms for end users applications. Further, these are treated in systems performance. Each algorithm consists a section of computations are in the form of pre-computation and or use of critical section. Pre-computation is an act of operations before-or-in critical section midair. Here is highlighted of enormous thought of its existing algorithms with its relative costs. On secret key k, or in general it is scalar, is considered in m-bits. The Most-Significant-Bit (MSB) algorithm needs m doublings and on average $m/2$ bits of addition operations. Means any scalar of m = 128 bits based requires 128 * 14000 clock cycle of doubling and 64 * 13617 clock cycle of addition operations. In a similar fashion Least-Significant-Bit (LSB) algorithm needs on average $m/2$ bits of doublings and same bits of additions. But both algorithms are suffer from side channel attack is possible that try to abstract the original key used for the algorithm, which has been considered to an extra source of information gain from physical implementations such as electromagnetic leakages, power consumption and sound released from the systems. Electromagnetic leakage is alarming in a sense the signal passes through medium are decoding by the adversary through the use of auxiliary equipments, instead the signals are low signals but for the interested users vulnerabilities have been reported. In a similar sense on behalf of power consumption and sound leads as a extra source of vulnerabilities. One solution for eliminating the side channel attack is use of Montgomery algorithm; in this the complexity is higher in m doubling and m addition. Further, using non-adjacent form (NAF) is one of variation of algorithm use to avoid the side channel attack on reduced complexity on average $m/2$ additions and $m/2$ doublings, representation of algorithm is in $\{-1, 0, 1\}$ [16, 17]. Again a window (w-NAF) method has been proposed on reduced complexity $m/(w+1)$ in additions only [18, 19]. One more variation in window method is available on escaping the series of zero on w-NAF, named by

sliding w-NAF, also known by Frobenious operations, that has counted as an enhancement in scalar multiplication [20, 21]. For the complexity determination, hamming-weight is in general be used for scalar representation.

ECC is likely to be secure on shorter lengths keys, due this reason it is attracting a relatively more favorable attention in more appropriateness to end user applications, as well as most suit for short memory devices, higher performance achievers etc. The real life applications are widely available in the forms of smart-cards, internet banking, mobile banking, etc. for its efficient and secure implementation approach. The applications are considered in exceptionally good functionalities in addition that may not lead to any leakages [22]. Abdulrahman and Masoleh [23] proposed a methodology on Radix-8 scalar multiplication without pre-computations with resistance to side channel attack. The main advantage of this proposed approach is without using doubling and addition, they are directly switched to arithmetic operations. This has given a slightly a new path for scalar multiplication on the computation cost $\log_8(m+1)$.

Therefore, in relation to above already proposed methodologies are representing a research gap to find a more efficient method to accelerate the scalar multiplication for ECC. Here we are going to extend the work of Radix-8 scalar multiplication without pre-computation to Radix-16 scalar multiplication. Also, we are going to elaborate the execution dependency from the hardware in Fig. 2, (here only its designed/comparison is available, interested author(s) refer the base paper) where the hardware implementation in its computation cost (basis (1/3 to 1/4) in %) = 8.33% accelerated, in Fig. 3. Further, the software execution and performance in presented in Fig. 4, where the major objective is in the relation to find the more efficient technique for accelerating the scalar multiplication in Elliptic Curve Cryptography (through the series of identified research gap), and established the same in more appropriateness with resistance to side channel attacks and safe-error fault attacks. Therefore, the novel contribution is based on the proposed algorithm of Radix-16 scalar multiplication, which is established on computation cost at $\log_{16}(k + 1)$. Compare to recently proposed Radix-8 scalar multiplication algorithm from the implementation point of view, the software performance gets an acceleration on proposed methodology with the basic difference's in its base or its computation cost on (1/8 to 1/16) in % = 6.25%, in Fig. 5.

3 Deployment Perspective of Radix-16 Scalar Multiplication

The Radix-16 scalar multiplication methodology is presented by Gautam and Hemraj [24] to records the Discrete Logarithmic Problem (DLP) for its assumed significance on finite basis. The DLP is computationally probable infeasible to get the used secret (scalar) key. In relation to these preferences the software and hardware performances are significantly improved. Interested author(s) can refer the dependency graph for the solution presented in 'Secure and Efficient ECC: Radix-16 Scalar Multiplication without Pre-Computation'. The proposed scalar multiplication technique is enriching its benefits on low computation costs. The new era's are mostly looking with stronger security in connection to advanced security approaches, where our objective is meeting with the same. The major attention is to deploy the same for application purposes. The applications are in online and offline services, such as in data processing, transactions

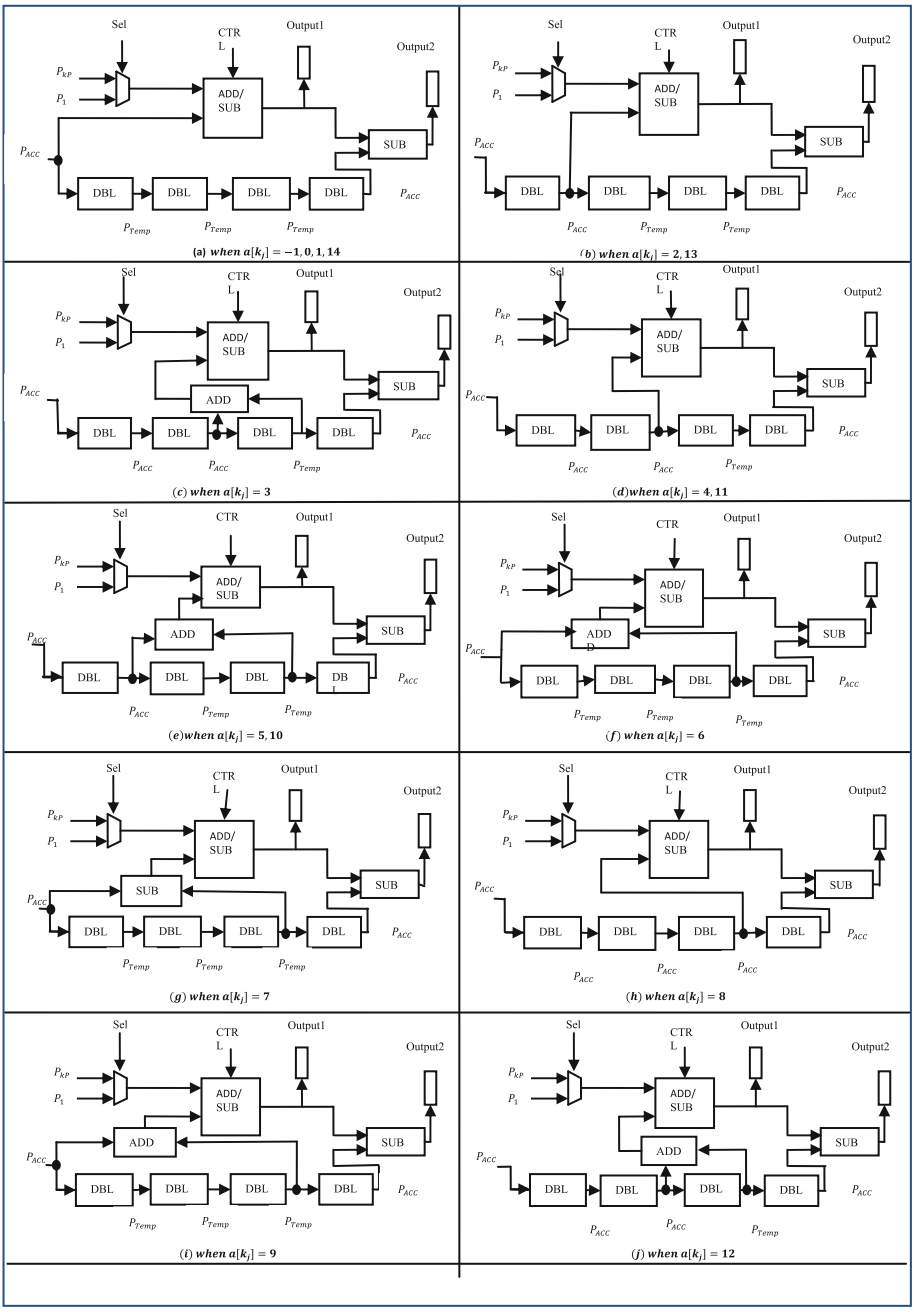

Fig. 2. Hardware dependency graph

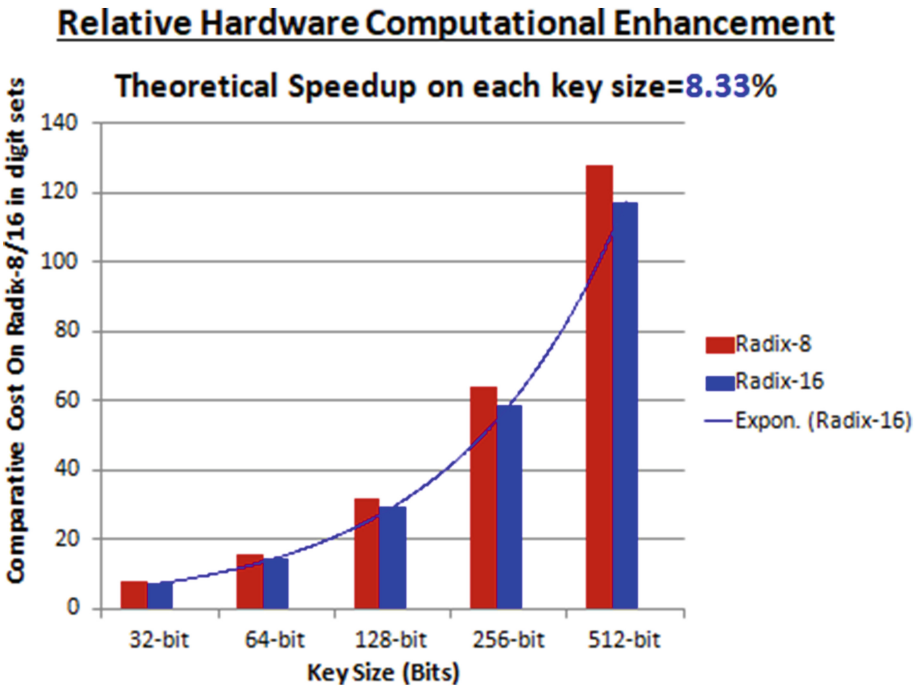

Fig. 3. Performance enhancement from hardware perspective

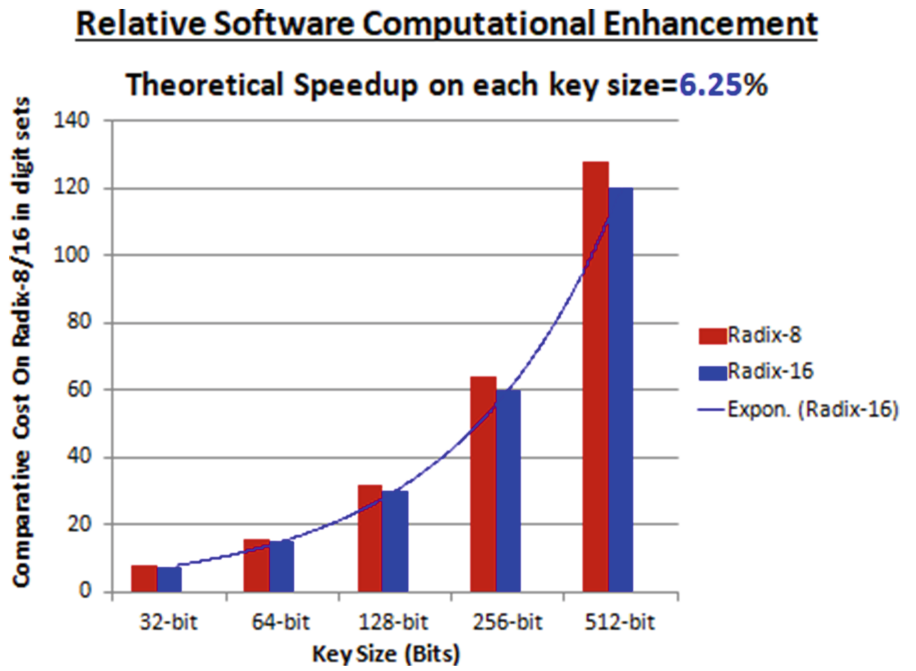

Fig. 4. Performance enhancement from hardware perspective

are most favorable cases. Implementing the same in firmware as a component of security points are also be a considerable situations.

3.1 Side Channel Attacks

Side channel attack defines an information gain from physical implementation such as electromagnetic leakages, power consumption, or sound that can give an extra source of information but it doesn't care about the theoretical computation or brute force attacks. It has considered independently outside the computation phase. This has been added to provide the various services against the following scenarios such as Power Analysis Attacks, Timing Attacks, Differential Faults Attacks, Data remanence etc.



Fig. 5. Comparison in radix-8 and radix-16

3.2 Power Analysis Attacks

The power analysis provides the detailed information about the power consumption by the CPU or cryptographic circuits. The attacks are differentiated in simple power analysis (SPA) and differential power analysis (DPA). The SPA interprets power traces, or graphs generations on electrical activity shown over time. Whereas the DPA allows the attacker to compute intermediate cryptographic computations on statistical

analysis collected from multiple operations. Using the newly introduced algorithm of radix-16 scalar multiplication in operation with the hardware support, power analysis attack can mostly be too sophisticated. In case of power analysis, the adversary(s) try to get secret key information either from internet, passing information through channel or from physical implementation. In a similar fashion its analysis is categorized on SPA and DPA. SPA observes the proposed scheme is fixed. The scheme is intrinsic confined against simple side channel attacks on each iterations in the main loop involment. It is observed from the adopted design principles, any dummy operations except in its domain brings an incorrect result on scalar. It is in favor to safe-error fault attacks if any inclusion.

3.3 Timing Attacks

The transmissions of signals release are the part of computer operations. But, due to interested adversary that try to abstract the pattern using the cryptographic algorithms and same pattern generations for its security appearances may lead to vulnerable issues. This is treated as a stunning that is alarming in the two senses: (i) a random interference comes first, which can be only be burglars, and (ii) these signals can be amplify through some auxiliary equipments for some useful purposes. A report is available that are suggesting on electromagnetic radiation interference with radio navigation devices, as (i) it is a general procedure and it is not a point to be considerable issue, but if (ii) applies who are interested in generating of such pattern of abstraction, then decoding and restoration can lead to vulnerable information safety, feedbacks and/or secret information leakage, where an adversary try to determine the private key by keeping track on how long a computer takes to decipher the secrets messages. In practice, proposed assumptions do lead to extreme timing variations. So in regards to the same enough variations to make the algorithms be a practical choice for applications.

3.4 Differential Fault Analysis

The differential fault analysis principle induces on faults due to unexpected conditions on environmental factors using the cryptographic algorithms design and implementations that steals to their internal working. Where, our proposed approach is meeting with the cryptographic function generations on fixed computations costs on multifold security properties. The real beauty of the algorithm lies on working nature in support of hardware perspective. Due this nature, the most level of confusion is applied to frustrate the adversaries.

3.5 Data Remanence

The data remanence is one of the important factor that represents the residual information that release or hide the information in likely intractable forms. The resultant residual may left intact information, or keeps nominal information even after deletion, or reformatting does not erase the data for verification purpose at later stage, or physical properties may be recoverable on previous used activity. It may make inadvertent in

uncontrolled environment to sensitive information. Depending on the used algorithms, a vast amount of algorithms are available for data remanence. But, some specific methods are possible through which encryption, destruction, overwriting and disgusting is possible, where radix-16 releasing benefits low computations costs.

3.6 Brute-Force Attacks

Possibly finding all the secret key and making a defense attacks the proposed approach is suit here, and using the hardware support it adds the additional strengths. This type of approach considered to be the special case in Elliptic Curve Cryptography. Therefore the presented scenario is sufficiently works on the smaller keyed length. In relation to the same, the execution time takes a shorter time for execution and reflects a big impact on efficiency consideration. A sufficient number of reports are available in regard to the computational performance in comparison to ECC and RSA algorithms, where our approach in regards the speed, efficiency, and cryptanalysis are better in many ways.

3.7 Chosen-Ciphertext Attacks

This attack is a form of active attack, where adversaries try to find plaintext corresponding to its ciphertexts by its choice. The first choice may experience on decryption module on a random chosen ciphertexts, before the actual ciphertext sent for an interested use. The second choice involves the same module on input of one's choice at any time, where these all are recorded and try to gain the actual plaintexts. As the presented algorithm experience a blind feedbacks, where the Noncommutative cryptography is not a vulnerable one to chosen ciphertext attacks (CCA) especially for ring or semi-ring, group and Heisenberg elements; because in CCA an adversary chooses a number of ciphertext and try to decrypt with targeted private keys, where the chosen cipher text is hashed with the corresponding polynomial exponentials.

3.8 General Consideration

Radix-16 scalar multiplication is lowering feasibility parallel consideration on arithmetic operations. The abstract reason clears the fundamental principle on computation of hexadecimal on binary information conversion. To add a random delay in the proposed algorithm is one of the good way to more frustrate the adversaries, instead of the same blinding creation in modulus and/or exponential of the computational procedure. It offers relatively faster computation, less memory requirements, and smaller execution of memory area.

4 Conclusion

In this manuscript, a radix-16 scalar multiplication deployment scenario is presented. Using this approach, as assessment of digit set elements are identify uniquely by a single digit set of used Radix-16 algorithm, so this may be considered as one of the advanced way to do the computation and applicable for desired applications in the

rapidly growing world. The scheme presentation is considered in software implementation point of view as well as hardware, where securities and performance are the most in demand and scarce resources use is the issue. In relation to same, reduced instruction set computing is one of the most suitable methods for widely applicable and use of short-memory devices are most attractive with resistant to simple-side channel attack and safe-error fault attack on deployment considerations.

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Unsupervised Document-Level Sentiment Analysis of Reviews Using Macaronic Parser

Sukhnandan Kaur & Rajni Mohana

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Abstract

Exponential rise in the multilingual web content affects the present-day decision support system to a great extent. To normalize such web content is

the need of an hour. Reliability of decision support system broadly depends on the flawless processing of the language data present over the web. Macaronic text is one of the text usually found over the web. It is basically the text that contains number of languages in a single document instead of uniform language for whole document. To cope up with such a text, in this paper we propose a macaronic parser. This parser is language-independent and task-independent. The output of the proposed system is the normalized uniform base language text. This output can further be used in many other language processing tasks.

Keywords

Sentiment analysis **Opinion mining** **Macaronic language**

Multilinguality **Sentiscore** **Sentistrength** **Punjabi text**

Hindi text

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Abstract Exponential rise in the multilingual web content affects the present-day decision support system to a great extent. To normalize such web content is the need of an hour. Reliability of decision support system broadly depends on the flawless processing of the language data present over the web. Macaronic text is one of the text usually found over the web. It is basically the text that contains number of languages in a single document instead of uniform language for whole document. To cope up with such a text, in this paper we propose a macaronic parser. This parser is language-independent and task-independent. The output of the proposed system is the normalized uniform base language text. This output can further be used in many other language processing tasks.

Keywords Sentiment analysis · Opinion mining · Macaronic language Multilinguality · Sentiscore · Sentistrength · Punjabi text · Hindi text

1 Introduction

Sentiment analysers are highly useful in enterprise business. There are huge number of social media sites such as Twitter, Facebook, BlogSpot, Amazon, etc., which are used for collecting the reviews of people about any entity. The web users act as an advisory body for various enterprises. Business people use this data for figuring out the major and minor flaws in their products or services. This also helps them to improve their product quality. There is no language barrier to write anything over the Internet. This makes the task of sentiment analysers a bit complex. Nowadays, there are large number of sentiment analysers available for different languages. To handle

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multilingual text is a big challenge in sentiment analysis. Along with multilingual text, people also use macaronic language over the Internet. Basically, macaronic language consists multilingual text which comprises of different languages/scripts together. With growing diversity, it has become of utmost importance that we acknowledge the existence of this kind of text. Especially, in the world where expressing opinions from anywhere in the world has become a fairly easy task. There have been a lot of studies on the information set that can be extracted from tweets and Facebook messages or posts. Twitter and Facebook information is the best way to keep a tab on the ongoing events, opinion of general public, trending topics, etc. However, one big challenge of this kind of information mining is the redundant and incongruous elements, we find along the way. Handling macaronic language not only useful in sentiment analysis but also in many natural language processing tasks such as named entity reorganization, pronoun resolution, feature extraction, etc.

However, there stands an obstacle in our way, while mining the text in one language; we seldom are able to handle a different language in the same context. We generally treat the other language/script words as foreign words, and lose major information in not treating these words. Processing this information is very useful for various automatic language processing tasks i.e. named entity recognization, pronoun resolution, automatic summarization along with sentiment analysis.

The given sentence is an example of macaronic text, it consists words other than base language.

Example1:

This is a ਚੰਗੀ *movie.*

Here the Punjabi language word (ਚੰਗੀ) of the context is taken as garbage and tossed aside and the English portion of it will be taken into consideration. With this we lost meaningful information. Here, the opining is about the movie is missed. We don't particularly know the opinion because it has been tossed aside. Similarly, if we apply the filter over the discarded words, i.e. foreign words and convert everything from Punjabi to English. We would be able to figure out the opinion about film.

Motivation

The motivation of the proposed technique is to handle the macaronic text by automatic identification of the fragments of the text belongs to different languages. The existing systems often discard the words other than the base language. The processing of the raw data often takes the text in multiple languages as an input. Sometimes, It discards text containing meaningful information. The proposed technique is designed to handle this type of discarded fragments. From example 1, it can be clearly seen that how important is the need to normalize the macaronic text for sentiment analysis. The state-of-the-art sentiment analysers give the neutral opinion about the movie although it is positive.

This arose the need to normalize the macaronic text. This paper proposes a method to fragment the text and autodetect the language used in the text based on Unicode information at a script level which is different for every language/script. The deduction of the corresponding language of the specific fragment other than the target language is also presented. Hence translate the particular foreign text into a base language. For our convenience, we have taken the English as a base language.

The remainder of the paper is organized as under: Section 2 describes the state-of-the-art sentiment analysis. Section 3 contains the detailed description of the proposed system. In Sect. 4, the proposed algorithm is presented. Section 5 investigates the results. Section 6, concludes the results.

2 Related Study

Various researchers are working in the field of sentiment analysis. They get huge success in their work. The task of sentiment analysis started decades ago. With time, it becomes the prime task for various enterprises to enhance their reputation in the market. Earliest works in the area of sentiment analysis is done by Hatzivassiloglou et al. [1]. They have used adjectives for deducing the polarity of the document. His work is then elaborated by Pang et al. [2]. They mainly focused over the supervised learning algorithms. They have used various machine learning algorithms for their work. The continuation of their work in the field of sentiment analysis is given in [3, 4], where they have used minicut algorithm for opinion summarization and also presented variousopinion mining techniques. Latest research paying more attention to the sentiment analysis over the data collected from various social sites. Researchers [5, 6] have used social media data for the sentiment analysis. Connor et al. [7] have used twitter data for sentiment analysis based on time series. Yang and Liang [8] (2010) proposed a new approach for identification of natural language, i.e. joint approach based on N-Gram frequency statistics and Wikipedia. Carter et al. [9] have used N-gram approach to identify five languages from the microblog. Later Lui et al. [10] followed same approach over the long and short textual documents. A detailed study of sentiment analysis at various levels of granularity [11] is explained by Kaur et al. Out of this literature study, we have found that the inclusion of normalization of macaronic language still needs attention. In this manuscript, we proposed a model to deal with the macaronic language for sentiment analysis.

3 Proposed System

We have taken the following approach to isolate and identify the language before embarking up on the journey to neutralize it through translation. The system design for the macaronic paerser is given in Fig. 1. Processing of the text passes through different phases of the system.

Phase1: In this phase, the input is given to the system as a web content, i.e. macaronic text/simple.

Phase 2: Based on tokens, filtration of the text is done at this level. The division of the text into base language and foreign words, i.e. other than the base language is done. The tokens which are from the base language are separated first along with their index values. The foreign words are then actually processed. These foreign

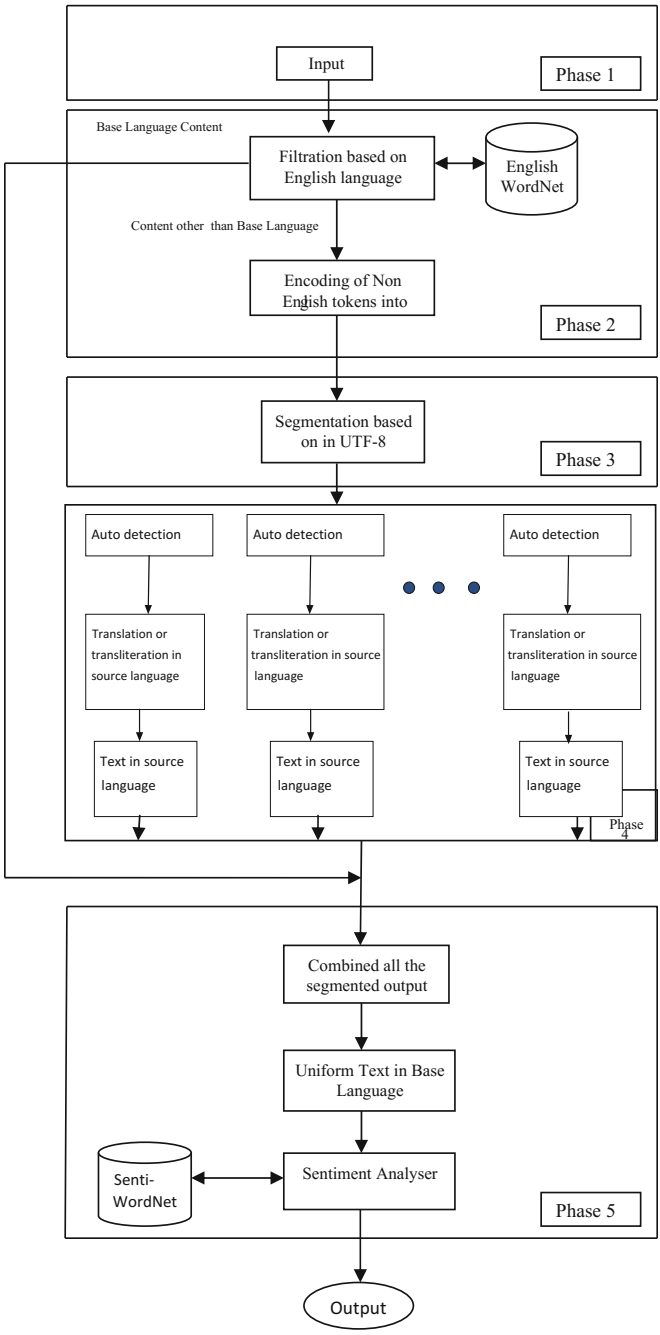

Fig. 1 Proposed system design of macaronic parser

words are tagged as non English tokens. We have used the English as base language for our work. Therefore, we have used English WordNet for the processing.

Phase3: In this phase, encoding of the tokens is done based on UTF-8. Each token is then has its encoded value.

Phase4: Under this phase, translation or transliteration is being done depending upon the number of languages we want to handle to cope up with the macaronic language. In this manuscript, the model represents the structural format of the processing of text. Under this, based on encoding automatic language detection algorithm is applied over it. After finding the language of the token, the working of translation or transliteration is started. The output of each sub-phase is the base language text.

Phase5: In the final phase of the model, whole text (English/Hindi/Punjabi)) is now converted into one language i.e. English. This converted text is then passed through the sentiment analyser to generate sentiscore for each document.

4 Proposed Algorithm

Input : Documents D = {d1, ..., dn}

'n' is the total no. of documents

Output : Document in a uniformed text ready for further language processing task.

Algorithm:

1. Set i to 1
2. for each document (d_i) in D
3. Encoding based on UTF-8 / UTF-16
4. Segmentation based on encoded document. //similar category segments are combined
5. for each segmented text
6. Detection of the language. // Hindi/English/Punjabi based on UTF-8 / UTF-16
7. Apply translation techniques
8. Content of each segment in source language.
9. End for
10. Combine all the fragmented text
11. End for
12 Apply POS tagging.
13. Processing of the formatted text for NER/ Opinion Mining/ Summarization/etc.

The proposed algorithm is very useful in dealing with the informal multilingual content present over the web. Following text describe the broad processing steps of the system.
Step 1: Extracting the stop words from the mainstream sentence. We do this by selecting a base language and running the words through a dictionary of that particular language. The index value for each token is retained. These tokens become handy while plugging back at their original place.

Input: User defined text

Output: Two list containing base language words and foreign words.

Step 2: The foreign language words are entirely different from that of English (base language in our case), and thus we understand that it is not completely useless but may or may not be informative to us. Hence, we decode the same and run it through a UTF16 to UTF 8 encoder which further gives us results for the information of the script type.

Our studies have shown that Devanagiri script when converted to UTF 8 bytes, gives us a combination of three bytes. the script range starts from [224] [164] [191] to [224] [165] [129].

Input: List containing foreign words

Output: Unicode information of the script in which the foreign words are written.

Step 3: We use this information to extract the script in which the particular text is written. We don't need any sort of prior knowledge for any language for the same. All we need to know is a Unicode set for a script and run the text by it. Using that, we will autodetect the language on its own, without the help of any language experts.

Input: Unicode information of the script in which the foreign words are written

Output: The script, in which the words are written.

Step 4: After we have extracted the information, we utilize some back ground information to finalize the language for a script. However, in this paper we limit our approach to only two languages Hindi and Punjabi language script.

Hence, we run out text to the translator API, which translates our language to the particular base language, i.e. English

Input: Foreign text along with the script information

Output: Translated or neutralized text in English (Base language)

Step 5: Plug the neutralized tokens back to the original text, to make the entire picture clear.

Input: or neutralized text in English (Base language)

Output: Full input text in one base language i.e. English in this paper.

Step 6: Part of speech tagging is done to perform the various language processing subtasks.

Input: Full input text in one base language i.e. English in this paper.

Output: POS tagged sentence.

Step 7: Depends on subtasks to be performed, the tagged text is passed to the system. As in this manuscript we have used sentiment analysis. Therefore, we have passed the text to sentiment analyser.

Input: POS tagged sentence

Output: Sentiscore associated to each document.

5 Evaluation of the System

We have evaluated the system over the semantically similar dataset comprises of 200 documents i.e. English dataset and the dataset consists of the Macaronic statements which have various foreign language words studded into it. In this manuscript, we have used Punjabi, Hindi words in a particular sentence. We have applied NLTK pos tagger to find the opinionated words. From Table 1, we can see that how the presence of foreign words actually affects most of the language processing tasks. In this manuscript we have analysed the system for sentiment analysis.

Table 1 Results of sentiment analyser

Test sentence (Macaronic)	Test sentence (English statements)	POS. Macaronic	POS. English	SentiStrength (Macaronic)	SentiStrength (English)
This phone has very ਵਧੀਆ battery backup	This phone has very good battery backup	This|DT phone|NN has|VBZ very|RB ਵਧੀਆ|: battery|NN backup|NN|	This|DT phone|NN has|VBZ very|RB good|JJ battery|NN	0.108	0.293
This phone has very अच्छा battery backup	This phone has very good battery backup	This|DT phone|NN has|VBZ very|RB अच्छा|: battery|NN backup|NN|	This|DT phone|NN has|VBZ very|RB good|JJ battery|NN backup|NN|	0.108	0.293
This ਫੋਨ has better battery backup	This phone has better battery backup	This|DT ਫੋਨ|NN has|VBZ better|JJR battery|NN backup|NN	This|DT phone|NN has|VBZ better|JJR battery|NN backup|NN	0.415	0.415
This दलिचस्प movie i will surely watch	This interesting movie i will surely watch	This|DT दलिचस्प|NN movie|NN i|PRP will|MD surely|RB watch|VB	This|DT interesting|JJ movie|NN i|PRP will|MD surely|RB watch|VB	0.053	0.117
ਇਸ restaurant ਦਾ ਖਾਣਾ ਬਹੁਤ good ਹੈ	The food of this restaurant is very good	ਇਸ|NN restaurant|VBD ਦਾ|CD ਖਾਣਾ|CD ਬਹੁਤ|CD good|JJ ਹੈ|NN	The|DT food|NN of|IN this|DT restaurant|NN is|VBZ very|RB good|JJ|	0.478	0.395
इस restaurant का खाना बहुत अच्छा है	The food of this restaurant is very good	इस|NN restaurant|VBD का|CD खाना|CD बहुत|CD अच्छा|CD है|CD	The|DT food|NN of|IN this|DT restaurant|NN is|VBZ very|RB good|JJ|	0	0.395

In Table 1, for the convenience top six sentences taken to show the results, SentiScore associated with the compound sentence i.e. contain foreign words from the Hindi or Punjabi language i.e. “Test Sentence (Macaronic Statements)” under the column name “SentiStrength(Macaronic)”. Other two columns show the corresponding English text and its sentiscore under the column heading “Test Sentence (English Statements)” and “SentiStrength (English)” respectively. From column “POS.Macaronic”, it can be seen that how the foreign language words in a single sentence are ignored by the present day pos taggers. We have tried other taggers also, they also gave unsatisfactory results. Most of them took the foreign language words as a noun irrespective to language. This harms the language processing results to a great extent.

We have used gold standard dataset to verify the results. In Figs. 2 and 3, it can be seen that for the reviews having same semantic structure irrespective to the language have different graph slopes. The results did not follow the actual trend set through the gold standard as shown in Fig. 3. After processing the reviews having

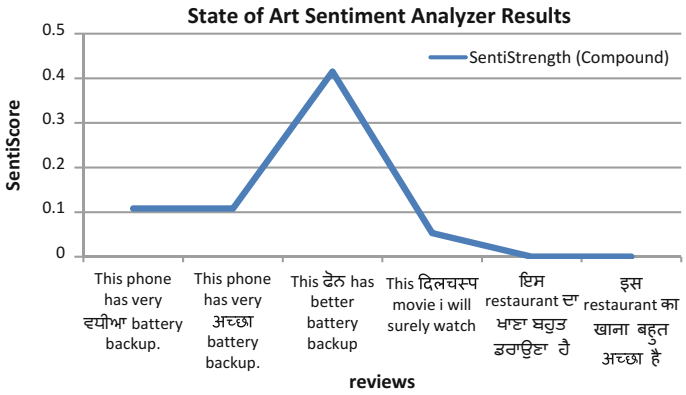

Fig. 2 Sentiscore calculated by state-of-the-art sentiment analysers

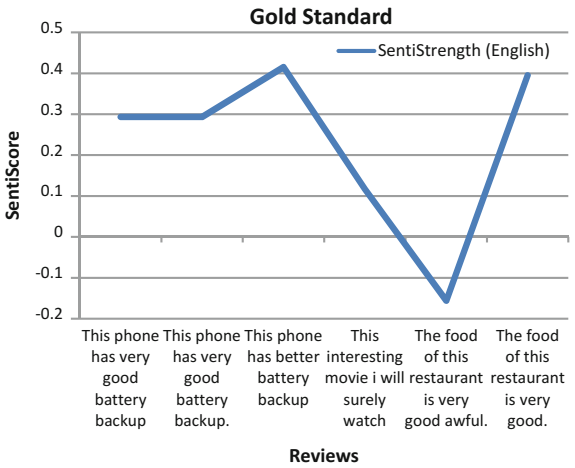

Fig. 3 Gold standard of Sentiscore

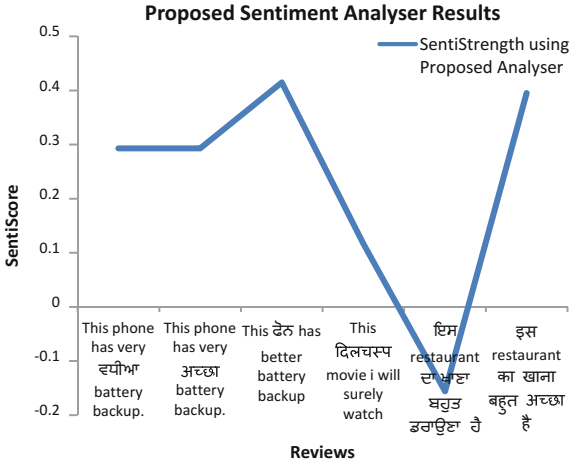

Fig. 4 Sentiscore calculated by proposed sentiment analysers

Macaronic language through the proposed sentiment analyser the results are fairly significant as shown in Fig. 4. It follows the same trend as shown in Fig. 3. This shows the significant results of the proposed system.

6 Conclusion

To recapitulate, this paper proposed macaronic parser to deal with the unnormalized web content. The results have shown the reliability of the proposed system is more as compared to the existing system. The sentiscore generated through proposed system is much closer to the gold standard of that particular dataset. Results suggest that this type of text processing is highly beneficial for the Named Entity Extraction, Feature Extraction, E-mail summarization, etc. To summarize the results, we can say that there is still a lot to do for resource scarce Indian languages to increase the feasibility of the decision support system.

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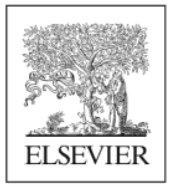



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CHAPTER 15

A Review on the Implications of Interaction Between Human Pathogenic Bacteria and the Host on Food Quality and Disease

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15.1 Human Pathogenic Enteric Bacteria and Their Association With Fresh Agricultural Products

Studies suggest that increasing health awareness has resulted in a significant increase in the demand for ready-to-eat fresh produce. However, several reports indicate the emergence and outbreaks of food-borne illness that have been found to be closely associated with fresh fruits and vegetables; therefore, researchers across the globe have been focusing on identifying microbial contamination of fresh produce (Tomasi et al., 2015; Mir et al., 2018). Until the advent of this century, much research was focused on studying the interaction of enteric pathogens with human and animal hosts and food-borne illness was believed to be result of postharvest microbial contaminations. Recently, the notion has been significantly questioned in the scientific community and, therefore, much research in today's scenario is focused on the ecology of enteric pathogens on plant surfaces. Previously, enteric pathogens were known to colonize human or animal digestive tract, an environment that provides protection from external environmental factors and also provided a variety of easily accessible nutrients. However, recently documented reports suggest that enteric pathogens colonize the phyllosphere and the rhizosphere of plants. In the present section, we shed light on the most important and classical examples of enteric pathogens that are known to be associated with food-borne illnesses of fresh fruits and vegetables.

15.1.1 Escherichia coli

Consumption of contaminated foods, especially raw or undercooked ground meat products and raw milk has been known to be associated with the transmission of *E. coli* O157:H7 into humans. Other sources of infection include fecal contamination of water and other foods,

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as well as cross-contamination during food preparation (from contaminated surfaces and kitchen utensils). *E. coli* O157:H7 has been considered as a serious pathogen because of its high pathogenicity, its ability to infect the host even at very low infective doses, its ability to survive harsh and deleterious environmental conditions, especially frozen conditions (Tilden Jr et al., 1996; Franz et al., 2008; van Elsas et al., 2011; Semenov et al., 2009; Yao et al., 2013; Wang et al., 2014) and what make it even a more serious and dangerous pathogen is its ability to transfer the virulence genes into nonpathogenic *E. coli* strains (Herold et al., 2004). The bacterial pathogen causes hemolytic uremic syndrome that can lead to death, particularly in children, elderly especially the ones who are immunocompromised. Of serious concern is the fact that raw fruits and vegetables, especially fresh-cut leafy greens, are more and more being recognized as the important vehicles for the transmission of *E. coli* O157:H7 (Fremaux et al., 2008). It is pertinent to mention here that *E. coli* O157:H7 was identified as the causal agent of the largest outbreak of bacterial enteric disease in recent times, with more than 6000 cases epidemiologically linked to contaminated radish sprouts in Japan in 1996 (National Institute of Health Infection Disease Control Division, 1998; Watanabe et al., 1999). Recently in 2013, consumption of contaminated, sprouted fenugreek seeds resulted in an outbreak of hemolytic-uremic syndrome (HUS) and hemorrhagic colitis (HC) that started in Germany and subsequently spread throughout Europe and North America. The causative agent was an enterohemorrhagic *E. coli* (EHEC) strain of serotype O104:H4 (European Food Safety Association, 2013). Bielaszewska et al. (2011) and Mellmann et al. (2011) reported that the strain possessed a combination of virulence factors from both Shiga toxin (Stx)-producing *E. coli* (STEC) and enteroaggregative *E. coli* (EAEC) strains. Information on *E. coli* contamination of fresh produce has been compiled and is presented in Table 15.1.

15.1.2 Salmonella enterica

A review on the literature of *Salmonella enterica* shows that the occurrences of *S. enterica* in fresh produce have been associated with surface waters, used commonly for irrigation purposes in agricultural fields. Documented literature also suggests that *S. enterica* is the cause for most frequent outbreaks from fresh produce (Barak and Schroeder, 2012). *S. enterica* serovar Typhimurium DT104 has been reported in cases where contaminated lettuce was consumed (Horby et al., 2003; Takkinen et al., 2005). The survival of the enteric pathogen on fresh produce has been studied in great detail over the last decade. Findings suggest that *S. enterica* has abilities to survive desiccation stress (Davies and Wray, 1995). Studies have shown that small populations of *S. enterica* can survive on crop plants and eventually increase to infectious dose levels once favorable conditions are restored. These characteristics of the pathogen make it a serious contaminant associated with fresh produce (details are presented in Table 15.1). A comprehensive analysis of the documented literature suggests that the reported cases of *S. enterica* outbreak on fresh produce are more on fruits as compared with leaves (Barak and Schroeder, 2012). Reports suggest that *S. enterica*

Table 15.1: Human pathogenic bacteria and their association with fresh agricultural produce

Pathogen	Contaminated Agricultural Produce	References
E. coli O157:H7	Spinach, radish, alfalfa, cabbage, celery, coriander, cress sprouts	Jay et al. (2007), Jay-Russell et al. (2010), Nathan (1997), and Zepeda-Lopez et al. (1995)
E. coli O157 CDC	Leafy greens	California Leafy Green Handler Marketing Board (2012)
E. coli O104:H4	Fenugreek	Buchholz et al. (2011)
E. coli O26	Clover sprouts	http://www.cdc.gov/ecoli/2012/O26-02-12/
E. coli O145	Lettuce	Taylor et al. (2013)
S. enterica	Alfalfa, mung, clover, tomato, cantaloupe, beet leaves, cabbage, cauliflower, chili, green onion, parsley, pepper, spinach	Rimhanen-Finne et al. (2011), Mohle-Boetani et al. (2009), and Orozco et al. (2008)
Clostridium difficile	Ready-to-eat salads; potatoes, onion, mushroom, carrot, radish, cucumber	Bakri et al. (2009) and Al Saif and Brazier (1996)
Bacillus cereus	Ready-to-eat vegetables, potato	Chon (2016) and Luo et al. (2016)
Campylobacter **spp.**	Leafy vegetables, lettuce, parsley, pepper, prepacked salads, spinach	Park and Sanders (1992) and Salaheen et al. (2016)
Listeria monocytogenes	Cucumber, cabbage, carrot, tomato, lettuce	Ajayeoba et al. (2016)
Cronobacter **spp.**	Chinese cabbage, cucumber, carrot, lettuce, strawberry, cabbage	Chen et al. (2016) and Vojkovska et al. (2016)

lacks biochemical assimilatory machinery for sucrose utilization (Lin, 1996), one of the main sugars present in leaf (Lindow and Brandl, 2003). The two most severe serotypes of *S. enterica* Typhi and Paratyphi A, which cause typhoid and paratyphoid fever, are responsible for hundreds of thousands of deaths worldwide every year. Results show that serovars have not evolved independently and recombination plays a key role in the genomic evolution, diversification, and ecological adaptation of lineages of *S. enterica* (Didelot et al., 2011).

15.1.3 Clostridium difficile

Clostridium difficile infection can often result in severe diarrhea. *C. difficile* a spore-forming, Gram-positive anaerobe produces two toxins, viz., toxin A (an enterotoxin) and toxin B (a cytotoxin), which can cause gastrointestinal disease, especially in immunosuppresed patients (Nitzan et al., 2013). A review of the documented literature shows that *C. difficile* has been reported from both animals and humans (Keessen et al., 2011; Songer, 2010). Reports on the occurrence of *C. difficile* in ready-to-eat salads and vegetables have been previously reported by several researchers (documented in Table 15.1). Recent studies have shown that the pathogen has potential of transmission through food supply. Eckert et al. (2013) assessed the prevalence of ready-to-eat raw vegetables contaminated with *C. difficile* and observed that ready-to-eat salads were contaminated. In another recent study, the prevalence of

C. difficile was observed in ready-to-eat foods, indicating food as a reservoir for the pathogen (Rahimi et al., 2015). Soil, fertilizers (manure), water, and processing environments could be the various possible sources of contamination of *C. difficile* in fresh produce (Weese, 2010). The spore-forming abilities of *C. difficile* allows the bacterium to survive environmentally unfavorable conditions, thereby facilitating its transmission.

15.1.4 Bacillus cereus

B. cereus is a group of free-living bacteria and some strains can cause food-borne illnesses in humans. *B. cereus* is one of the major pathogens associated with raw vegetables worldwide (Park et al., 2013). The two types of gastrointestinal disease (emesis and diarrhea) are caused by *B. cereus* (Ki Kim et al., 2009; Arslan et al., 2014). Ingestion of the toxin cereulide secreted by *B. cereus* causes an emetic type of illness (Takeno et al., 2012), whereas consumption of food contaminated with diarrheal toxin secreted by *B. cereus* causes diarrhea (Kim et al., 2011). Since *B. cereus* is a soil deviling microbe, its wide occurrence in vegetables and other agricultural fresh food is not surprising. Compiled information on the occurrence of *B. cereus* on fresh produce is presented in Table 15.1. Occurrence of *B. cereus* in fresh vegetables depends significantly on whether or not the crops were fertilized with human or animal wastes or irrigated with water containing such wastes. A review on the recent literature indicates occurrence of *B. cereus* in a wide variety of foods (Dzieciol et al., 2013; Li et al., 2016). Recent studies carried out by Kim et al. (2011) and Hwang and Park (2015) have shed light on the molecular characterization of enterotoxin genes in *B. cereus*. Their findings show that four different enterotoxins, viz., hemolysin BL (Hbl), nonhemolytic enterotoxin (Nhe), cytolysin K (CytK), and enterotoxin FM (EntFM), are hypothesized to play key roles in disease.

15.1.5 Campylobacter *spp.*

Recent documented literature suggests that cross-contamination from fertilizers, soil, and irrigation water is among the prime reasons for *Campylobacter* spp. contamination in fresh produce (information on the occurrence of *Campylobacter* spp. on fresh produce is presented in Table 15.1). The pathogen has resulted in a number of food-borne outbreaks associated with raw fruits and vegetables (Khalid et al., 2015; Tang et al., 2016). Chai et al. (2009) also reported *Campylobacter* spp. contamination in vegetable farms. One of the major concerns associated with *Campylobacter* spp. contamination (especially *C. jejuni*) is that of multidrug resistance especially toward quinolones and erythromycin (Ge et al., 2013). Studies carried out by Sheppard et al. (2013) highlight the molecular mechanisms involved in the pathogenicity. Their findings indicate that *C. coli* became progressively adapted to the agricultural niche via genomic introgression with *C. jejuni*. Recent studies by Pascoe et al. (2015) have shown that the mechanism of biofilm production in *Campylobacter* spp. has

considerably evolved and is a result of different genetic backgrounds. These evolved biofilm formation mechanisms are believed to be responsible for the organism's survival and dispersal in agricultural environments. Pearson et al. (2015) have recently carried out studies on *C. coli* and *C. jejuni* isolates in agricultural and nonagricultural systems to evaluate whether phylogenetic relatedness or sharing of environmental niches affects the distribution and dissemination of type II CRISPR (clustered regularly interspaced short palindromic repeats)-Cas (CRISPR-associated) system.

15.1.6 Listeria monocytogenes

Among the six known species of *Listeria* (*L. monocytogenes, L. ivanovit, L. seeligeri, L. innocua, L. welshimeri, and L. grayi*), *L. monocytogenes* is considered to be the most deleterious food-borne pathogen. Its detection in vegetables, fruits, and dairy products has been widely reported (Kasalica et al., 2011; Ajayeoba et al., 2016). The pathogen is a Gram-positive, facultative anaerobe that is a nonsporulating motile bacterium capable of causing listeriosis (Bayoub et al., 2010). Recent studies have suggested the involvement of previously uncharacterized cellobiose PTS system in central nervous system infections (Grad and Fortune, 2016). The occurrence of the pathogen in ready-to-eat vegetables has been a matter of serious concern (details in Table 15.1), considering the high demand of such products in the market. The primary source of contamination of agricultural fresh produce has been associated with the contaminated water from sewage sludge for the purpose of irrigation (Oranusi and Olorunfemi, 2011). A comprehensive detailed overview has been recently documented in a review on the fresh farm produces as a source of pathogens by Mritunjay and Kumar (2015). They highlight that a major source of contamination of fresh agricultural produce is because of the use of contaminated water (used for sprinkling purpose in order to keep the vegetables fresh) and contaminated containers (used for transportation purposes). Recent report by Stea et al. (2015) highlights the prevalence and diversity of *L. monocytogenes*, in an urban and a rural municipal source. The study documents important findings that can go a long way in order to understand the ecology and occurrence of the pathogen under agriculturally diverse environments.

15.1.7 Cronobacter *spp.*

Cronobacter spp. was formerly described in the literature as *Enterobacter sakazakii*. The recent literature based on whole-genome sequencing and multilocus sequence typing (MLST) targeting 7 genes (atpD, fusA, glnS, gltB, gyrB, infB, ppsA) has resulted in the identification of seven species in the *Cronobacter* genus viz. *C. sakazakii, C. malonaticus, C. turicensis, C. muytjensii, C. dublinensis, C. universalis, and C. condiment* (Forsythe et al., 2014). Studies on the virulence factors associated with the pathogenicity of *C. sakazakii* have been recently published from our laboratory (Singh et al., 2016). The authors highlight that in addition to

different virulence factors viz. outer membrane protein A (ompA), plasmid-associated genes such as filamentous hemagglutinin (fhaBC), *Cronobacter* plasminogen activator (cpa), and genes responsible for iron acquisition (eitCBAD and iucABD/iutA), several biophysical growth factors such as the formation of biofilms and resistance to various environmental stresses also contribute to the pathogenic potential of this pathogen. Recent studies carried out by Chen et al. (2016) have focused on analyzing a large number of vegetables in an attempt to find the source for this pathogen. Similar studies have been carried out in our laboratory that have been focusing on the isolation of *C. sakazakii* from a wide variety of food sources (for details please refer to Singh et al., 2015a, b). From our laboratory studies, it is evident that out of the 219 food samples have been evaluated, a total of 45 *Cronobacter* spp. were isolated. *Cronobacter* spp. in a food sample category of herbs and spices accounted for 34.3% of total samples, whereas 26% were from vegetables and fruits. In another recent study, Vojkovska et al. (2016) detected *Cronobacter* spp. in vegetables, fruit, and environmental samples collected from local farms and supermarkets in the Czech Republic. They further reported that environmental isolates of *Cronobacter* spp. create the capsule more often than the isolates of clinical origin. The capsule formulation facilitates enhanced desiccation resistance of the bacterium and increases its ability to attach to surfaces and create biofilms.

15.2 Entry of Human Pathogenic Bacteria into the Food Chain: Tracking the Point of Origin

A review on the literature, in an attempt to track the point of origin of entry of human pathogenic, enteric bacteria into the food chain (with special reference to fresh produce) shows that the entire process can be divided into two broad categories: first, the point of entry of enteric pathogen is at the site where the agricultural produce is being raised. The contaminating sources include water (used commonly for irrigation purposes) and raw or inadequately amended manure. Second, the enteric pathogen can enter the food chain during postharvest processing. In the following section, we review the potential sources of contamination of enteric pathogens in fresh agricultural produce.

15.2.1 The Potential Role of Water in the Contamination of Fresh Agricultural Produce

As a general practice in agricultural farms, groundwater is used for irrigation purposes. However, it is well-established and a well-known fact that irrigation water could be a potential source of enteric pathogen contamination, since it is often contaminated by effluents from municipal waste (Pachepsky et al., 2011). The problem is highly reported in underdeveloped and developing countries. A recent report by Akinde et al. (2016) highlights that fresh vegetables could be an easily available transmission vehicle for human pathogens, because of poor irrigation water quality at vegetable farms in southwestern Nigeria.

Contamination of agricultural produce in fields irrigated with contaminated waters is easily possible when the produce is in close contact with the soil matrix. Contaminated water can lead to the colonization of enteric pathogens into aerial tissues and root systems of fruit and vegetable plants (Martínez-Vaz et al., 2014). The consumption of raw agricultural produce by humans can eventually lead to the transmission of enteric pathogens and therefore has been identified as the most likely cause of disease outbreak as discussed in detail earlier, in Section 15.2.

Contamination of irrigation waters in agricultural fields as a result of municipal waste is only one of the possible means of transmission of enteric pathogens. Water can also be contaminated by livestock (cattle or sheep) defecation, especially if they use rivers for drinking or as crossing points. Runoff from animal pastures into artificial or natural water bodies can also create havoc. A review of the documented literature in this context shows interesting reports and reviews on the contamination of water sources by *E. coli* O157 (Quilliam et al., 2011). Recently, Hamm et al. (2016) documented a first report on cattle being an important reservoir of an unusual, highly virulent EHEC O104:H4 strain. As discussed previously in Section 15.2.1, the pathogen resulted in a serious outbreak in early May 2011.

The development of quick and reliable methods for the detection of enteric pathogens in water samples is the need of the hour. In this regard, recently researchers have been focusing on developing accurate and less time-consuming methodologies. Recently, Banting et al. (2016) described a most probable number (MPN)-qPCR assay for molecular-based detection of *Campylobacter* spp. especially in irrigation water samples. Henao-Herreño et al. (2017) evaluated *Salmonella* contamination in Bogotá River water that was being used for irrigation purposes for lettuce, broccoli, and cabbage. Based on the *Salmonella* concentration, the authors developed a qPCR-based quantitative microbial risk assessment model. Their results emphasized the presence of wastewater treatment, before Bogotá River water is used for irrigation purposes.

15.2.2 The Potential Role of Noncomposted or Improperly Composted Manure in the Contamination of Agricultural Fresh Produce

Organic fertilizer inputs in agricultural fields in the present scenario has significant environmental benefits over the use of chemical fertilizers and the practice has gained much importance. Organic matters such as animal manure, sewage sludge, and food wastes are decomposed using the anaerobic digestion process which has been reported to be an effective measure in controlling enteric pathogens (Horan et al., 2004). However, it has been observed that there are reports on the occurrence of food-borne pathogenic bacteria on crops, which were grown in soil that contained contaminated manures. A recent study in this regard carried out by Biswas et al. (2016) suggests that there exists significant variations in the survival of pathogens (the authors carried out their study with three enteric pathogens viz. *E. coli*, *Salmonella* spp., and *Listeria monocytogenes*) with temperature and environmental conditions, that is, liquid dairy manure in anaerobic and limited aerobic storage conditions.

Another important aspect of enteric pathogens in manure, which eventually contaminate the fresh produce, is the ability of these pathogens to be able to develop resistance against antibiotics. A review of the documented literature shows that there is a significant rise in antibiotic-resistant bacteria in animal feces, which can enter into the food chain since the animal manure is extensively used in farmlands (da Costa et al., 2013). A recently documented report by Takemura et al. (2016) indicates that because of extensive use of veterinary antibiotics, there is high persistence and survival of antibiotic-resistant bacteria in livestock manure. Similar studies on the prevalence and persistence of potentially pathogenic and antibiotic-resistant bacteria during anaerobic digestion treatment of cattle manure have been reported by Resende et al. (2014).

Considering the above problems of persistence and survival of enteric pathogens in noncomposted or improperly composted manure, we must (a) understand the factors the can help in the reduction of enteric pathogens in manure and (b) develop biotechnologies for improvement of dairy manure treatment. The physical character of the manure (i.e., liquid manure, slurry manure, or solid manure) can significantly influence the survival of enteric pathogens, which in turn depends on the farm management practices and also on the livestock. In manure which is in slurry or liquid form, survival of the enteric pathogens is high because of the presence of favorable moisture and alkaline pH (Cools et al., 2001). In case of solid/dried manure, the temperature is an important factor that determines the persistence of enteric pathogens in the manure. Recent reports published by Park et al., 2016, specifically focus on the role of temperature in the survival of manure-borne generic *E. coli*, *E. coli* O157:H7, and fecal coliform in soils. Erickson (2016) carried out studies on the survival of *Salmonella* or *E. coli O157:H7* during the holding of manure-based compost mixtures at sublethal temperatures (20–40°C). They simultaneously interrogated the influence of carbon amendment to the compost mixtures. An environmental concern which has recently received much attention is that agricultural facilities having storage of large quantities of manure especially in dried form, may serve as a source of airborne contamination of leafy greens being cultivated in nearby fields. Dehydrated animal manure, results in the generation of dust-like particles that can be small enough to become readily airborne (Berry et al., 2015). Research in regard has been initiated and Oni et al. (2015) has recently documented a report that focuses on the characterization of parameters that focus on the survival of *S. enterica* in or on dust particles of dried turkey manure and litter that could be aerosolized during handling and survive on leafy greens in the fields.

Biotechnologies for the reduction of survival and persistence of enteric pathogen in manure are highly advocated. Anaerobic digestion of cattle manure is one of the most environmentally favorable biotechnologies for managing enteric pathogen microbial load (Manyi-Loh et al., 2013). Recently Manyi-Loh et al. (2014) documented a 1-log reduction of *E. coli* and *Campylobacter* spp. (i.e., 90% decay rate) as opposed to a 2-log reduction of *Salmonella* spp. that occurred between day 9 and 14, but a similar 1-log reduction of these cells during the rest of the process indicating a 90%–99% kill rate was achieved in mesophilic

anaerobic digestion. A detailed review on the use of anaerobic digestion technology for reducing the persistence and survival of enteric pathogens has been recently documented in a review by Manyi-Loh et al. (2016).

15.2.3 Enteric Pathogen Can Enter the Food Chain During Postharvest Processing

Contamination of fresh produce during the postharvest processing is one of the most significant points of entry of enteric pathogens into food chain. The contamination can be due to injury to the plants during the harvesting or during storage and transportation of the fresh produce. Mechanical means to harvest the fresh produce at times result in injury to the plant tissue. Such injuries are an open invitation for the enteric pathogens to colonize the plants, since the nutrients available are easily accessible to the bacterium. Similar problems arise during storage and transportation of fresh produce. Washing of the fresh produce, is a common practice, however, the presence of pathogenic bacterium in contaminated water can easily result in entry of the bacterium into the agricultural produce. Good manufacturing practices (GMPs) can play a significant role in preventing the risk of contamination. A recent review article by Gil et al. (2015), highlights the strategies that can be employed to prevent microbial contamination in fresh leafy vegetables during pre- and postharvest processes.

15.3 Interaction Between Enteric Pathogens and Plant Hosts

Previously, it had been believed that enteric bacterial pathogenesis on humans was defined by their ecological niche. However, reports on the outbreak of disease that have been caused as a result of consumption of contaminated fresh produce have challenged the traditional view point (recent reports are discussed in Sections 15.2 and 15.3). It is now a well-established fact that enteric pathogens colonize plant tissues and thereby uses the plant host as a transmission vehicle to gain eventually entry into the human host. In an attempt to understand the dynamics of the interaction between enteric pathogens and plant hosts, we must first understand (a) fitness of plant surfaces as host, (b) factors influencing the survival and growth of enteric pathogens on fresh produce, and (c) molecular/genomic capabilities of enteric pathogens that allows them to use plants as vehicles for the transmission. These aspects have been discussed in the following sections.

15.3.1 Enteric Pathogens in Plant Habitats

The enteric pathogens survival in the plant habitat is subject to its point of contact with the plant tissue. Ideally, the pathogenic bacteria can interact with the plant host at three points, viz. in the rhizosphere, at the leaf surface, that is, plyllosphere and finally in the spermosphere (the zone surrounding the seeds). In the following sections, we discuss the fitness of these three regions as host for enteric pathogens.

15.3.1.1 Plant rhizosphere as a habitat for enteric pathogens

The rhizosphere has been long considered as a hot spot for microbial interactions because of the influence of the below-ground system of the plants, which are known to release large amounts of nutrient-rich root exudates. In the rhizosphere, diverse microbial communities both beneficial and deleterious coexist and interact (Mahajan and Shirkot, 2014). More light on this has been shed because of the recent developments in metagenomics (Hirsch and Mauchline, 2012). Recent studies using metagenomic analysis on the rhizosphere microbiome show evidence for plant species-specific microbiomes (İnceoğlu et al., 2012) and existence of plant genotype-specific rhizosphere microbiomes (Weinert et al., 2011). Recent studies carried out in field-grown potato rhizosphere show that the rhizosphere microbiome is affected by the growth stage of the plant (İnceoğlu et al., 2012).

Organic materials (e.g., farm-yard manure and slurry) have been considered as the most economically viable option for improving soil quality (Semenov et al., 2009). With the increasing demand of organic fertilizer application in fields, it is often observed that immature manure is often used in the farms. This problem often results in enteric bacterial contamination of fruits and vegetables (as discussed in detail in Section 15.3.2). Several reports on the persistence and survival of enteric pathogens in organic manure have been documented. Recently, Yao et al. (2015) studied the survival of *E. coli* O157:H7 in different organic fertilizers (vermicompost, pig manure, chicken manure, peat, and oil residue).

Raw fruits and vegetables, especially cut-leafy greens grown in soils amended with enteric pathogen-contaminated organic fertilizers are highly prone to food-borne contamination, since the below-ground plant system is in direct contact with pathogens. The primary step involved is the attraction followed by colonization. It is believed that rhizobacteria and enteric pathogens both preferentially colonize root tips and/or at the root base where lateral roots emerge (Jablasone et al., 2005; Cooley et al., 2003). The associations might correlate with the fact that the nutrient-rich rhizosphere is commonly available for both pathogenic and nonpathogenic microbes. Distinct and localized spatial patterns of sucrose, amino acids, and nitrate abundance have also been mapped in the rhizosphere (DeAngelis et al., 2005; Jaeger et al., 1999). *S. enterica* is an enteric human pathogen that has been reported by Barak and Schroeder (2012) to colonize crop plants as secondary hosts. Similar findings have also been reported in lettuce by Klerks et al. (2007). It is believed that the movement of *S. enterica* in lettuce rhizosphere is because of the chemotaxis toward the sugar compounds in lettuce root exudates. In a detailed review by Barak and Schroeder (2012), the authors highlight that enteric pathogens especially *S. enteric* prefer to colonize specific leafy greens radicchio and endive compared with lettuce. The researchers are of the opinion that this specificity is primarily due to the difference in nature of root exudates. Following colonization, the survival of the enteric pathogens in plant rhizosphere is believed to be favored by the nutrient-rich rhizosphere. In the rhizosphere, the enteric pathogens are challenged by environmentally

unfavorable conditions; therefore they tend to colonize the internal regions of the plant tissue. A recent report has shown that *E. coli* O157:H7 endophytically colonize spinach and lettuce plants Wright et al. (2013). High-resolution microscopic examination and O-antigen labeling have shown that the food-borne enteric pathogen colonization occurred within the apoplast, between the plant cells.

15.3.1.2 Phyllosphere as a habitat for enteric pathogens

The above-ground regions of the plant are physically more easily accessible to the enteric pathogens. Soil splashing, irrigation, and insect transmission (as discussed in Section 15.3) are easy modes available for the transmission of pathogens. The phyllosphere accounts for the aerial parts of plants, which are dominated by leaves. A recent review by Vorholt (2012) on the microflora associated with the phyllosphere shows that the global bacterial population present in the phyllosphere could comprise up to 10^{26} cells.

In spite of the large leaf surface area offered to the microbes, their colonization is subject to several environmental challenges such as limited nutrient availability, high ultraviolet radiation, and fluctuating water availability. It is surprising that in spite of such stringent environmental pressure, the microbial populations survive on the phyllosphere. Several documented reports on the occurrence of enteric pathogens on the leaf surface have been documented. Recently, Han and Micallef (2016) reported *S. enterica* colonization on tomato plant surface. Their findings have shown that tomato surface compounds and exudates play an important role in colonization by the enteric pathogen. Documentation of previous reports indicates that *S. enterica* colonization on phyllosphere is a result of chemotaxis. Furthermore, the colonization by the enteric pathogen in phyllosphere is highly concentrated in type 1 trichomes, which happen to be an area on the phyllosphere in the genus *Solanum* where maximum exudates are synthesized and accumulated (Barak et al., 2011).

In an attempt to understand the risk associated with irrigation water as a potential source of enteric pathogen contamination especially in the phyllosphere, Wood et al. (2010) studied the survival behavior of enteric pathogen (*E. coli*). They introduced the enteric pathogen into agricultural systems during irrigation in the spinach phyllosphere and observed declines in their culturable *E. coli* populations on spinach leaf surface under open environmental conditions. The possible reason associated could be the ability of enteric pathogenic bacteria to colonize the internal regions of the phyllosphere. Recent documented literature have indicated that enteric pathogens are also known to internalize the leafy green phyllosphere tissue, in order to avoid the harsh environmental conditions, as discussed earlier in this section. Erickson et al. (2014) reported internal colonization by *E. coli* O157:H7 into the spinach tissue. They reported that the mobilization of enteric pathogen cells into the leaf surface and its further survival were not influenced by virulence factors of Shiga toxin since they used Shiga toxin-negative *E. coli* O157:H7 isolates in their study.

15.3.1.3 Spermosphere as a habitat for enteric pathogens

Spermosphere is an extremely small zone (2–12 mm) around the seed, where interactions between soil, microbial communities, and germinating seeds take place (Schiltz et al., 2015). The spermosphere has a very short-lived interface, that is, only during the seed germination, yet it is highly significant. This is the first point of contact between the plant and the microbial community in the soil, which can be beneficial microbes, plant pathogenic microbes, or enteric pathogens (in the context of the present book chapter). These associations are known to influence the future microflora in the rhizosphere, which in turn influences the future plant growth and yield (Singh et al., 2011). Once the seed imbibes, it is believed that a number of compounds are exuded into the spermosphere (Schiltz et al., 2015). Several reports are well documented in literature that report on the characterization of the exudates during germination. A few recent reports by da Silva Lima et al. (2014), Scarafoni et al. (2013), and Kamilova et al. (2006) have shown that the exudates during germination process include (a) carbohydrates, viz. arabinose, fructose, galactose, glucose, maltose, mannose, lactose, raffinose, rhamnose, ribose, sorbose, sucrose, xylose; (b) amino acids viz. alanine, glutamic acid, glutamine, glycine, homoserine, leucine/isoleucine, methionine, phenylalanine, pyroglutamic acid, serine, threonine, tryptophan, tyrosine, valine; (c) organic acids, viz., acetic acid, citric acid, formic acid, malonic acid, oxalic acid, succinic acid; (d) fatty acids viz. hexadecanoic acid, octadecanoic acid isomers, tridecanoic acid; (e) proteins, viz., chitinases, cysteine-rich protein, galactosidases, glycosyl hydrolases; (f) secondary metabolites, viz., phenolic derivatives, steroids, terpenoids. As a result, the microbial communities in the soil are believed to be attracted toward the spermosphere because of the chemotaxis toward the exudates.

Enteric pathogens as earlier discussed (in Section 15.1) are known to be associated with food-associated disease outbreaks, which are especially similar to contaminated seeds. Harris et al. (2003) reported that sprouted-seed-related disease outbreaks were linked to seeds contaminated with *S. enterica*. Much recently in 2013, sprouted fenugreek seeds were contaminated with *E. coli* (EHEC) strain of serotype O104:H4 (European Food Safety Association, 2013). Their consumption resulted in an outbreak of HUS and HC. Reports on epidemiological investigation suggested that the seed contamination with STEC O104:H4 occurred more than a year before the seeds were used for sprout production. Recently, Knödler et al. (2016) carried out long-term survival studies and observed that in none of the strains tested cultivable cells were found without enrichment on contaminated seeds after more than 24 weeks of storage, thereby suggesting that contamination previous to the distribution of fenugreek seeds from the importer was less likely.

Much recently, researchers have been attempting to understand the changes that occur in the composition of seed and early root exudates once the seeds are contaminated with *S. enterica.* Kwan et al. (2015) in this context carried out studies using *S. enterica*-contaminated alfalfa

seeds as a model system. The authors concluded that individual amino acids are important, but not essential, for *S. enterica* growth in the spermosphere. The protein surveys carried out by the researchers revealed that central carbon metabolites serve as essential intermediates for cellular biosynthesis and therefore to achieve dramatic reductions in bacterial growth in spermospheres, central metabolic networks need to be targeted in future studies.

15.3.2 Survival and Growth of Enteric Bacterial Pathogens on Fresh Produce

For enteric pathogenic bacteria to survive on fresh produce, it must possess certain characteristic features that allow them (a) to form synergistic/antagonistic relation with the existing microbiota, (b) to separate themselves from the existing microbiota in space, (c) to evade plant defense, just like certain phytopathogens, and (d) formation of specialized biological networks, that is, biofilm formation.

15.3.2.1 Synergistic/antagonistic relation of enteric bacteria with the existing microbiota

The existing microbiota on the plant may be plant beneficial or pathogenic to the host plant. Therefore, the enteric pathogenic bacteria must be in synergism/antagonistic relation with either of them or both. Recent research in this regard indicates that the presence of plant pathogenic bacteria would idly favor the colonization by enteric bacteria; therefore the two groups of bacterium are believed to act in synergism. The two probable reasons are (a) because of the injury to the plants, the entry for the enteric pathogenic bacteria into the plant is facilitated and (b) because of the damaged plant tissue, the wide variety of nutrients are easily accessible to the enteric pathogens (Campbell et al., 2001, Wu et al., 2000). Enteric pathogens synergism or antagonism with the host plants microbiota is also believed to be dependent on the iron acquisition systems with enteric pathogens in the plant habitat (Brandl, 2006). This mechanism of iron acquisition is believed to be carried out by siderophores (low-molecular-weight molecules that bind ferric iron with an extremely high affinity). In the case of enteric bacterial pathogens, it is hypothesized that the siderophores act in a similar manner as that observed in the case of plant pathogens. The iron-acquiring ability of siderophore assists the pathogenic microbe to chelate iron and thereby increase its possibilities to colonize the host plant.

15.3.2.2 Ability of enteric bacteria to colonize internal plant tissue

Enteric bacteria causing food-borne diseases have the ability to colonize the internal plant tissues, in a manner similar to the one adopted by beneficial or pathogenic microbes residing in the phyllosphere/rhizosphere. In an attempt to avoid the harsh environmental conditions, enteric bacterial pathogens are known to gain entry within the plant tissue. Similar to phytopathogens, enteric pathogenic bacteria can preferentially attach to the cut surfaces and natural openings such as the stomata that provides not only a protective niche, but also a source of nutrients into the apoplastic fluid. Documented literature is testament to the

endophytic colonization of pathogens such as *Salmonella* and *E. coli* O157:H7 into the cracks of the developing lateral roots of seedlings, which is especially relevant for sprouted seeds such as alfalfa, mung bean sprouts, and spinach (Klerks et al., 2007; Warriner et al., 2003; Dong et al., 2003; Cooley et al., 2003; Erickson et al., 2014). Many researchers have reported internal colonization by *E. coli* O157:H7 into tissues. Warriner and Namvar (2010) based on their review of the documented literature suggested that under preharvest conditions and natural environmental conditions there is significantly low frequency of internal colonization by enteric pathogens. The possible reason being the fact that tissue injury is very frequent. However, with the modernization of agricultural systems and the use of modern machinery in farms, the green leafy vegetables and other crops can sustain injury which can facilitate the entry of enteric pathogens and thus can cause food-borne disease outbreaks.

15.3.2.3 The ability of enteric bacterial pathogens to evade plant defense mechanisms

Plant defense system has been studied in great deal over the last decade, in an attempt to understand the response of plants against phytopathogens (Esposito et al., 2008; Mahajan and Shirkot 2014). Upon infection plants respond by a hypersensitive response, coupled with secretion of plant hormones (salicylic acid, jasmonic acid, and ethylene). This activates the PR genes that trigger the systemic acquired resistance (SAR) defense. With the continuous evolution of phytopathogens, certain strategies have been developed to avoid detection by plant defenses. Enteric pathogenic bacteria such as *Salmonella* have devised similar methods as that of phytopathogens to avoid detection. They are known to avoid detection by alteration of their LPS and their lack of outer structures, such as the ability of *Salmonella* to shed flagella, facilitates its unnoticed entry into the plant system.

15.3.2.4 Specialized abilities of enteric bacteria to form biofilms

The bacterial cells that colonize the phyllosphere are subjected to adverse environmental conditions (as discussed previously). The bacteria can secrete exopolysaccharides, which can contribute to the formation of a specialized matrix-like structure referred to as biofilm. Researchers since the advent of 21st century have been carrying out studies on the ability of enteric pathogenic bacteria to form biofilm on agricultural fresh produce. Fett (2000) studied biofilm formation by *Salmonella* and *E. coli* O157:H7 on different plant parts of broccoli, cloves, and afalfa. Several well-documented reports of biofilm formation on leaf surfaces of Chinese cabbage, spinach, lettuce, and other green leafy vegetables are available (Méric et al., 2013). Recent studies carried out by Méric et al. (2013) show that plant-associated *E. coli* when compared with strains from other sources had a greater ability to form biofilms. Moreover, significant differences were also observed in the utilization of common carbon sources between strains of *E. coli* isolated from spinach and rocket salad in comparison to *E. coli* strains isolated from the mammalian counterpart. Recent work being carried out in our laboratory on *Cronobacter* spp. shows the biofilm-forming ability on different biotic and abiotic surfaces (Singh et al., 2017).

Quorum sensing (QS) mechanism is a well-known mechanism for bacterial cell-to-cell communication and several documented reports suggest that QS is essential for biofilm formation, which is often used as a strategy by phytopathogens to colonize the plant hosts. A review of the documented literature shows that Hughes and Sperandio (2008) reviewed the presence of the mechanism as part of plants' defense system, in which the plants secrete hormones that mimic bacterial QS signals and as a result causing confusion in the signaling pathogenic bacterium. It would be of interest to investigate that whether on similar lines food-borne pathogenic enteric bacteria could be prevented to form biofilms on fresh produce by plant hosts using a similar mechanism.

15.3.3 Molecular Capabilities of Enteric Pathogens That Allow Them to Use Plants as Vehicles for the Transmission

As discussed in the above sections, the survival and growth of enteric pathogenic bacteria relies essentially on its ability to colonize plant host. A recent review on enteric pathogen-plant interactions, Martínez-Vaz et al. (2014) highlight the importance of genes involved in the cell surface structures, virulence, motility, and biofilm formation.

Previous reports highlight the presence and role of virulence genes such as *intimin* and *stx* in *E. coli* O157:H7. Kyle et al. (2010) tracked the expression of these genes on lettuce leaves. Molecular interaction of enteric bacteria with green leafy vegetables is mediated by a number of diverse genes. In *E. coli*, genes involved in Curli formation (*csgA*) and flagella biosynthesis (*fliN*) have been reported. Similarly regulator of biofilm formation through the production of colanic acid (*ybiM*) has also been reported by researchers to play an important role in biofilm formation (Fink et al., 2012; Hou et al., 2012). In *S. enteric* genes involved in stress response regulator and biofilm modulation (*ycfR*), cellulose biosynthesis (*bcsA*), adhesin expressed from pathogenicity island-3 (*misL),* and response regulator involved in biofilm formation *(sirA)* are few of the important documented genes involved in attachment and biofilm formation (Fink et al., 2012; Hou et al., 2012; Kroupitski et al., 2013; Salazar et al., 2013).

Transcriptomic analysis of enteric bacterial association with agricultural fresh produce has been recently carried out by researchers in an attempt to understand transcriptional responses triggered by the association of these organisms with plant tissues. Transcriptional responses of the *E. coli* strains K-12 and O157:H7 associated with intact lettuce leaves has been recently studied in detail by Fink et al. (2012). The authors reported that genes involved in the formation of biofilms and curli fibers were expressed at high levels. A time-dependent experiment studying the transcriptional responses of phyllosphere-associated K-12 and O157:H7 over 3 days showed that adaptation to the leaf environment was characterized by an overall decrease in the expression of genes mediating cellular energy and metabolism, especially those involved in the synthesis of ribosomal RNA and iron homeostasis. The findings thus supported the hypothesis that enteric pathogens survive and propagate in leafy

greens by inducing physiological responses that allowed them to cope with the scarcity of food sources encountered on vegetable surfaces. Studies on the molecular events triggered by the association of enteric pathogens with green leafy vegetables have improved our understanding of the mechanisms by which these organisms survive outside their normal host (Martínez-Vaz et al., 2014).

15.4 Future Research Prospects and Conclusion

In today's scenario, where global population is on an all time high, there is an ever-increasing pressure on the food industry to deliver. In order to feed the growing population, it is essential to have ready-to-eat food available, with the prerequisite being that the quality of food is not compromised. Contamination of fresh vegetables with enteric pathogens has reached concerning proportions in recent years. The slogan of "farm to fork" can be truly realized if appropriate diagnostic tests are available to keep a check on the enteric pathogenic contaminants. As researchers make new discoveries it is essential that the implications of the basic and fundamental research reach the consumer. Recent technological advancements allow us to track the course of contamination; however, it is worthwhile to mention that these technological advancements are put to use before there is any disease outbreak.

Today the scientific community has advanced understanding of food-borne enteric bacterial contaminations in fresh produce. However, the presence of cross-domain pathogens continues to challenge human health. Bacterial evolution poses a challenge in managing food-borne diseases because of the horizontal gene transfer. Another challenge being faced by researchers is the viable but nonculturable state, which the enteric pathogens enter while they interact with the foods at different stages of the food production chain. The use of highly sensitive and rapid diagnostic methodologies, backed by molecular biology tools for analysis of the global transcriptional changes that occur in enteric food-borne pathogens while they interact with agricultural fresh produce is the need of the hour.

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Hsp70 in Fungi: Evolution, Function and Vaccine Candidate



Shraddha Tiwari and Jata Shankar

Abstract In fungal system, Hsp70 protein being highly conserved in nature has played a major role in various stress conditions. Genes encoding for Hsp70 proteins in fungi are highly conserved. Hsp70 protein performs chaperone dependent or independent function, essential for growth and morphogenesis of fungi. Functional distinction of Hsp70 protein conjointly depends on the prevalence of Hsp70 in numerous cellular compartments. Fungal Hsp70 protein is involved in protein aggregation, folding as well as in degradation of nascent polypeptide. Additionally, Hsp70 protein has a vital role in the formation of prions in case of yeasts. Fungi showed expression of hsp70 mRNA during interaction with plant. Also, fungal hsp70 showed expression in human during various infections, and may provide lead as a potential bio-marker for disease conditions. This chapter summarizes our present knowledge on fungal Hsp70 proteins and their role in morphogenesis, stress responses and a potential candidate for vaccine.

Keywords Fungi · HSP70 · Morphogenesis · Stress responses · Vaccine candidate

Abbreviations

AmB	Amphotericin B
CFTR	cystic fibrosis transmembrane conductance regulator
Hsp	heat shock protein
kDa	kilo Dalton
NEF	nucleotide exchange factor

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Introduction

Kingdom Fungi, distributed worldwide, having a unique entity within living organisms belong to eukaryotes. These are a diverse taxonomy, classified based on their diversity, germination stages, reproduction, evolution, ability of inflicting contamination and toxins production (Guarro et al. 1999; Shankar 2013). Throughout the phylogenies, fungi have showed a great deal of variety in reproduction mode and adaptability towards their surrounding (Galagan et al. 2005). Optimum growth conditions required for fungal growth is warm (30–37 °C) (Shankar et al. 2004) and humid conditions, which if absent leads to spore formation (dormant stage), whereas extreme increase in temperature will cause fungal death (Dix 2012). Under certain conditions or stress, life cycle and cellular processes of fungi is affected. In stress conditions such as modulation of temperature, protein denaturation has been reported that leads to misfolding and aggregation of proteins inflicting loss of biological functions (Sharma et al. 2009a, b). A unique set of proteins are involved in stress related changes, hence involved in the fungal survival, termed as Heat Shock Proteins. These proteins could be present in mitochondria, cytosol, nucleus, endoplasmic reticulum and cell membrane (Kregel 2002). Hsp are extremely preserved biomolecules involve in activation of various intermediates of signal transduction pathway in fungi (Kregel 2002; Verghese et al. 2012). Fungal kingdom encompasses three predominant heat shock proteins, Hsp90, Hsp70, and Hsp20–40, that shows crucial role in stress adaptation and morphogenesis. The class of the 70-kDa Hsp family is considered as one of the potent immunogenic protein families involved in nascent and damaged intracellular protein refolding (Lindquist and Craig 1988; Daugaard et al. 2007; Cleare et al. 2017). Hsp70 plays a major role in folding of protein and newly synthesized oligomeric gathering, the transport of protein structures across membranes, misfolded proteins refolding to prevent aggregation and also the activation and regulation of signal of transduction proteins (Bukau and Horwich 1998; Tiwari et al. 2015). In addition, Hsp70 has a great impact in the field of medicine and has been proposed as a vaccine candidate against fungal pathogen (Wormley Jr. 2011; Blatzer et al. 2015). Thus, we reviewed Hsp70 in various stress responses and alternative fungal biological conditions. In this chapter, we focused on the role of 70-kDa heat shock protein in fungi. In addition application of Hsp70 as a vaccine candidate has also been discussed.

Genes Encoding HSP70 in Fungi

Hsp70 is evolutionary conserved protein within the eukaryotes that shares approximately 50% amino acid sequence similarity with prokaryotic Hsp70 protein (DnaK) (Gupta and Singh 1994; Daugaard et al. 2007). Fungal Hsp70 molecule contains an ATP domain at N-terminal region and, a domain specific for substrate-binding which has affinity for client proteins, present in C-terminal region and a C-terminal domain

of variable length (Mayer and Bukau 2005). The deduced amino acid sequence of the Hsp70 corresponds to 636 amino acid sequences with a molecular mass of 70.56 kDa and a pI of 6.01 which exhibited a strong sequence homology with many other eukaryotic Hsp70 family proteins. Similarly, Hsp70 of B. emersonii has been cloned and showed it consists of 650 amino acids with molecular mass of 70.8 kDa. These observations suggested that yeast and fungi have conserved hsp70 genes (Stefani and Gomes 1995). Hsp70 subfamilies have shown to be conserved in terms of function and evolution. For example, *S. cerevisiae* Ssq1, involved in iron sulfur clustering which involved sub functioning as to mimic Ssc1 (Craig and Marszalek 2011). Ssa and Ssc are Hsp70 proteins, evolved due to higher change of copy number in gene evolution, while some Hsp70 family proteins such as Ssz, Lhs, Kar have evolved from change in few copy. Seven subfamilies of *S. cerevisiae* hsp70 blast analysis revealed similarity with 53 ascomycota genome associated 491 orthologs. Also, four different strains of Basidiomycota genomes analysis for hsp70 showed thirty hsp70 genes, hence studied for fungal hsp70 evolution (Kominek et al. 2013).

S. cerevisiae is the leading organism for hsp70 genomic studies, thus served as a model organism to understand hsp70 in fungi (Morano et al. 2012). *S. cerevisiae* exhibits multigene family of hsp70, which involves eight members, including constructive as well as stress inducible ones (Craig et al. 1993). There are 14 well characterized Hsp70 proteins of *S. cerevisiae* available that categorized into seven different subfamilies: four canonical-type Hsp70 chaperones (Kar, Ssa, Ssb, and Ssc), three atypical regulatory Hsp70s (Ssz, Sse, and Lhs), actively modulating Hsp70 partners activity (Kominek et al. 2013). Fungal Hsp70 have been ubiquitously distributed in all cellular compartments majorly cytosol, mitochondria, endoplasmic reticulum, and ribosome (Boorstein et al. 1994; Easton et al. 2000).From the seven Hsp70 homologues in *S. cerevisiae*, six have been observed to be located in cytosol, namely, Ssa1, Ssa2, Ssa3, Ssa4, Ssb1, and Ssb2 (Werner-Washburne et al. 1987; Černila et al. 2003). It is observed that cytosolic proteins have diversified and overlapping functions. For example, Ssb proteins did not showed substitution for Ssa protein survival in yeast (Boorstein et al. 1994). Ssd1/Kar2 is known to present in endoplasmic reticulum (Werner-Washburne and Craig 1989). Fungi have a specialized ribosomal Hsp70, have specific binding site on ribosome 36 position. Fungi also have a specialized ribosome-associated Hsp70, Ssb, which independently associates with the 60S subunit. Binding of Ssb in ribosome depends on conserved residue, which is specific in the peptide-binding domain at valine 442 region, allows flexibility (Pfund et al. 2001). In mitochondria, three different hsp70 encoded by the genes ecm10, ssc1 and ssq1 were observed. Deletion of ssc1 was lethal under all conditions. ssc1 have similar functions as of jac1 (Kampinga and Craig 2010). ssa1 and ssa2 are involved in transport of aminopeptidase-I from the cytoplasm into the vacuole (Satyanarayana et al. 2000). Recently, a variety of eukaryotes have showed a special class of protein known as Hsp110 protein which is found in the endoplamic reticulum and cytoplasm. At molecular level, they are large and vast protein but belonging to hsp70 gene superfamily as they have same functional and structural similarities (Easton et al. 2000; Nikolaidis and Nei 2004).

Role of HSP70 in Morphogenesis

Asexual reproduction in fungi accounts for fungal morphogenesis which comprises different stages, namely, conidia in dormant stage, vegetative hyphae and mycelia (Wang and Lin 2012). Hsp70 has a vital role in morphogenesis of fungi in stress related conditions (Tiwari et al. 2015). Transcripts of hsp70 were observed during lag and log phase followed by reduction at aerial hyphae in early stage and the hsp70 transcripts were found maximum at later stages of aerial hyphae. This is because of activation of hsp70 transcription or decrease mRNA degradation rate (Häfker et al. 1998). Xavier et al, also showed that expression of the heat shock inducible hsp70 gene depend on the various development stages of fungi and found maximum inducibility in late aerial hyphae due to lower mRNA degradation rate (Xavier 1998). Studies on *N. crassa* exhibited highest hsp70 transcripts at aerial and dormant conidia stage which fluctuate on later stages of germination (Fracella et al. 1997). Proteome profile of germinating conidia of *A. flavus* showed the expression of Hsp70, suggesting their role during transition from conidia to hyphae (Tiwari et al. 2016). With the increase in temperature (from room temperature to higher), Paracoccidioides converts from mycelia to yeast form, a pathogenic form. *P. brasiliensis* and *P. lutzii* showed high hsp70 transcripts in yeast form (Monteiro et al. 2009; Shankar et al. 2011a, b). Hyphal stage in *C. albicans* showed upregulated Ssa (Hsp70), suggesting the key role of Hsp70 protein in morphogenesis of fungi (Brand 2011). *C. albicans* showed higher accumulation of Hsp70 protein in its cell wall which was found to be expressed in all conditions (Lopez-Ribot et al. 1996). *A. flavus* (toxigenic and atoxigenic strains) showed expression of hsp70 transcripts at 30 °C, however, downregulated expression was observed in toxigenic strain in comparison to atoxigenic strain, thus suggesting lower expression of hsp70 transcripts favor aflatoxin biosynthesis (Thakur et al. 2016). Hsp70 induction and overexpression has been observed in the compensation of cwh41 gene, which codes for glucosidase-I in *A. fumigatus*, important for cell wall synthesis and morphology of fungi (Jin 2011).

During stress response, fungus such as *C. albicans, P. lutzii*, *H. capsulatum* etc existing in mycelia form converts to yeast form and vice versa, this phenomenon is termed as dimorphism (Brand 2011). *Penicillium marneffei* showed temperature dependent upregulation of hsp70 transcripts during the mycelium to yeast phase transition (increase at 39 °C followed by decrease at 42 °C) (Kummasook et al. 2007). Similar studies have also shown in *H. capsulatum* with higher expression of hsp70 from mycelia to yeast transition (Caruso et al. 1987; Shearer Jr. et al. 1987). This finding showed that hsp70 plays a very essential role in heat stress dependent fungal dimorphism.Hsp90 plays a major role in the fungal morphogenesis which requires the co-operation of Hsp70. Hsp70 acts as co-chaperon for Hsp90 and requires Sti1/Hop1 as an adapter protein for Hsp90 mediated polypeptide release (Rohl et al. 2015). Hsp70 also works in combination with Hsp30 and Hsp80 to interact with unfolded polypeptide, hence mimicking Hsp90 activity in fungal morphogenesis. Hsp70 interaction with Hsp30-Hsp80 complex has been observed in various yeasts such as *S. cerevisiae, N. crassa* and *C. albicans* in their dormant conidial stage (Ouimet and Kapoor 1999; Girvitz et al. 2000).

Role of HSP70 Co-factors

Hsp70 of fungi are the ubiquitous chaperonin family protein found in cellular compartments, and involved in various cellular functions such as protein synthesis, translocation and degradation of protein and also in protein folding (Frydman 2001). To perform the vital functions Hsp70 chaperone requires a specific binding to substrate protein which is controlled by ATPase cycle. The rate of substrate binding and release from ATP bound domains of Hsp70 is high and the affinity for substrates is low. This process is reversed by the hydrolysis of ATP bound Hsp70 which is converted to ADP-bound confirmation form, hence trapping the substrate with higher affinity. This whole cycle relies on interaction of Hsp70 with some specific co-factors which are regulatory molecules (Andréasson et al. 2010). Co- factors are involved in ATP hydrolysis or exchange of ATP for ADP. Some of the major co-factors of fungal Hsp70 chaperone protein have been described in this study.

Nucleotide Exchange Factors

Substrate release from Hsp70 is mediated by Nucleotide Exchange Factors (NEFs) which performs dissociation of nucleotides and rebinding of ATP. Hsp70 requires NEFs as they have low affinity for nucleotide binding. Fungi can possess multiple NEFs which may have specific interactions with different HSp70s. For example, multiple NEFs have been reported in *S. cerevisiae* such as Sls1, Snl1, Fes1, Sil1, Lhs1, and Sse1 (Kabani et al. 2000; Tyson and Stirling 2000; Sondermann et al. 2002). However, Sse1 stimulates yeast cytosolic Hsp70s whereas endoplasmic reticulum specific Hsp70 function is enhanced by Lhs1 (Steel et al. 2004; Shaner et al. 2006; Andréasson et al. 2010). Some NEFs may have functional overlapping. Lhs1 is more potent than Sil1 whereas, Sse1 is more effective with Ssa Hsp70s than Fes1 (Steel et al. 2004; Sharma and Masison 2009). Ssa1p and Hsp110 is the cytosolic Hsp70 chaperone of *S. cerevisiae* which when present in ADP bound form associates with Fes1p (nucleotide exchange factor) and favors nucleotide release. Translation related defects have been seen due to deletion of fes1p (Kabani et al. 2002). Grp170 (Lhs1) is the NEF of endoplasmic reticulum Hsp70 in yeast.

Hsp40 Co-chaperones

Hsp70 interacts with a client proteins known as J-proteins (also called Hsp40s) (Kampinga and Craig 2010). Hsp40s are critical companion of all Hsp70s in the regulation of Hsp70 activity (Steel et al. 2004). Hsp40s are present in multiple isoforms and regulate ATP dependent polypeptide binding of Hsp70 protein (Shen et al. 2002; Craig et al. 2006). Hsp40 is divided in three classes viz. class I, class II

and class III which differs in their structural patterns (Cheetham and Caplan 1998; Hennessy et al. 2000). Yeast Hsp70 Sis1, a class II Hsp40 has structure similarity with Ydj1 which is a class I Hsp70 of yeast (Li et al. 2003a, b). *S. cerevisiae* Hsp70, that is, Ssa1 and Ssa2 interacts with Djp1, Ydj1, Sis, Hlj1 and Swa2, the binding/interaction of which is based on cellular location (Hettema et al. 1998; Sharma and Masison 2009). For example, Djp1 interacts with Ssa1 and 2 in peroxisomes biogenesis, Ydj1 in endoplasmic reticulum membrane, Sis1 in ribosome (Brodsky et al. 1998; Hettema et al. 1998; Horton et al. 2001). Another class of yeast Hsp40 co-chaperone Zou1 has shown interactions with Ssz1 (yeast Hsp70) (Craig et al. 2003).

Hsp70 Functions in Fungi

Hsp70 has been involved in various cellular processes. The following sections discuss the examples Hsp70 functions.

Protein Folding and Prevention of Aggregation

Hsp70 plays an important role in maintaining native conformations of folded proteins from their synthesis until their degradation. *S. cerevisiae* cytosolic Hsp70, Ssa and Ssb are highly identical (Craig et al. 1995). Ssb interacts at early stage of synthesis of polypeptide thus facilitates nascent polypeptide chains elongation whereas Ssa interacts with the secondary structure developed from nascent chain and helps in translocation of protein (Sharma and Masison 2009). Translation in fungi is sometimes hurdled by aggregation of peptides due to non-native (exposed) form of hydrophobic residues, so requires native contacts of all amino acids emerged from ribosome, which is mediated by Hsp70 (Sharma and Masison 2009).

Role of Hsp70 in Protein Degradation

Hsp70 that assists protein folding, also involved in misfolded protein degradation, in association with Hsp40. Genetic studies have shown that Ssa1, which is a yeast Hsp70 chaperone and yeast Hsp40 chaperone Sis1, together play an important role in degradation of misfolded substrate which hampers the quality of proteins (Shiber et al. 2013). Function of Sis1 is ubiquitinization of substrate that is carry forwarded by Ssa1 which functions by forwarding the ubiquitinilated substrate to proteosome (Shiber et al. 2013; Shiber and Ravid 2014). Hsp70 subfamilies are highly dependent on substrates hence, showing specificity towards protein degradation. For example, normal yeast strains containing Ssa1 showed cystic fibrosis

transmembrane conductance regulator (CFTR) degradation whereas, 60% CFTR degradation was observed by ssa1 mutant yeast cells. Also, yeast Kar2 (BiP), which is known to have a regulatory domain which responded to unfolded proteins in endoplasmic reticulum, when mutated showed no effect on CFTR degradation. This suggests that CFTR degradation in yeast is dependent on Hsp70 chaperone, Ssa, and not on Kar2 (Molinari et al. 2002). Ssb and Ssa have also been involved in cytosolic protein degradation in yeast. Proteosomal protein degradation in yeast is mediated by Ssb1 (Luders et al. 2000).

Role of Hsp70s in Formation and Propagation of Yeast Prions

Prions are isoform of proteins which self-engendering and transmissible. Prions have been reported in several yeasts which exists in soluble form (normal state) or amyloid form (transmitting state) (Liebman and Chernoff 2012). To maintain themselves in fungal/yeast population, prions relies on Hsp70 function, which may depend on the abundance of Hsp70 for prion propagation (Jones et al. 2004). Extensively studied prions in *S. cerevisiae* are [PSI+] and [URE3], which are derived from Sup35 and Ure2 proteins in their amyloid form responsible to cause infection (Jung et al. 2000; Tibor Roberts et al. 2004). Hsp70 chaperons such as Hsp40s and Hsp104 have impact on propagation of prions, as studies showed that conjugated role of Ssa1 and Ydj1 is involved in inhibition of polymerization of Sup35 (Song and Masison 2005).In yeast, mutant strain of Ssa1 (Hsp70 chaperone) has shown impair mitotic stability leading to partial inhibition of [PSI+] mediated allosuppresion (Jung et al. 2000; Song et al. 2005). This inhibition of prion is also dependent on the variety of Hsp70 chaperons present, as if mutated Ssa1 is only present in cytosol, then it have more pronounced effect on prions weakening. Mutation in Ssa1 also weakens [URE3] activity whereas mutation in Ssa2 weakens both [PSI+] and [URE3] activity (Sharma et al. 2009a, b). In absence of Ssa1 polymers have shown to be self associated and self aggregated, so it can be said that Ssa1 may prevent higher polymer aggregation hence preventing aggregation of prions (Song et al. 2005). Apart from similar homology of Ssa and Ssb, both vary in yeast prion propagation, as Ssb increases [PSI+] formation and Ssb inhibits propagation of [PSI+] (Allen et al. 2005). Prions propagation is also influenced by Hsp70 specific co-factors. For example, Hsp40 over expression, TPR, or NEFs (Fes1 or Sse1) deletion, is involved in the impairment of propagation of [PSI+] (Jones et al. 2004; Qiu et al. 2006). Long term interaction of Hsp70 with Sup35 present in improper folded form may cause inhibition of conversion to prion state. So it is required for Hsp70 to perform proper activity alone or in co-operation with co-factors to prevent aggregation of polymers or prion regeneration (Sharma and Masison 2009).

Role of Hsp70 in Stress

Hsp are induced by two mechanisms in fungi, specific mechanism and general mechanism. Specific mechanism generally encompasses temperature related stress whereas, generalized mechanism by other stresses such as pH, oxidative stress, osmotic stress, starvation, or antifungal stress (Tereshina 2005). Thus, the roles of Hsp70 involved in stress responses have been categorized below.

Hsp70 Response Against Heat Stress/Thermotolerance

Hsp70 is a high molecular weight chaperone, which exists in fungi without any heat stress, but as the heat stress is given to fungi they starts increasing in number (Plesofsky-Vig and Brambl 1985a). The enhancement of fungal hsp70 mRNA due to different temperature gradients revealed a strong stress induced response. In response to heat stress, Hsp70 in association with Hsp40 and Hsp104 has been involved in unfolding of denatured protein, mediating thermotolerance in fungi (Sanchez et al. 1993). A temperature dependent increase of hsp70 expression was found in *A. fumigatus*, *A. terreus*, *C. cladosporioides* and *T. mentagrophytes*, but *P. chrysogenum* and *S. apiospermum* showed no stress induced response. At different incubation temperatures, *A. fumigatus* showed an induction of the hsp70 expression level. *A. fumigatus* showed upregulation of gene expression from 25 to 35 °C, while further increase in temperature resulted in lowering the expression of hsp70. Similarly, *A. terreus* and *C. cladosporioides* showed higher hsp70 expression at 40 °C. Hence it suggests that expression of hsp70 is most at temperature range between 35 and 40 °C. Other fungi such as *T. mentagrophytes* showed hsp70 expression at lower temperature of 25 °C. However, expression of hsp70 in these fungi (*P. chrysogenum* and *S. apiospermum*) is temperature independent (Salzer 2008). *Achlya ambisemalis*, an oomycete, in response to heat shock of 30–35 °C for 10–30 min, showed higher expression of hsp70 (Gwynne and Brandhorst 1982). Similar results were also seen during heat shock response in *A. nidulans*, at 37–43 °C for 1 h (Newbury and Peberdy 1996). *N. crassa* is a filamentous fungus widely studied for stress responses. Heat stress mediated response of *N. crassa* showed accumulation of nuclear associated 78 kDa heat shock protein (Kapoor 1983). Later, *N. crassa* conidia in response to heat stress at 45 °C, showed assembly of 70 kDa Hsp (Plesofsky-Vig and Brambl 1985b). Different morphological stages (mycelia or yeast) have shown no effect on the expression of hsp70 in few fungi, in response to stress (Kummasook et al. 2007). For example, *P. marneffei*, dimorphic fungi have shown same expression level of hsp70 when exposed to 39 °C (Kummasook et al. 2007). Also, *N. crassa* converts from mycelia to hyphae in response to heat stress (25–37 °C), with the higher expression of hsp70 in response to temperature but not during the transition state (Perlman and Feldman 1982). In in-vivo condition, expression of hsp70 plays a very important role, as it mediates resistance of fungi in host in response to high body temperature. Further, suggesting Hsp70 as a virulent

factor in fungal mediated infection. To uphold this statement, studies on *N. crassa* treatment at 48 °C for 14 h, showed upregulation of hsp70 expression (Kapoor et al. 1995). Although, studies on *P. brasiliensis* showed that temperature above 42 °C have decreased the hsp70 mRNA expression (Da Silva et al. 1999). So, hsp70 mediates thermo-tolerance in fungi is thought to be species dependent.

Role of Hsp70 in Acid/Alkaline Stress

pH signaling is important for various cellular processes in fungi such as, gene expression regulation, virulence of fungi, secretion of nutritional enzymes, metabolic processes, etc. (Caddick et al. 1986; Ferreira-Nozawa et al. 2006). PacA/PacC pathway is involved in the pH mediated response in fungi (Penalva and Arst 2002). *A. nidulans* is known fungal model used for the study of pH response (Silva et al. 2008). Nucleotide sequence studies of hsp70 of *A. nidulans* revealed that it contains a binding site for PacC in their upstream region. It suggests that in normal conditions (acidic, optimum temperature) PacC with Hsp70 is responsible to maintain normal conditions in fungi. The transcription of hsp70 is mediated by palA (transcriptional factor) in normal growth condition (acidic environment), which is encoded by pacC (Tilburn et al. 1995). But, if the heat stress is given to fungi for 1–2 h in the absence of palA, the hsp70 response becomes independent of both acid and alkaline pH, so PalA in that condition does not play any role in hsp70 expression. *A. nidulans* showed high expression of hsp70 at pH 8 and the activation of palA (Freitas et al. 2011). Studies on pH mediated hsp70 response in *N. crassa* showed that hsp70 was highly expressed at acidic pH and optimum temperature (30 °C) but did not show any upregulation at alkaline pH, depending on PacC mediated signaling pathway. Also, Squina et al, showed that pH mediated expression of hsp70 vary depending upon culture conditions and heat stress. Some hsp70 genes respond to these conditions in addition to pH response (For example; hsp70-1 and hsp70-2 of *N. crassa*) while some hsp70 only depends on culture conditions or heat stress but not on pH (For example; hsp70-3 of *N. crassa*) (Squina et al. 2010). Another fungus, *Candida glabrata*, also showed same expression of hsp70 towards alkaline pH. Hsp70 (cytosolic Ssa1) protein was found to be downregulated at pH 7.4 and 8, which suggests that in fungi hsp70 expression is mediated by acidic pH (Schmidt et al. 2008).

Oxidative Stress and Osmotic Pressure Response

Oxidative stress and response towards osmotic pressure is a functional challenge for fungal cells that generally all fungus experience. Fungus overcomes the effect of reactive oxygen species by mediating activation of transcriptional processes and by producing stress response proteins. Very little information is available for the role of Hsp70 in oxidative stress response in fungi. Skn7 is a oxidative stress response mediated transcription factor which in co-ordination with heat shock transcriptional

factor hsf1 induces heat shock genes (Raitt et al. 2000). Loss in Skn7 in *S. cerevisiae* showed inhibition of Hsp70 (Ssa1) (Morano et al. 2012). This finding might also related Hsp70 role in oxidative stress response. In response to H_2O_2 stress in Paracoccidioides yeast cells, hsp70 was found to be expressed which showed the important part of oxidative stress response fungal machinery (de Arruda Grossklaus et al. 2013). Kunal et al, showed that in response to oxidative stress in fungi, *Ascochyta rabiei*, hsp70 was found to be upregulated (Singh et al. 2012). Hypoxia is a state of deprived oxygen, causing oxidative stress. In fungi, the hypoxia conditions has led to heat shock responses, for example, C. *neoformans, Drosophila melanogaster, C. albicans* and *B. emersonii* in hypoxia condition, showed higher expression of hsp70 and the survivability of fungi was found to be increased significantly (Setiadi et al. 2006; Chun et al. 2007; de Castro Georg and Gomes 2007; Azad et al. 2009). *Metarhizium anisopliae*, an entomopathogenic fungus, is responsible for infection in insects. Osmotic stress response in this fungus is mediated by mos1 gene. When mos1 was knock down, showed the downregulated expression of hsp70 transcripts, possibly leading to delay in osmotic stress response (Wang et al. 2008).

Drug Response

To prevent the harmful effect of fungal species, various antifungal medications have been employed which have specific fungal targets for their action. Major antifungal drugs used are amphotericin, itraconazole, fluconazole, ketoconazole, clotrimazole, miconazole, terbinafine, etc. (Odds et al. 2003). Some of these antifungals have been studied for their effect on hsp70 mediated responses in fungi. In *A. terreus* hsp70 play a vital role in response to amphoteracin B (AmB). Transcriptome analysis of AmB resistance strain of *A. terreus* revealed relatively high ssa and ssb mRNA expression in comparison to AmB susceptible strains whereas mitochondrial and endoplasmic reticulum specific hsp70 members, kar and ssc, were downregulated. In addition, sse and ssz (nucleotide exchange factors) were also uplifted in response to AmB resistant *A. terreus*. Susceptibility of AmB towards A. terreus were found to increased in absence of Hsp70. AmB when combined with pifithrin (Hsp70 inhibitor) inhibited AmB resistant *A. terreus* (Blatzer et al. 2015), whereas *A. fumigatus* treated with AmB showed downregulation of mitochondrial Hsp70 protein (Gautam et al. 2008). 17β-estradiol is a female hormone that inhibits dimorphic fungus (Paracoccidioides) in their transition from mycelia to yeast, thus women are observed to be resistant to paracoccidioidomycosis (Shankar et al. 2011a, b). In Paracoccidioides, the transcriptional profile during temporal transition from mycelia to yeasts form showed differential regulation of hsp70 in response to 17β-estradiol. Expression of hsp70 was observed during 4–12 h of germination, which dropped further at 144 h, which suggested the role of hsp70 in delaying the morphological transitions from mycelium to yeast under the influence of 17β-estradiol (Shankar et al. 2011a, b). Genome wide studies of *C. albicans* treated with 17β-estradiol showed expression of hsp90, whereas the regulation of hsp70 was not onserved

(Burt et al. 2003; Banerjee et al. 2007; Clemons et al. 2010). Paromomycin is an antibiotic which is used as antifungal compound. *S. cerevisiae* when exposed to paromomycin showed induction of hsp70 mRNA translation (Grant and Tuite 1994). In other studies on *S. cerevisiae* treated with thiolutin (antifungal), induce the transcription of ssa4 (hsp70) (Adams and Gross 1991). These findings may signify that hsp70 is a novel target against pathogenic fungi.

Other Stress Responses

Apart from heat stress, Hsp70 in fungi have been found to play important role in salt, metal or ion stress etc. Weitzel et al, showed the increase in expression of hsp70 in response to dinitrophenol in *S. cerevisiae* (Weitzel et al. 1985). Also, *S. cerevisiae* has shown the increase in expression of hsp70 in response to NaCl ranging from 0.3 to 0.7 M (Antelo et al. 1992; Lewis et al. 1995). Thiolutin (RNA polymerase inhibitor) and parornomycin (antibiotic) was also showed high expression of ssa4 in *S. cerevisiae* (Grant et al. 1989; Adams and Gross 1991). In continuation, *S. cerevisiae* showed same expression level of hsp70 in response to ethanol treatment, which was not observed in case of *N. crassa* (Plesset et al. 1982; Roychowdhury and Kapoor 1988). *N. crassa* cells when treated with hydrogen peroxide showed the synthesis of Hsp70 protein (Kapoor and Lewis 1987). In several studies high concentration of sodium arsenite showed the increased transcripts of hsp70 in *N. crassa*. In addition, cadmium when inoculated with sodium arsenite, showed no effect on expression of hsp70 (Chakraborty et al. 1995). However, cadmium showed upregulation of hsp70 in *A. fumigatus*. Further, *A. fumigatus* also showed upregulation hsp70 on treatment with cadmium chloride (Damelin et al. 2000; Georg and Gomes 2007).

Role of HSP70 in Fungus-Plant Interaction

Fungus mediated plant pathogenesis and disease is responsible to cause loss of food products worldwide. So, studies are needed further to deduce the fungal targets which are essential for disease progression. In few studies on fungal-plant interaction, hsp70 has been observed to be upregulated, contributing to pathogenesis. For example, *Colletotrichum gloeosporioides*, showed higher expression of hsp70 in coffee plant in its infectious state (coffee berry disease) (Chen et al. 2003). *Magnaporthe oryzae* Hsp70 proteins (Lhs1p and Kar2p), were also found to accumulate in the endoplasmic reticulum of fungi and responsible for disease development in rice plant (Yi et al. 2009). *Rhizoctonia solani* is a plant pathogenic fungus causing various diseases in plants such as damping, root rot, collar rot, etc. (Zhu et al. 2016). Proteomic studies revealed that heat shock protein of 70 kDa was observed during cell wall degradation of soybean seedlings, thereby, assisting virulence (Lakshman et al. 2016).

HSP70 in Pathogenesis and Potential Diagnostic or a Vaccine Candidate

Fungal diseases, in recent years, have been taken into account due to their dramatic increase and aggressiveness that demands better medical diagnosis and therapies. Fungal diseases/contamination has made its impact on immune-compromised patients (Thakur et al. 2015) as well as on several food crops (Chauhan et al. 2016). Fungal resistance over major antifungal drugs has raised a need to develop new and efficient drug targets for pathogenic fungi and vaccine candidate. Fungal pathogen after entering into the host body suffers temperature shifts. Hence, to overcome temperature shift stress, fungus produces heat shock proteins that may play role in fungal survival/growth in the host. In various transcriptomic and proteomic studies, it has been shown that Hsp of fungi are up-regulated during infection. Hsp70 is a major chaperone that has been widely studied due to their role in infection/contamination in animals/plants. For example, Hsp70 in *C. albicans* has been reported in systemic murine candidiasis, which has been identified as an antigen by host immune system (Bromuro et al. 1998). Proteomic studies of *A. flavus* cultured on corn flour showed expression Hsp70 proteins (Tiwari and Shankar 2018). Thus, it suggests that fungal Hsp70 is important for both human and plant. Allergens from *C. cladosporioides* also showed expression of 72 kDa protein (Li et al. 2008). Systemic mycosis is prevalently caused by *P. brasiliensis* in yeast phase showed higher expression of hsp70 mRNA during infection (McEwen et al. 2000; Goldman et al. 2003; Cleare et al. 2017). *Cryptococcus neoformans* being a pathogenic fungus, is involved in impairing immunity of patients (HIV, defective T cells) causing severe infections. Studies on murine pulmonary cryptococcosis caused by *C. neoformans* have shown hsp70 as a target molecule for immune response (Kakeya et al. 1999). Hsp70 mediated immune response e.g., IL-12 and IFN-γ has been observed in immunological studies of *H. capsulatum* (Allendoerfer et al. 1996; Deepe Jr. and Gibbons 2002; Cutler et al. 2007). Immune response against Hsp70 also accounts production of tumor necrotic factors and interleukin 6, which have role in the prevention yeast infection (Bromuro et al. 1998). AntEroles et al., showed that heat stress induces the formation of *C. albicans* spores. These spores when reacted with polyclonal antibody of rabbit, exhibited hsp70 expression having homology with *S. cerevisiae* Ssa1 gene (Eroles et al. 1995). Studies from Li et al, showed that histatin 5 (a salivary protein) has antifungal properties and possess affinity towards Ssa1 and Ssa2 (Li et al. 2003a, b). Previously hsp70 of *Penicillium citrinum* has also been screened from asthmatic patients (Shen et al. 1997). Moreover, in other bacteria such as *P. carinii*, *P. rattus* and *P. jirovecii* also showed the expression of hsp70 during their pathogenic phase (Stedman et al. 1998; Latouche et al. 2001; Burnie et al. 2006). These literatures suggest that fungal Hsp70 plays a major role in pathogenesis and act as a potent antigen for mediating host immune response. Thus, Hsp70 has potential as a diagnostic candidate and may be a promising protein to study as a vaccine candidate (Cleare et al. 2017).

Conclusions

Fungi are the diverse genera produce Hsp70 in response to stress conditions for accomplishing various biological functions. Hsp70 has been observed to be highly conserved in the evolution of fungal kingdom. *S. cerevisiae* had been a best studied model for nucleotides and amino acid sequences of hsp70, which correlates with other fungal species. Majorly, Hsp70 protein has been reported in protein folding, protein aggregation and disaggregation, regulating transcription and post-transcription, morphogenesis and thermotolerance. Also, it has also showed role in other stress response such as osmotic, oxidative or response towards pH and stress response towards meal ion, antibiotics, alcohols etc. Hsp70 has emerged as a major heat shock protein expressed in fungi during the stress after Hsp90. Expression of fungal Hsp70 in the host system added a molecule to study for the development of vaccine candidate using Hsp70 protein/epitopes against various fungal infections.

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Unsupervised and Semi-Supervised Learning

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Chapter 7
Chemical Reaction-Based Optimization Algorithm for Solving Clustering Problems



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7.1 Introduction

Clustering is an important data analysis and well-recognized technique in the field of data mining. Since past few decades, it has attained a wide awareness from research community having theoretical as well as practical views. It is an unsupervised classification technique, and there is no need for training and testing of data objects. This technique can split the data objects into different clusters using a distance criterion. Literature survey has revealed the use of this technique in diverse research domains [3, 4, 7, 8, 18, 19, 21] . In recent years, a number of heuristics algorithms have been reported to determine the optimal solution for clustering problems. These algorithms have been derived from the heuristics, natural phenomena, swarms behavior, insects, animals, etc. Some physics-based algorithms (such as charged system search algorithm, galaxy-based algorithm, black hole optimization algorithm, magnetic charged system search algorithm) have also been used to find out the optimal solution for optimization problems [6, 9, 10, 16]. Some other algorithms like CSS [11], MCSS [12], BH [6], and CSO [13, 14] have also been applied successfully to solve the clustering problems. With time, the

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importance and significance of these algorithms have increased among the research community due to following reasons:

- These algorithms have a variety of solution strategies.
- These algorithms do not depend on the size of the problem, variables, constraints, and solution space.
- These algorithms can be adopted according to the problem. Only need to adjust the objectives and fitness functions. It means no hard mathematical functions are defined in these algorithms.
- These algorithms provide efficient and effective results for combinatorial and nonlinear problems.
- These algorithms have the low computation power and minimum chances to trap in local optima.
- These algorithms have the capacity to solve the problem with different initial points.
- These algorithms provide better results as compared to the classical methods.

Due to abovementioned advantages, these algorithms have been used in diverse fields such as image processing, biology, sciences, market research, biomedical process, engineering, etc. Some new versions of these algorithms also have been proposed. Artificial chemical reaction optimization (ACRO) algorithm is a chemistry-based heuristic algorithm to solve the global optimization problems [1, 2]. This algorithm is based on the chemical reactions such as their types, evaluation, decomposition, etc. ACRO algorithm is mainly described in terms of reactants. For reactants, any encoding schemes, like integer, real, floating, and character, are used for solving the optimization problems. Further, in the ACRO algorithm, some reaction rules are specified to consume and generate the reactants. The execution of the algorithm is stopped when termination condition is met. The primary objective of this work is to investigate the competences of the ACRO algorithm for finding the optimal cluster centers for partitional clustering problems. The performance of proposed algorithm is examined on well-known benchmark datasets downloaded from UCI repository and few artificial datasets. The simulation results are compared with several meta-heuristic algorithms such as K-means [15], particle swarm optimization (PSO) [20], ant colony optimization (ACO) [17], and bat algorithm (BA) [5].

Organization of the Paper: The ACRO algorithm and different chemical reactions adopted in the algorithm are presented in Sect. 7.2. Section 7.3 presents the ACRO algorithm for partitional clustering problems. Section 7.4 illustrates the results of the proposed study. Section 7.5 gives a summary of the entire work.

7.2 Chemical Reactions

The chemical reaction can be defined as the formation of new chemical products using chemical reactants. Reaction completion timings may differ like some chemical reactions take few minutes, while others may take hours or days. Some

chemical reactions require single step for product formation, while others need multiple steps. In general, chemical reactions can be divided into two categories such as consecutive reaction and competing reaction. Basically, the motion of the electrons is generally responsible for the formation and breakage of the chemical bond in chemical reactions. It is also possible that the newly derive products, may differ in properties from reactants. A chemical process contains different types of molecules or chemical species, and further, these molecules can participate in one or more chemical reactions. Reactions may be exothermic or endothermic in nature. Reactions may be reversible or irreversible. In some reactions, the rate of the forward reaction is equal to rate of the reverse reaction such condition is known as chemical equilibrium condition. In equilibrium state, concentrations of reactants and products are constant. Observation shows that sometime output of a reaction is the input of other reaction. Broadly, chemical reactions can be characterized into following categories:

7.2.1 Synthesis Reactions

In these reactions, two or more reactants combine for producing a single product or compound. The reaction is given below.

$$2K + Cl_2 \rightarrow 2KCl \qquad \text{(Elements)}$$

$$2KCl + 3O_2 \rightarrow 2KClO_3 \qquad \text{(Compounds)}$$

7.2.2 Decomposition Reactions

Through this reaction, two or more compounds form using a single reactant. It just reverses of the synthesis reaction. Decomposition reactions need some energy source like heat, light, or electricity. A decomposition reaction can be shown as

$$MgCl_2 \rightarrow Mg + Cl_2$$

7.2.3 Single Displacement Reactions

In single displacement reaction, an element can interact with another element of a compound and takes position of another element in the resultant compound. This reaction can be given as

$$Zn + 2HCl \rightarrow 2ZnCl_2 + H_2$$

7.2.4 Metathesis

In metathesis reactions, after the interaction of the elements, the position of cations and anions changes and produce two new elements. This reaction can be specified as given below.

$$AgNO_3 + NaCl \rightarrow 2AgCl + NaNO_3$$

7.2.5 Combustion Reactions

In this reaction, oxygen reacts with an element and produced energy in terms of heat and light. Combustion reactions can be given as

$$C_2H_5 + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

7.2.6 Redox Reactions

In this reaction, electrons transfer from one reactant to another reactant in terms of release and uptake. The element that can uptake the electrons is called an oxidizing agent, whereas the element that can release the electrons is known as the reducing agent. The example of such reaction is given as

$$MnO_4^- (aq) + I^- (aq) \rightarrow Mn^{+2} (aq) + I_2 (s)$$

Mn gains five electrons to form Mn^{2+}. Further, iodine lost electrons, so it is an oxidizing agent. Moreover, Mn^{2+} gains five electrons, so it is a reducing agent.

7.2.7 Reversible Reactions

These reactions occur both in forward and backward direction. In such types of reactions, the products change into reactants and reactants into products. The example of such reaction is given below.

$$H_2CO_3 (l) + H_2O (l) \leftrightarrow \ HCO_3{}^- (aq) + H_3O (aq)$$

7.3 Artificial Chemical Reaction Optimization (ACRO) Algorithm

The motivation behind the artificial chemical reaction optimization (ACRO) algorithm is the chemical reaction. It is discovered that atoms and molecules constantly move and collide in a viscous fluid filled 2D cellular space. Atoms are defined as the elementary particle of a chemical reaction and having a type, charge, mass, position, radius, orientation, and velocity. Whereas, a molecule can be defined as a group of two or more atoms linked through bonds. During a chemical reaction, several changes occur like formation and breaking of bonds, orientation change, substitution, and replacement in molecules. It is considered that ACRO algorithm begins with the action of reactants in a vessel. Let us consider a fixed volume vessel filled with a uniform mixture of N chemical reactants which undergo different types of chemical reactions. Let $Ri \in (1 \leq i \geq N)$ is the list of chemical types, and it is considered that these types can cooperate through M specified chemical reaction channels. In ACRO algorithm, the encoding scheme of the reactants depends on the user choice, and it can be binary, real, string, integer, etc. The new reactant produces through the interaction of one or two reactants. The ACRO algorithm starts with a set of initial reactants in a solution. Further, reactants are consumed and produced through different chemical reactions. The algorithm stops; either the termination condition is met or when no more reaction occurs. For the chemical reactions, reactants are chosen based on their concentrations and potentials. Moreover, it is observed that consecutive and competing reactions are the two mainly reported reactions. Reactants are joined together serially in a consecutive reaction, whereas in competing type reactions, different products are produced depending on the specific condition. It is also noticed that sometimes output of one reaction may act as a reactant for other reaction. There are many factors that can affect the execution of a reaction. However, the ACRO algorithm is based on a simple concept of an equal probability of monomolecular or bimolecular reactions and their alternatives. The main steps of the ACRO algorithm are listed below.

Step 1: Initialize the problem and algorithm parameters.
Step 2: Evaluate the initial reactants and evaluation.
Step 3: Apply chemical reactions.
Step 4: Update reactants.
Step 5: Termination condition.

7.4 Proposed ACRO Algorithm for Clustering Problems

This section describes the proposed ACRO algorithm to find the optimal cluster centers for the partition-based clustering problems. In partition-based clustering problems, numbers of clusters are known in advance, and the main task is to find the

optimum set of cluster centers such that the intra-cluster distance between cluster centers and objects should be minimized. The steps of the proposed algorithm are described in Sect. 7.4.1.

7.4.1 Steps of Proposed ACRO Algorithm

Step 1: Initialization of the User-Defined Parameters and Problem Statement
The clustering problem can be expressed as minimization problem and defined as follows:

$$\text{Minimize } f\left(\boldsymbol{x} \textbf{ subject } \boldsymbol{to}\ \boldsymbol{x_i} \in \boldsymbol{C_k}; \textbf{ where } \boldsymbol{i} = \mathbf{1}, \mathbf{2}, \mathbf{3}, \ldots, \boldsymbol{D} \textbf{ and } \boldsymbol{k} = \mathbf{1}, \mathbf{2}, \ldots, \boldsymbol{K}\right)$$

where $f(x)$ is an objective function which is defined in terms of Euclidean distance, $x_i$is the set of data objects, D is the dimension of data object, C_k is the set of kth cluster centers, and K describes a number of clusters in a given dataset. It is to be noted that the computed cluster centers should be in the range of $x_i^{\min}$and $x_i^{\max}$and also known as boundary constraints. Further, in this work, integer encoding scheme is used to obtain the desired results. The user-defined parameters of ACROA and Reactnum (maximum number of iterations) are also defined in this step.

Step 2: Set Initial Reactants and Evaluation
In this step, the population of the ACRO algorithm is specified; the population is defined in terms of initial reactants. The initial reactants are uniformly identified from the feasible search space. For clustering problem, initially, two reactants, i.e., R_1 and R_2, are identified from the dataset such as $R_1 = \{x_{i,1}, x_{i,2}, \ldots, x_{i,d}\}$, $R_2 = \{x_{j,1}, x_{j,2}, \ldots, x_{j,d}\}$, where d denotes the length (dimension) of reactant. The number of reactants is similar to a number of clusters (K). Then, rests of reactants are derived from initially determined reactants R_1 and R_2 using the following procedure. To compute R_1 and R_2, firstly, a dividing factor (k) is initialized. Suppose $k = 2$; then, two new extra reactants, i.e., R_3, R_4, are generated from R_1 and R_2 using below mentioned procedure:

$$R_3 = \left\{ \begin{array}{c} r * x_{i,1}, r * x_{i,2}, \ldots, r * x_{i,\frac{d}{2}}; \\ r * x_{j,\frac{d}{2}+1}, r * x_{j,d-\frac{1}{2}+2}, \ldots, r * x_{j,1} \end{array} \right\} \tag{7.1}$$

$$R_4 = \left\{ \begin{array}{c} r * x_{j,1}, r * x_{j,2}, \ldots, r * x_{j,\frac{d}{2}}; \\ r * x_{i,\frac{d}{2}+1}, r * x_{i,\ d-\frac{1}{2}+2}, \ldots, r * x_{i,1} \end{array} \right\} \tag{7.2}$$

where r denotes a random number and should be in the range of $0 \leq r \geq 1$. Further, more reactants are generated using the following procedure until the number of reactants is not similar to the desired clusters (K):

$$R_5 = \left\{ \begin{array}{c} r * x_{i,1}, r * x_{i,2}, \ldots, r * x_{i,\frac{2d}{3}}; \\ r * x_{j,2d/3+1}, r * x_{j,2(d-1)/3+2}, \ldots, r * x_{j,1} \end{array} \right\} \tag{7.3}$$

$$R_6 = \left\{ \begin{array}{c} r * x_{i,1}, r * x_{i,2}, \ldots, r * x_{i,\frac{d}{3}}; \quad r * x_{j,d/3+1}, r * x_{j,2(d-1)/3+2}, \\ r * x_{i,\frac{2d}{3}}, \ldots, r * x_{j,1} \end{array} \right\} \tag{7.4}$$

$$R_7 = \left\{ r * x_{i,1}, r * x_{i,2}, \ldots, r * x_{i,\frac{d}{3}}; \quad r * x_{j,d/3+1}, , \ldots, r * x_{j,1} \right\} \tag{7.5}$$

$$R_8 = \left\{ r * x_{j,1}, r * x_{j,2}, \ldots, r * x_{j,\frac{d}{3}}; \quad r * x_{i,\frac{d}{3}}, \quad \ldots, r * x_{i,1} \right\} \tag{7.6}$$

$$R_9 = \left\{ \begin{array}{c} r * x_{j,1}, r * x_{j,2}, \ldots, r * x_{j,\frac{d}{3}}; \quad r * x_{i,\frac{d}{3}+1}, r * x_{i,\frac{2(d-1)}{3}}, \\ r \ * x_{j,2d/3+1} \ldots, r * x_{i,1} \end{array} \right\} \tag{7.7}$$

$$R_{10} = \left\{ r * x_{j,1}, r * x_{j,2}, \ldots, r * x_{j,\frac{2d}{3}}; r * x_{i,\frac{2(d-1)}{3}+1}, r * x_{i,\frac{2d}{3}+2}, \ldots, r * x_{i,1} \right\} \tag{7.8}$$

Step 3: Applying Chemical Reactions

Step 3.1: Bimolecular Reactions

Let us consider $R_1 = \{x_{i,1}, x_{i,2}, \ldots, x_{i,d}\}$ and $R_2 = \{x_{j,1}, x_{j,2}, \ldots, x_{j,d}\}$ are two reactants that can participate in bimolecular reaction. As a result of this, various bimolecular reactions are incorporated in the ACRO algorithm such as synthesis reaction, displacement reaction, redox 2 reaction, and monomolecular reaction. For all these operations, integer representation of the population is considered rather than binary encoding. The detailed explanation of these reactions is described as below.

Step 3.2: Synthesis Reaction: Using this reaction, a new reactant can be obtained using the following equation:

$$R = \left(r_1, r_2, r_3, \ldots, r_i, r_j, r_k, \ldots, r_n\right); \text{where, } R_{i,\text{new}} = R_i + \lambda_i \left(R_j - R_i\right) \tag{7.9}$$

In the above equation, λ_i is a random value in the interval [0.25, 1.25]; R_i and R_j are randomly selected reactants.

Step 3.3: Displacement Reaction

The new reactants are obtained using below mentioned procedure. Suppose $R_k = (R_1, R_2 \ldots R_i, R_j, \ldots, R_K)$ where, $k = 1,2 \ldots \ldots .K$:

$$\mathrm{R_{i,new}} = R_i \left(1 - \lambda_{\mathrm{td}} R_j\right) \tag{7.10}$$

$$R_{j,\text{new}} = \lambda_{\mathrm{td}} R_j + (1 - \lambda_{\mathrm{td}} R_i) \tag{7.11}$$

where $\lambda_{td} \in \{0, 1\}$ and$\lambda_{td+1} = 2.3\ (\lambda_{td})^{2\sin(\pi\lambda_{td})}$ and where in λ_{td} the suffix "td" is increased by 1, when the reaction is completed.

Step 3.4: Redox 2 Reaction

In this reaction, if R_1 is a better reactant in terms of the objective function, then in $\lambda_{tr,}$ the suffix "tr" is updated by using 1 when the reaction is performed and it is computed using the following equation:

$$R_{i,\text{new}} = R_i + \lambda_{tr}\left(R_i - R_j\right); \text{where,}\quad \lambda_{tr} \in \{0, 1\} \tag{7.12}$$

Otherwise, if R_2 is a better reactant, then in $\lambda_{tr,}$ the suffix "tr" is updated by using 1 when the reaction is performed and it is computed using the following equation:

$$R_{j,\text{new}} = R_j + \lambda_{tr}\left(R_j - R_i\right); \text{where,}\quad \lambda_{tr} \in \{0, 1\} \tag{7.13}$$

The value of λ_{tr} is computed using the following equation:

$$\lambda_{tr+1} = \begin{cases} 0 & \lambda_{tr} = 0 \\ \frac{1}{\lambda_{tr} \bmod(1)}\lambda_{tr} & \lambda_{tr} \in (0, 1) \end{cases} \tag{7.14}$$

$$1/\lambda_{tr} \bmod(1) = \frac{1}{\lambda_{tr}} - \left\lfloor \frac{1}{\lambda_{tr}} \right\rfloor \tag{7.15}$$

Step 3.4: Monomolecular Reactions

Step 3.4.1: Decomposition Reaction

In this reaction, suppose $R = (R_1, R_2 \ldots R_i, R_j, \ldots, R_n)$ is the reactant and $C_k \in \{R_m, R_n\}$ is an atom that takes part in monomolecular reaction. The new atom of the molecule $R_{i,\text{ new}}$ is a random population or reactant from $\{R_m, R_n\} \in C_k$, but $\{R_m, R_n\} \neq (R_i \text{ and } R_j)$.

Step 3.4.2: Redox 1 Reaction

In this reaction, the new reactant is generated using the following procedure:

$$R_{i,\text{new}} = R_m + \lambda_t\ (R_n - R_m) \tag{7.16}$$

where $\lambda_t \in \{0, 1\}$ such that initial $\lambda_0 \in \{0.0, 0.25, 0.5, 0.75, 1.0\}$ and $\lambda_{t+1} = 4\lambda_t(1 - \lambda_t)$; t is updated by using 1 when the reaction is performed.

Step 4: Reactants Update

In this step, a chemical equilibrium test is carried out. If the fitness function of the new generated reactants is better than another, the generated reactant includes into the chemical reaction process and excludes the worst reactant from reversible chemical reactions.

Table 7.1 Description of the datasets used for experiment

Dataset	Cluster (K)	Attributes	Objects	Objects in clusters
Iris	3	4	150	(50, 50, 50)
Wine	3	13	178	(59, 71, 48)
CMC	3	9	1473	(629,334, 510)
Cancer	2	9	683	(444, 239)
Glass	6	9	214	(70,17, 76, 13, 9, 29)

Step 5: Termination Condition
If the Reactnum is equal to the user-defined maximum number of iterations, then the algorithm stops its execution and produces the optimal cluster centers; otherwise steps 3 and 4 are repeated, until the desired results are not obtained or termination condition is not satisfied.

7.5 Simulation Results

This section presents the experimental results of our study. To examine the efficacy of the proposed ACRO based clustering algorithm, some well-known benchmark datasets are taken from the UCI repository. These datasets are iris, CMC, glass, wine, and cancer. The description these datasets are reported in Table 7.1. Further, in this work, intra-cluster distance and f-measure parameters are adopted as performance measure parameters. The intra-cluster distance parameter presents the quality of clusters, and it can be measured using best, average, and worst intra-cluster distances. The precision can be computed using f-measure parameter. The MATLAB environment is used to implement the proposed algorithm using Windows-based operating system. Table 7.1 demonstrates the details of datasets taken for the experiments. The simulation results of proposed algorithm are compared with other well-known clustering algorithms K-means [15], particle swarm optimization (PSO) [20], ant colony optimization (ACO) [17], and bat algorithm (BA) [5].

7.5.1 Performance Matrices

In this section, different performance matrices are described that are adopted to compute the performance of the ACRO algorithm for partitional clustering problems. In this work, f-measure and intra-cluster distance parameters are taken to evaluate the performance of the algorithms. These matrices are explained as below.

- Intra-cluster distances

This parameter is used to compute the distance between data objects and cluster centers and also represents the quality of clustering. The results describe using best, average, and worst cases.

- F-Measure

It is expressed in terms of recall and precision. The value of f-measure parameter is computed through Eq. 7.17.

$$F\left(i,j\right) = \sum_{i=1}^{n} \frac{n_i}{n}^{*} \max_{i}^{*} F\left(i,j\right) \tag{7.17}$$

Where, $F(i,j)$is determined using Eq. 7.18.

$$F\left(i,j\right) = \frac{2 * (\text{Recall} * \text{Precision})}{(\text{Recall} + \text{Precision})} \tag{7.18}$$

The recall and precision are measured using Eq. 7.19.

$$\text{Recall}\left(r\left(i,j\right)\right) = \frac{n_{i,j}}{n_i} \quad \text{and} \quad \text{Precision}\left(p\left(i,j\right)\right) = \frac{n_{i,j}}{n_j} \tag{7.19}$$

7.5.2 Results and Discussion

This subsection describes the results of our study using proposed algorithm. Tables 7.2 and 7.3 present the results of the proposed ACRO algorithm and other clustering using artificial dataset 1 and artificial dataset 2. It is noticed that the proposed algorithm gives better results in comparison to all other algorithms. It is also observed that K-means algorithm obtains worst results among all other algorithm using intra-cluster distance parameter both of artificial dataset1 and artificial dataset 2 using intra-cluster distance parameter.

Tables 7.4 and 7.5 illustrate the results of the proposed algorithm and other algorithms using iris and cancer dataset. It is reported that the proposed algorithm

Table 7.2 Performance comparison of proposed ACRO and other algorithms using artificial dataset 1

Parameters	K-means	PSO	ACO	CSO	BA	Proposed ACRO
Best case	161.32	153.45	154.29	159.73	151.81	143.36
Avg. case	166.12	161.24	158.52	163.37	154.98	149.56
Worst case	174.64	169.39	165.42	168.13	159.08	154.21
SD	7.625	6.437	4.712	5.418	4.564	5.243
F-Measure	0.94	0.96	0.99	0.95	0.97	1

Table 7.3 Performance comparison of proposed ACRO and other algorithms using artificial dataset 2

Parameters	K-means	PSO	ACO	CSO	Bat	Proposed ACRO
Best case	761.45	753.24	759.87	752.34	756.09	746.53
Avg. case	768.38	759.82	766.15	756.21	761.44	752.26
Worst case	776.49	769.58	773.41	764.39	169.17	758.13
SD	6.837	7.614	6.845	4.936	5.432	4.214
F-Measure	0.89	0.91	0.93	0.937	0.946	0.976

Table 7.4 Performance comparison of proposed ACRO and other algorithms using iris dataset

Parameters	K-means	PSO	ACO	CSO	Bat	Proposed ACRO
Best case	97.52	97.05	97.21	96.98	96.84	95.56
Avg. case	113.56	98.73	98.36	97.64	97.53	96.73
Worst case	125.23	99.89	99.59	98.78	98.09	97.48
SD	15.326	0.467	0.426	0.392	0.263	0.196
F-Measure	0.781	0.78	0.778	0.781	0.782	0.785

Table 7.5 Performance comparison of proposed ACRO and other algorithms using cancer dataset

Parameters	K-means	PSO	ACO	CSO	Bat	Proposed ACRO
Best case	2989.46	2978.68	2983.49	2985.16	2972.36	2912.66
Avg. case	3248.25	3116.64	3178.09	3124.15	3098.93	3063.34
Worst case	3566.94	3358.43	3292.41	3443.56	3282.75	3179.25
SD	256.58	107.14	93.45	128.46	56.24	71.22
F-Measure	0.832	0.826	0.829	0.831	0.833	0.835

obtains better quality results than other algorithms. Further, it is noted that the K-means algorithm obtains a maximum intra-cluster distance among all algorithms using both of datasets. It is also noticed that the performance of the K-means, PSO, ACO, and CSO algorithm is similar in case of f-measure parameter using iris dataset. But, the significant difference occurs in terms of intra-cluster distance parameter. It is observed that the PSO algorithm has worst performance using f-measure parameter among the rest of algorithms for cancer dataset.

Tables 7.6, 7.7, and 7.8 demonstrate the results of proposed ACRO and other algorithms using CMC, wine, and glass dataset. It is revealed that the proposed algorithm provides enhanced results in comparison to other algorithms for CMC and wine datasets. Moreover, it is noticed that the performance of BA algorithm is better for the glass dataset in comparison to all other algorithms. Further, it is reported that K-means algorithm obtains maximum intra-cluster distance for CMC and wine datasets, whereas, an ACO algorithm obtains a maximum intra-cluster distance for glass dataset. For wine and glass datasets, K-means and ACO algorithms exhibit worst f-measure results. In case of the CMC dataset, PSO, ACO, and CSO provide similar f-measure results.

Table 7.6 Performance comparison of proposed ACRO and other algorithms using CMC dataset

Parameters	K-means	PSO	ACO	CSO	Bat	Proposed ACRO
Best case	5828.25	5792.48	5756.42	5712.78	5689.16	5681.56
Avg. case	5903.82	5846.63	5831.25	5804.52	5778.14	5746.32
Worst case	5974.46	5936.14	5929.36	5921.28	5914.25	5894.63
SD	49.62	48.86	44.34	43.29	39.54	36.41
F-Measure	0.337	0.333	0.332	0.334	0.336	0.339

Table 7.7 Performance comparison of proposed ACRO and other algorithms using wine dataset

Parameters	K-means	PSO	ACO	CSO	Bat	Proposed ACRO
Best case	16768.18	16483.61	16448.35	16431.76	16372.02	16256.42
Avg. case	18061.24	16417.47	16530.53	16395.18	16357.89	16336.21
Worst case	18764.49	16594.26	16616.36	16589.54	16556.76	16396. 56
SD	796.13	88.27	48.86	62.41	41.78	37.83
F-Measure	0.519	0.516	0.522	0.521	0.523	0.526

Table 7.8 Performance comparison of proposed ACRO and other algorithms using glass dataset

Parameters	K-means	PSO	ACO	CSO	Bat	Proposed ACRO
Best case	222.43	264.56	273.22	256.53	256.47	261.47
Avg. case	246.51	278.71	281.46	264.44	261.61	266.23
Worst case	258.38	283.52	286.08	282.27	278.24	274.14
SD	18.32	8.59	6.58	15.43	7.09	8.11
F-Measure	0.426	0.412	0.402	0.416	0.430	0.428

Figures 7.1, 7.2 and 7.3 illustrate the dispersion of the data objects in artificial dataset 1 and dataset 2, respectively. These artificial datasets are generated in the MATLAB. Artificial dataset 1 is a two-dimensional dataset, whereas artificial dataset 2 is three-dimensional datasets. Figures 7.2, 7.3 and 7.4 show the clustering of the data objects into different clusters using the proposed algorithm.

Figures 7.5 and 7.6 show the clustering of the iris dataset using proposed artificial chemical reaction optimization algorithm. The data objects of iris dataset are divided into three clusters such as setosa, versicolor, and virginica. It is seen that data objects in setosa cluster are linearly separable from versicolor and virginica, while the data objects of versicolor and virginica clusters are linearly inseparable that can also affect the performance of the algorithm. But, it is observed that the proposed algorithm gives better results for all three clusters. Figure 7.5 shows the illustration of the data objects of the iris dataset using sepal width and petal width attributes, whereas Fig. 7.6 shows the illustration of data objects using petal length, sepal width, and petal width.

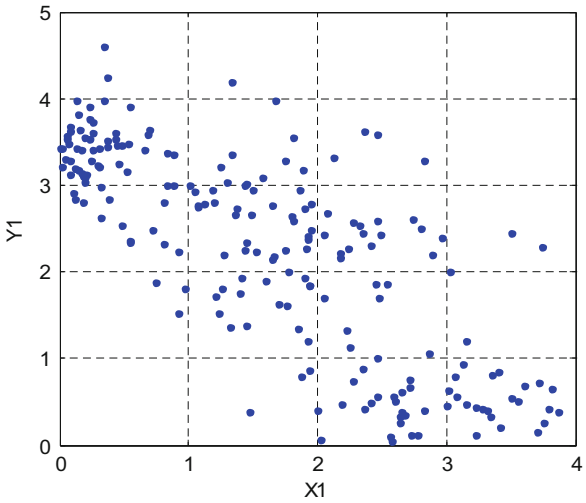

Fig. 7.1 Distribution of data objects in artificial dataset 1

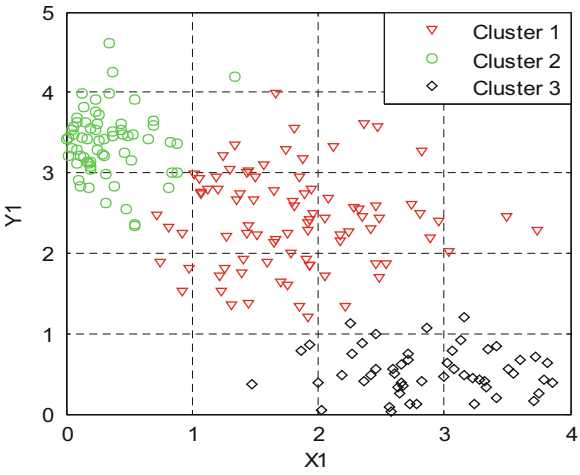

Fig. 7.2 Clustering results of proposed ACRO algorithm on artificial dataset 1

7.6 Conclusion

In this work, an artificial chemical reaction optimization algorithm is presented for solving partitional clustering problems. The proposed algorithm is inspired by the chemical reaction process. In this algorithm, reactants are used to search the optimal solution, and these reactants are uniformly determined from the search space. Further, optimal solution for the problems can be represented using the reactants. The main work of the ACRO algorithm is to measure optimal cluster centroid for partitional clustering problems. The reactants represent the initial cluster centers, which are determined uniformly from the dataset. The proposed algorithm is applied to optimize the value of initially chosen reactants through its

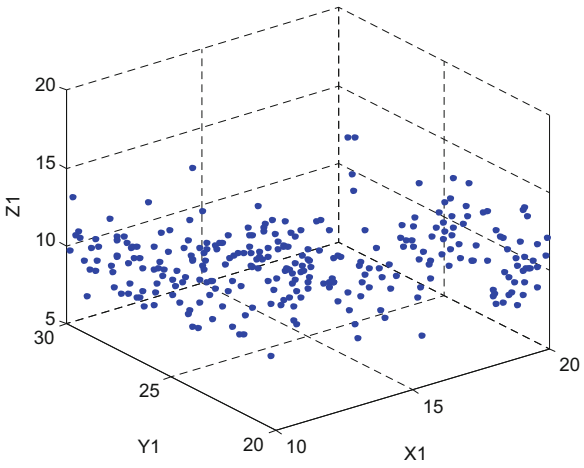

Fig. 7.3 Distribution of data objects in artificial dataset 2

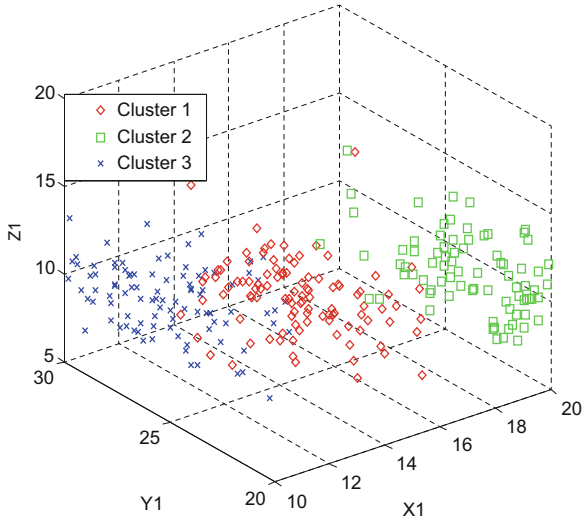

Fig. 7.4 Clustering results of proposed ACRO algorithm on artificial dataset 2

various steps. The performance of the proposed algorithm is tested on several real-life clustering problems and compared with state-of-the-art clustering algorithms. From the simulation results, it is noticed that the proposed algorithm achieves better clustering results in comparison to other clustering algorithms. Finally, it is stated that proposed ACRO algorithm is one of the efficient and effective algorithm for solving partitional clustering problems.

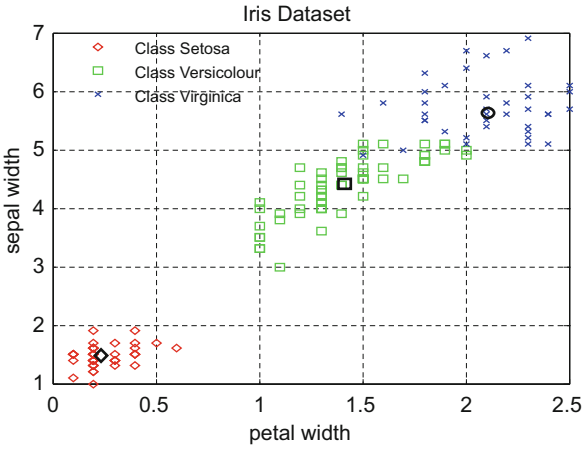

Fig. 7.5 Clustering results of proposed ACRO algorithm on iris dataset (2D view)

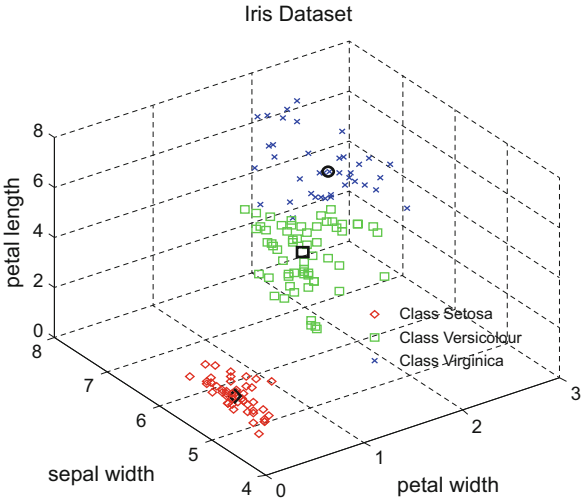

Fig. 7.6 Clustering results of proposed ACRO algorithm on iris dataset (3D view)

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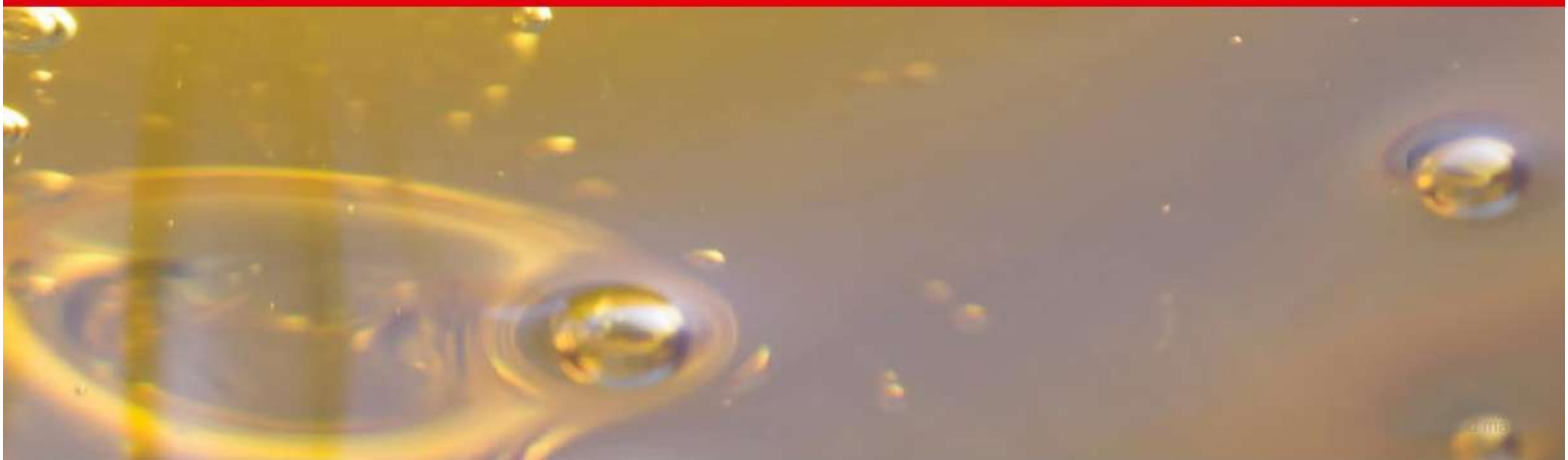

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Chapter 2

Palm Oil Mill Effluent as an Environmental Pollutant

Hesam Kamyab, Shreeshivadasan Chelliapan, Mohd Fadhil Md Din, Shahabaldin Rezania, Tayebeh Khademi and Ashok Kumar

Additional information is available at the end of the chapter

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Abstract

In recent decades, Malaysia has been known as one of the world's leading producers and exporters of palm oil products. Every year, the number of palm oil mills increases rapidly, thus increasing the capacity of fresh fruit bunch waste or effluent discharge. Based on the data from the Malaysian Palm Oil Board in 2012, Malaysia produced 99.85 million tons of fresh fruit bunch (FFB) per year. However, about 5–5.7 tons of water was required in order to sterilize the palm fruit bunches and clarify the extracted oil to produce 1 ton of crude palm oil resulting in 50% of the water turning into palm oil mill effluent (POME). POME is one of the major environmental pollutants in Malaysia. The characteristics of POME and its behavior, if discharged directly, in water are described in this chapter. The suspended solid and nutrient content in POME could be able to support the growth of algae. This chapter aims to demonstrate that POME could be used as a main source for algae production, and this effluent is one of the main environmental problems in the tropical region especially in Malaysia.

Keywords: POME, Malaysia, wastewater, environmental pollution,industry

1. Introduction

These days, palm oil enterprise is developing quickly and turning into a noteworthy agriculture-based industry in Malaysia. The quantity of palm oil mills has elevated relatively, at beginning with 10 mills in 1960 moved to 410 operated mills in 2008. At least 44 million tons of POME was produced and are increasing every year in Malaysia [1], particularly because of the initiative of the government to promote palm oil industry. While the palm oil industry has been recognized strongly for its contribution toward economic growth and rapid

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development, it has also contributed to environmental pollution due to the production of large quantities of by-products during the process of oil extraction [2, 3]. Furthermore, it is necessary to properly address the POME treatment so as not to contribute to human health hazards and environmental pollution.

POME is the wastewater produced by processing oil palm and comprises of different suspended materials. POME is 100 times more polluted than the municipal sewage which has a high biochemical oxygen demand (BOD) and chemical oxygen demand (COD). The effluent also contains higher concentration of organic nitrogen, phosphorus and different supplement substance [4]. POME is a non-harmful waste; however, it will pose environmental issue because of vast oxygen draining capacity to oceanic framework because of natural and supplement substance. It is also known to be a good source of nutrients [5]. The waste products generated during palm oil processing consist of oil palm trunks (OPT), oil palm fronds (OPF), empty fruit bunches (EFB), palm pressed fibers (PPF) and palm kernel shells, less fibrous material such as palm kernel cake and liquid discharge POME [2]. The wastes are in the form of high organic matter concentration such as cellulosic wastes with a mixture of carbohydrates and oils. The discharge of untreated POME creates adverse impact to the environment [6].

Nowadays, biological process is the most common practice way for the treatment of POME based on anaerobic and aerobic ponding system [2]. While the emerging technologies for the treatment of POME, the notion of nurturing POME and its derivatives as valuable resources should not be dismissed. Furthermore, it is necessary to properly address the POME treatment so as not to contribute to human health hazards and environmental pollution. At the point when contrasted with those routine wastewater treatment processes which introduce activated sludge and living floc to degrade natural carbonaceous issue to CO_2, and microalgae may acclimatize natural toxins into cell constituents, for example, lipid and carbohydrate, therefore attaining pollutant decrease in a more ecological friendly way [7]. Actually, microalgae have turned into the consideration for both wastewater treatment and biomass production as early as 1950s [8]. Small scale and economically viable technologies that combine wastewater treatment and energy production can treat the industrial effluents and enhance the availability of the energy simultaneously [9]. The feasible way that is more attentions in the present time is the use of microalgae, which is known to have the potential to treat wastewater [10] such as removal of CO_2 and NOx [11] and high capacity of nutrient uptake [12]. The idea of using microalgae in wastewater treatment has been investigated since 1950s by Oswald and Gotaas [8]. There are several important aspects to be considered during the current study. POME is the major source of water pollutant in Malaysia [13]. For example, in a conventional palm oil mill, 600–700 kg of POME is generated for every 1000 kg of processed fresh fruit bunches (FFB) [14]. By utilizing the ingredients present in POME, this study will play a major role to solve the pollution problem resulting from the POME as it will pollute the environment if it is improperly discharged into the environment.

2. Palm oil mill effluent

In particular, POME is a basic expression referring to the effluent from the last phases of palm oil manufacture in the mill. It incorporates different fluids, dirt, leftover oil and suspended

solids. POME in its untreated shape is a high quality waste, relying upon the operation of the procedure. POME is generated mainly from oil extraction, washing and cleaning processes in the mill, and these contain cellulosic material, fat, oil and grease, and so on [15]. POME also contains substantial quantities of solids; both suspended solids and total dissolved solids in the range of 18,000 and 40,500 mg/L, respectively.

Oil palm is the most productive oil producing plant in the world, with 1 ha of oil palm producing between 10 and 35 tons of fresh fruit bunch (FFB) per year [15]. During processing of oil palm, more than 70% by weight of the fresh fruit brunch was left over as waste [16]. Usually, the harvested part is the fruit whereby oil is obtained from the fleshy mesocarp of the fruit. Despite the importance of the edible oil and fats extracted from the palm fruits, the POME contains residual oil which affects the environment cannot be ignored. Treatment and disposal of oily wastewater such as POME is presently one of the serious environmental problems. Palm oil mill wastes have existed for years but their effects on environment are at present more noticeable [15]. The oily waste has to be removed to prevent problems which are considered as hazardous pollutants particularly in the aquatic environments because they are highly toxic to the aquatic organisms. Discharging the effluents or by-products on the lands or release to the river may lead to pollution and might deteriorate the surrounding environment. In order to conserve the environment, an efficient management system in the treatment of these by-products is needed [17]. Treatment of POME is essential to avoid environmental pollution [18].

POME wastes are the fiber free non-oil components obtained from the clarification zone of an oil mills. The significant contamination comes out of the fresh fruit brunch (FFB). In fact, every ton of FFB is composed of 230–250 kg of empty fruit bunches (EFB), 130–150 kg of fibers, 60–65 kg of shell and 55–60 kg of kernels and 160–200 kg of unrefined oil [19]. POME contains high amounts of oil and grease (4000 mg/L) and COD (50,000 mg/L). Although the effluent is nontoxic, it has a very high concentration of biochemical oxygen demand (BOD) (i.e., 25,000 mg/L) which becomes a serious threat to aquatic life when discharged in relatively large quantities into watercourses. The high amount of total solids (40,500 mg/L) contributes to the large amount of nutrients available in the wastewater, hence possible algae bloom.

Most palm oil mills in Malaysia have adopted the ponding system for the treatment of POME [20]. In general, there are four types of treatment systems adopted by the palm oil industry, which are as follows:

a. Waste stabilization ponds,

b. Activated sludge system,

c. Closed anaerobic digester and

d. Land application system.

The most proper secondary treatment for POME is natural assimilation with the blend of anaerobic and aerobic ponds. Right now, the management of POME has developed from treatment of waste for transfer to gainful use of assets. POME contains generous amounts of significant plant supplement that shift as indicated by the level of treatment to which it is subjected. The potential utilization of recovery of water and natural issues from POME has been applied for different applications [21]. Commercial trials and applications of these

technologies are currently underway, especially conversion of the solid residual materials into saleable value-added products.

2.1. Malaysian palm oil industry

In 2011, Malaysia was the second biggest oil palm producer in the world, with an aggregate of 16.6 million tons, a sum lesser than 1% from the total world's supply behind Indonesia. Since the oil palm industry is tremendous, with 67% of agricultural land secured with oil palm tree, biomass from oil palm contributes the most. As of now, 85.5% of the biomass residues are originating from the oil palm industry. Palm oil has a very good potential in producing alternative energy due to its calorific content. With 50% efficiency, biomass from oil palm can generate 8 Mton of energy and can save RM 7.5 billion per year of crude oil [14, 19]. More than 85% of palm oil mills in Malaysia have adopted ponding system for treating POME [20], while the rest have opted for open digesting tank [22]. These methods are regarded as conventional POME treatment method, whereby longer retention time and large treatment areas are required [23]. The effluent that comes out from palm oil mill is hazardous to the ecosystem due to its high-volume composition and nutrient. The discharge can lead to land and aquatic pollution if it is left untreated [24].

In view of the measurement estimation of aggregate unrefined palm oil generation in May 2001, the production of 985,063 ton of crude palm oil means, a total of 1,477,595 m^3 of water is being used, and likewise, 738,797 m^3 POME is discharged for a month. Without appropriate treatment, this wastewater will contaminate the encompassing surrounding. The present treatment technology of POME normally comprises of natural aerobic and anaerobic digestion. Biologically treated effluent is disposed via land provision system, hence providing vital supplements for growing plants. This system might be a decent decision for the disposal of treated effluent. However, acknowledging those rates of daily wastewater generation, for instance, around 26 m^3/d for an average palm oil mill with an operating limit of 35 t/d FFB, it is doubtful that the surrounding plantations receiving it might effectively absorb all the treated effluent [25].

2.2. Palm oil management

Around 44 million m^3 of POME were produced in year 2013 to yield 19.66 million tons of total crude palm oil [14]. Around 85% of palm oil mills have treated raw POME using biological treatment [26]. The biological treatment of POME is a series of pond systems, including anaerobic, facultative and aerobic pond systems [19, 27]. However, the final treatment by aerobic pond system is struggling to achieve the discharge standards because of inefficient operational design [3]. The final effluent of the treated POME must comply with the discharge standards set by the Department of Environment (DOE), Malaysia. There is a requirement for a sound and effective management system in the treatment of these by-products in such a way that will assist to protect the environment and check the deterioration of air and river water quality. Treatment of POME is vital to avoid environmental contamination [28].

2.3. Current state of POME treatment

Indonesia and Malaysia are the two biggest oil palm manufacturing nations and is rich in various endemic and forest dwelling species [29]. Malaysia has a tropical atmosphere and is

prosperous with regular assets. Oil palm as of now involves the biggest real acreage of cultivated land in Malaysia [30, 31]. The total oil palm acreage from 1970 to 2000 has expanded from 320 to 3338 ha. In the year 2003, there were more than 3.79 million ha of land under palm oil cultivation, occupying more than 33% of the total developed area and 11% of the total land area of Malaysia [32]. Palm oil, edible oil, is derived from the meaty mesocarp of the fruit of oil palm (*Elaeis guineensis*). One hectare of oil palm produces 10–35 tons of fresh fruit bunches (FFB) per year [2, 33]. Malaysia produces about 41% of the world's supply of palm oil as shown in **Figure 1**. Malaysia also accounts for the highest percentage of global vegetable oils and fats trade in the year 2005 [34].

The oil palm has the expectancy of over 200 years, whereas the economic life is about 20–25 years. The nursery period is 11–15 months for plants, and first harvest is done after 32–38 months of planting. It takes 5–10 years for palm oil plant to reach the highest yield. The yield is approximately 45–56% of FFB, and the fleshy mesocarp of the fruit is used to get oil. The yield of oil from the kernel is about 40–50% [35]. Both mesocarp and kernel of fruit produce about 17 t ha^{-1} yr^{-1} of oil [6]. Starting with 5.8 ton of FFB about 1 ton of crude palm oil (CPO) is produced [2]. The world palm oil production is shown in **Table 1**.

While the oil palm industry has been recognized for its contribution toward economic growth and rapid development, it has also contributed to environmental pollution due to the production of huge quantities of by-products from the oil extraction process [2].

2.4. Characteristic of POME and utilization by microalgae

POME contains high content of degradable organic matter, which is due in part to the presence of uncovered palm oil [36]. The discharge of improperly treated POME creates adverse impact to the environment (**Table 2**). However, the substances in POME are able to support the growth of microalgae. Microalgae naturally exist in many palm oil mill processes, phenomena known as "algae bloom," hence declining the water quality. Because POME consists of large amount of organic compounds and inorganic compounds which is hazardous to environmental health, microalgae have been suggested as a potential candidate to remove these pollutants and able to breakdown the organic compounds present in it [37, 38].

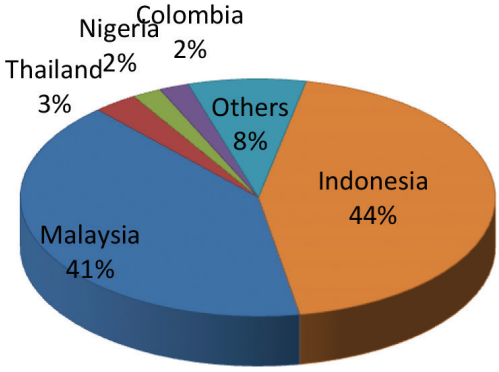

Figure 1. Palm oil production in 2007 [6].

Country	Share (%)	Amount (tons)
Indonesia	44	19,000
Malaysia	41	17,350
Thailand	3	1123
Nigeria	2	850
Colombia	2	832
Others	8	832

Table 1. World palm oil production [2].

Parameters	Concentration (mg/L)	Standard limit (mg/L)
pH	4.7	5–9
Oil and grease	4000	50
BOD	25,000	100
COD	50,000	—
Total solids	40,500	—
Suspended solids	18,000	400
Total nitrogen	750	150

Table 2. Characteristics of POME and its respective standard discharge limit by the Malaysian Department of Environment [19, 20].

Alternatively, culturing microalgae in wastewater offers an economy, which is alternative to the traditional types of wastewater treatment [39, 40]. In the meantime, microalgae can apply the nitrogen and phosphorus compound in wastewater to produce microalgae biomass for various kinds of lipid generation, which can serve as a substrate for biofuel production [38, 41].

POME is a colloidal suspension, starting from the blend of sterilizer condensate, separator sludge and hydrocyclone wastewater in a proportion of 9:15:1, respectively [1]. In total, about 2.5–3.0 tons of POME for huge amounts of produced crude palm oil is obtained in the extraction procedure [42]. Fresh POME is a thick brownish colloidal blend of water, oil and fine-suspended solids. It is hot (80–900°C) and has a high BOD, which is 100 times as contaminating as domestic sewage [1]. The effluent is not hazardous, as no chemicals are added to the extraction procedure [43], and also acidic with a pH around 4.5 as it contains organic acids in complex forms that are suitable to be used as carbon sources [44]. Palm oil mill effluent is a high-strength pollutant with low pH due to the organic and free fatty acids arising from partial degradation of palm fruits before processing. The characteristics of POME depend on the quality of the raw material and the production processes [24]. It typically contains large amounts of total solids (40,500–75,000 mg/L) and oil and grease (2000–8300 mg/L). Its total nitrogen in the range of 400–800 mg/L and suspended solids contents in the range

of 18,000–47,000 mg/L. POME also has very high BOD and COD contents which are in the range 25,000–54,000 mg/L and 50,000–100,000 mg/L, respectively [45]. POME while fresh is hot acidic and pH range between 4 and 5, brownish colloidal suspension containing high concentrations of natural matter, high quantities of total solids (40,500 mg/L), oil and grease (4000 mg/L) COD (50,000 mg/L) and BOD (25,000 mg/L) [15]. However, it also contains appreciable amounts of N, P, K, Mg and Ca which are the vital nutrient elements for plant growth [46]. The characteristic of POME based on Malaysian Palm Oil Board is shown in **Table 3**.

According to Kamyab et al. [46], the raw or partially treated POME has an extremely high content of degradable organic matter. However, it has nontoxic nature and has fertilizing properties, POME can be used as fertilizer or animal feed substitute, in terms of providing sufficient mineral requirements. The Malaysian government provides an effort to reduce the effluent of palm oil through licensing system, which mainly consists of effluent standards and effluent charges. According to POME characteristic and standard discharge limit in Environmental Quality Act (EQA) 1974, the palm oil industry faces the challenge of balancing the environmental protection, its economic viability and sustainable development. The year 1978 witnessed the enactment of the Environmental Quality Regulations detailing POME discharge standards. **Table 4** shows the palm oil mill effluent discharge standard that must be followed.

Normally, the characteristics of POME may vary considerably for different batches, days and factories, depending on the processing techniques and the age or type of fruit as well as the discharge limit of the factory, climate and condition of the palm oil processing [19]. Occasional oil palm cropping and activities of the palm oil will also impact those quality and quantity of the discharged POME, thus influence the ecological treatment procedure of POME [27]. Hence, the variation of the characteristics of POME, in terms of its quality and quantity, is the main reason that causes selection in the treatment of POME in the palm oil industries [1, 47].

Parameter	Mean	Range
pH	4.2	3.4–5.2
Biological oxygen demand	25,000	10,250–43,750
Chemical oxygen demand	51,000	15,000–100,000
Total solids	40,000	11,500–79,000
Suspended solids	18,000	5000–54,000
Volatile solids	34,000	9000–72,000
Oil and grease	6000	130–18,000
Ammoniacal nitrogen	35	4–80
Total nitrogen	750	180–1400

*Units in mg/L except pH.

Table 3. Characteristics of POME [14].

Palm oil mill effluent discharge standards	1/7/78–30/6/79	1/7/79–30/6/80	1/7/80–30/6/81	1/7/81–30/6/82	1/7/82–31/12/83	1/1/84–there after
pH	5–9	5–9	5–9	5–9	5–9	5–9
BOD	5000	2000	1000	500	250	100
COD	10,000	4000	2000	1000	—	—
Total solids	4000	2500	2000	1500	—	—
Suspended solids	1200	800	600	400	400	400
Oil and grease	150	100	75	50	50	50
Ammoniacal nitrogen	25	15	15	10	150	100
Total nitrogen	200	100	75	50	—	—
Temperature °C	45	45	45	45	45	45

*Units in mg/L except pH and temperature.

Table 4. Environmental quality [14, 42].

2.5. Wastewater treatment technology

The wastewater treatment technologies are expensive, dependent on skilled personnel and hard to carry out, as the volume of contaminated wastewater is huge [38]. Furthermore, the common conventional treatment is unable to meet the regulations set by the Department of Environment (DOE) with the level of BOD at 100 mg/L. According to Ahmad et al. [19], large quantities of water are used during the extraction of crude palm oil from the fresh fruit bunch, and about 50% of the water results in POME. The disposal of this very contaminating effluent is turning into a noteworthy issue assuming that it may be not continuously treated appropriately as well as a severe standard boundary obligatory set by the Malaysian Department of Environment for the discharge of effluent. A POME treatment system based on membrane technology shows high potential for decreasing the ecological issue, and also, this alternative treatment system offers water reusing [19].

The utilization of wastewater for the microalgal growth is considered beneficial for limiting the utilization of freshwater, dropping the cost of supplement option, expelling nitrogen and phosphorus from wastewater and generating microalgal biomass as bioresources for biofuel or value-added by-products. Three primary sources of wastewater are municipal (domestic), agricultural and industrial wastewater which included a variety of elements. Some elements in the wastewater, such as nitrogen and phosphorus, are valuable components for microalgal cultures [48].

2.6. POME as nutrients source to culture microalgae

A life cycle assessment on microalgae cultivation has underlined that 50% of energy use and greenhouse gas emissions are associated with fertilizer (nutrients) [49]. In general, culturing of microalgae on a large scale required high nitrogen and other related chemical fertilizers, which driven the process toward non-environmental friendly. On the other hand, culturing microalgae can actually play an important role as a self-purification process of natural wastewaters [50].

Utilizing POME as supplements source to culture microalgae is not an another scenario in Malaysia. Most palm oil millers favor the culture of microalgae as a tertiary treatment before POME is released because of practically low cost and high impact. Consequently, vast majority of the nutrients such as nitrate and ortho-phosphates that are not detached during anaerobic digestion will be additionally treated in a microalgae pond. Thus, the cultured microalgae will be used as a food nutrition for live feed culture [50] Meanwhile, nitrogen source (usually

Source of POME/ concentration	Microalgae	Growth condition	References
POME collected from pond with no dilution	*Chlorella pyrenoidosa*	3 L PBR system	[56]
		Temperature: 24–26°C	
		Mixing 60 rpm	
		Lighting 8 h:16 h L:D	
		pH 6.5–7.5	
		Light intensity of 150 μmol m^{-2} s^{-1}	
Fresh POME with dilution 50% + 1 g/L urea	*Chlorella* sp.	1 L glass flask disk	[4]
		Light intensity 3000 lx	
		pH 6.8–7.2,	
		Temperature 28°C	
		Mixing using aeration aquarium air pump	
POME from anaerobic pond with 40% dilution	*Spirulina platensis*	1 L glass flask disk	[57]
		Mixing using aeration aquarium air pump	
		pH 9–10.5	
		Light intensity, 4000–6000 lx	
POME collected from pond with concentration 250 mg COD/L	*Chlorella sorokiniana*	Room temperature	[58]
		Light intensity-continuous illumination at intensity of ±15 μmol m^{-2} s^{-1}	
POME collected from pond with concentration 250 mg COD/L	*Chlorella pyrenoidosa*	5 L HPBR reactor with turbine impeller	[46]
		Temperature, 30°C	
		Light intensity, illuminated by four 32 W white fluorescence light continuous lighting (24 h) (Philip, Germany)	
		C:N, 100:6	
		OLR, 36 kg COD m^{-3} d^{-1}	
POME collected from pond with concentration 250 mg COD/L	*Chlamydomonas incerta*	250 mL Erlenmeyer flask	[38]
		Temperature, 30°C	
		Light intensity, 15 μmol m^{-2} s^{-1}	
		C:N, 100:7	
		OLR, 36 kg COD m^{-3} d^{-1}	

Source of POME/ concentration	Microalgae	Growth condition	References
Fresh POME with dilution of 500 mL of POME in 400 mL deionized water	*Chlorella* sp.	1 L conical flask Pressure regulators bring down the pressure of both CO_2 and compressed air to 2 bars before entering their flow meters. The sparging tube of a flask culture was placed at the bottom of the flask Light intensity, 10,000 lx CO_2 concentration (% v/v), 16% Sparging rate (vvm), 0.8 vvm	[59]
Fresh POME with dilution of 1%	*Arthrospira platensis*	10 L of culture media in 20 L tank Outdoor	[60]

Table 5. Growth conditions for microalgae using POME.

appears in nitrate form) plays an important role in promoting microalgae growth. In order to grow microalgae effectively, the basic nitrate concentration required is in the range of 200–400 mg/L [51]. Others minerals such as Fe, Zn, P, Mg, Ca and K that are required for microalgae growth are also present in POME. Thus, POME emerged to be an alternative option as a chemical remediation to grow microalgae for biomass production and simultaneously act as a part of wastewater treatment process [50].

These days, there is an incredible and nonstop increment in industrialization, foundation and urban expansion in Asia, which has added to the critical wastes demand and water deficiency because of water contamination [52]. Industry in particular agro-based industry is one of the significant divisions releasing extensive amount of wastewater yearly influencing the other water sources and human life. The palm oil industry in Malaysia is generating the biggest amount of natural contamination loads into rivers [30, 33]. POME is a highly polluted waste having unpleasant odor. There is a greater need to find alternative way to utilize these organic pollutants for the good benefit of both human beings and the environment [21]. Microalgae cultivation in POME offers an alternative to conventional forms of tertiary wastewater treatments and spontaneously utilizes organic compounds present in POME to generate microalgae biomass for algae oil production [50]. There are several environmental and operational factors, which can affect the microalgae growth in order to make the cultivation fruitful. The natural effluent discarded from palm oil mill might be colloidal, dark and viscous, which should be considered prior media preparation for culturing the microalgae [53]. Vairappan and Yen [54] had found that for the marine *Isochrysis* sp., the concentration of POME at 5% dilution is the best concentration for culture media due to properties of POME. This dilution procedure will then enhance the light penetration into media for the algal growth in wastewater [55]. As described in **Table 5**, limited growth conditions are required for the growth of microalgae using palm oil mill effluent.

The concentrated nutrients (i.e., C, N, P, carbohydrate, lipid, protein and minerals) in POME are highly applied in biotechnology studies for growing microalgae [46]. The concentration extend about POME in various accepting water body may give high effect on the aquatic environments if the release surpasses the limit of standards set by Malaysia Environmental Quality Act.

Microalgae	Nutrient reduction (%)	Lipid production (%)	Growth rate (d^{-1})	Biomass productivity (g/L/d)	Duration (d)	Ref.
C. pyrenoidosa	—	42	—	2.19	18	[56]
Chlorella sp.	—	—	0.066	0.058	15	[57]
S. platensis	—	—	—	9.8	13	[57]
C. sorokiniana	—	28.27	0.099	8.0	20	[58]
C. pyrenoidosa	COD, 71.16%	68	1.8	0.13	10	[28]
Chlorella sp.	—	—	—	1.562	7	[59]
A. platensis	—	—	—	0.211	7	[60]

Table 6. Microalgae growth in POME.

Numerous species of microalgae exist in freshwater, seawater or brackish make them appropriate to be grown in great scale reactor on unfertile lands. The usage of macroalgae and microalgae in the utilization or remediation of the excess nutrients and CO_2 present in natural water resources, lagoons and ponds is called as phycoremediation [55]. This biological remediative treatment was introduced about 40 years ago when it was usually used in tertiary wastewater treatment [61]. The performance of microalgae growth cultivated in POME is shown in **Table 6**.

As seen from **Table 6**, Kamyab et al. [28] have done their studies by focusing on the nutrients reduction in POME, lipid production and microalgae growth. Meanwhile, it can be found that other researchers have not focused much on nutrient reduction, which is to be considered more important in relation to the growth of microalgae.

3. Conclusion

Malaysia is the biggest generator and exporter of palm oil. Palm oil processing is achieved in palm oil mills where oil is removed from a palm oil fruit bunch. Expansive amounts of water are utilized throughout the extraction of crude palm oil from the fresh fruit bunch, and around half of the water consequences in POME, which is a highly polluting wastewater that pollutes the environment if discharged directly due to its high COD and BOD concentration. In conclusion, the research was carried out mainly to investigate the influence of discharging POME from the treatment plant especially in tropical region like Malaysia and the effect on microalgae growth efficiency in POME. In other words, a combination of wastewater treatment and renewable bioenergies production would be an added advantage to the palm oil industry.

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Conflict of interest

The authors declare that there is no conflict of interest.

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Matrix Method for Evaluation of Existing Solid Waste Management Processes in Jalandhar City, Punjab, India



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Abstract Solid waste management is one of the most serious problems being faced by Indian cities due to increased urbanization and industrialization in India. The present study highlights the existing status of solid waste management practices in Jalandhar city, Punjab, India considering a dumpsite of Wariana village and Suchipind of Jalandhar and suggests remedial measures to the major problems being faced by the existing system of solid waste management. The waste generation of municipal solid waste in Jalandhar city was reported as 400 ton per day. A total of 350 ton of solid waste is disposed of in different disposal sites daily in the city. The per capita waste generation rate in Jalandhar is approximately 0.6 kg/capita/day. The collection efficiency of the municipal solid waste is reported about 70% in the city. The study also summarizes the 'wasteaware' benchmark indicators for the evaluation of the existing scenario of solid waste management in Jalandhar city and matrix method for comparing the overall score of the existing management of municipal solid waste of Jalandhar city with Chandigarh city. The overall score of the analysis of the matrix method for Jalandhar city was reported as 32% and the same for Chandigarh city was 46%. However, the quantification score of Jalandhar city was considerably lower than Chandigarh city. The analysis of matrix method suggested that the management of municipal solid waste in Jalandhar city can be categorized under the category of low index, whereas Chandigarh city was categorized under low–medium index.

Keywords Municipal solid waste · Open dumping · 'Wasteaware' benchmark indicators · Matrix method

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12.1 Introduction

Increased urbanization and industrialization has led to severe environmental pollution in the cities due to the drastic increase in the generation of solid waste (Puri et al. 2008; Sethi et al. 2013). Population growth and rising living standards contribute to an increase in the amount and variety of solid waste generated in the countries. In particular, solid waste management has been a pertinent issue for developing countries (Shekdar 2009). The poor waste management practices are primarily due to the lack of authentic data and information to analyse the waste management practices (Chang and Davilla 2007; Hancs et al. 2011; Katiyar et al. 2013). The population of India is reported as 1083 million in 2001 and 1253 million in 2013 (Census report 2011). In general, Indian megacities including [Ahmedabad (6.3 million), Hyderabad (7.7 million), Bengal (8.4 million), Chennai (8.6 million), Kolkata (14.1 million), Delhi (16.3 million) and Greater Mumbai (18.4 million)] having a drastical increase in population as reported by Kumar et al. (2009). The substantial growth in population is the major contributor of solid waste in country (Anand 2005). There is no proper statistics about the nature, volume, collection, transportation and dumping of solid wastes generated in city (Sharholy et al. 2008; Ramachandra 2009). Since there is a lack of proper management of solid wastes, its increased generation coupled with lack of public awareness makes it potentially effective in causing environmental and human health effects. Further, it also reduces the visual aesthetics of the surrounding environment. In India, the existing status of municipal solid waste management is highly unsatisfactory. Currently, about 960 million tonnes of solid waste is being generated annually as by-products during municipal, industrial, mining, agricultural and other processes in India (Pappu et al. 2004). The per capita waste generation is 0.17 kg/capita/day in small towns and 0.62 kg/capita/day in the cities of India (Kumar et al. 2009; Modak et al. 2012). The population growth of major cities in India has been shown in Table 12.1. The statistics of municipal solid waste generated in different states in India has been shown in Table 12.2 and the waste generation rate of major cities in India has been shown in Table 12.3.

Solid waste thus generated in India is not managed properly due to the poor management of municipal corporation of the cities; about 90% of the waste is disposed of as an open dumping in the ground and hence contributes to the

Table 12.1 Population growth of major cities in India (Census 2011)

Sl. No.	City name	Population growth (10^6)
1.	Ahmedabad	6.3
2.	Hyderabad	7.7
3.	Bangalore	8.4
4.	Chennai	8.6
5.	Kolkata	14.1
6.	Delhi	16.3
7.	Mumbai	18.4

Table 12.2 Statistics of municipal solid waste generated in different states in India (CPCB 2015)

Sl. No.	Name of the state/UT	Municipal solid waste MT/day (2009–2012)
1.	Andaman and Nicobar	50
2.	Andhra Pradesh	11,500
3.	Arunachal Pradesh	93.802
4.	Assam	1146.28
5.	Bihar	1670
6.	Chandigarh	380
7.	Chhattisgarh	1167
8.	Daman Diu and Dadra	41
9.	Delhi	7384
10.	Goa	193
11.	Gujarat	7378.775
12.	Haryana	536.85
13.	Himachal Pradesh	304.3
14.	Jammu and Kashmir	1792
15.	Jharkhand	1710
16.	Karnataka	6500
17.	Kerala	8338
18.	Lakshadweep	21
19.	Maharashtra	19.204
20.	Manipur	112.9
21.	Meghalaya	284.6
22.	Mizoram	4742
23.	Madhya Pradesh	4500
24.	Nagaland	187.6
25.	Orissa	2239.2
26.	Puducherry	380
27.	Punjab	2793.5
28.	Rajasthan	5037.3
29.	Sikkim	40
30.	Tamil Nadu	12,504
31.	Tripura	360
32.	Uttar Pradesh	11.585
33.	Uttaranchal	752
34.	West Bengal	12,557
Total		127,485.107

environment pollution. The major problem of ineffective management of solid waste is due to deficit of requisite budgetary provisions for the management of solid waste (Rana et al. 2015).

Table 12.3 Waste generation of major cities in India (CPCB 2015)

Region/city	MSW (TPD)	Compostable (%)	Recyclables (%)	Inerts (%)	Moisture (%)	Cal. value (kcal/kg)
Metros	51,402	50.89	16.28	32.82	46	1523
Other cities	2723	51.91	19.23	28.86	49	2084
East India	380	50.41	21.44	28.15	46	2341
North India	6835	52.38	16.78	30.85	49	1623
South India	2343	53.41	17.02	29.57	51	1827
West India	380	50.41	21.44	28.15	46	2341
Overall Urban India	130,000	51.3	17.48	31.21	47	1751

The present study focuses on the existing solid waste management systems practised in Jalandhar city, Punjab, India. The study also employs the 'Wasteaware Benchmark' techniques and matrix method for grading the efficiency of the existing system. The paper also proposes suitable remedial measures for improving the existing system of municipal solid waste management carried out at these sites.

12.2 Methodology

12.2.1 Site Location

Jalandhar city lies in the coordinates of 31.3260°N and 75.5762°E with a population of 8,73,725 (Census 2011) with an MSW generation of 400 TPD with a collection efficiency of 70% which is openly dumped in land. The location of study area has been shown in Fig. 12.1.

12.2.2 'Wasteaware' Benchmark Indicators

The problem of municipal solid waste management is getting more awful due to diverse factors including poor technical and less financial resources, deficit of enforcement of regulations, lack of coordination between the authorities and scarcity of policies (Kumar et al. 2009).

The major downside of the ineffectual municipal solid waste management system is the absence of relentless data for the designing and interpretation of effective solid waste management system for comparative basis. Integrated solid waste management benchmark indicators are the effective tool to analyse the performance of recycling and municipal solid waste management of the city and municipality. The basic principle of benchmark indicators is to allow the city to determine or

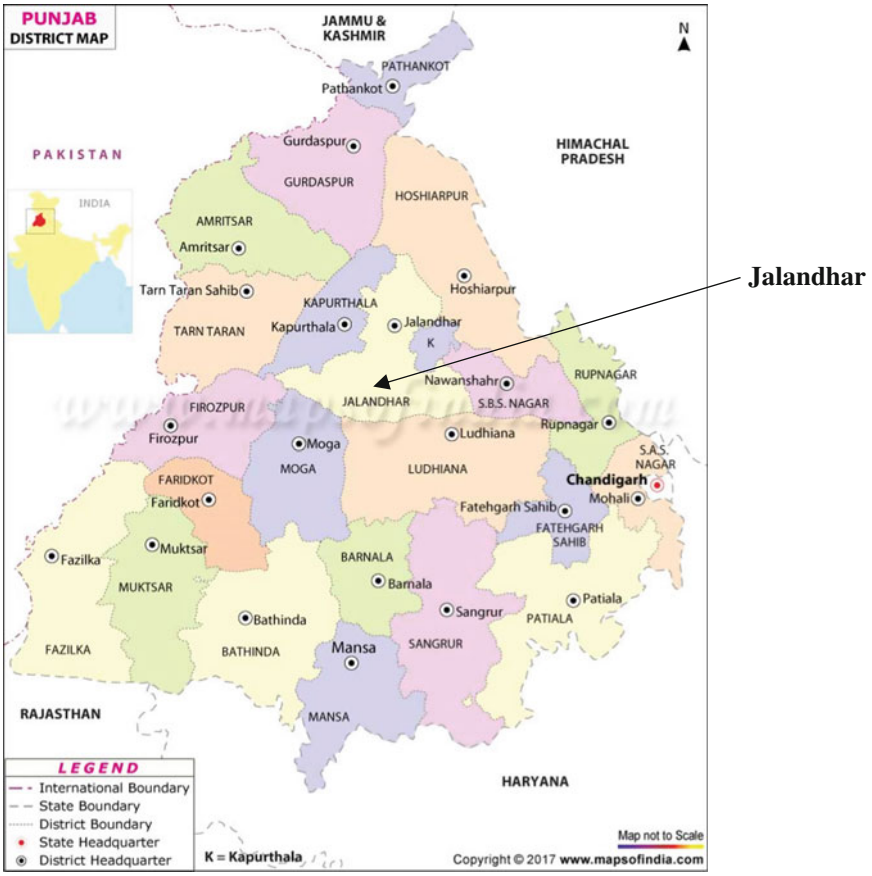

Fig. 12.1 Location of study area in Punjab

judge its performance of waste management services with different cities. Moreover, it also provides information for decision-making on primary issues regarding funds for the improvement of waste management services.

The 'wasteaware' benchmark parameters integrate both qualitative and quantitative indicators (Wilson et al. 2013, 2015) for determining the performance of municipal solid waste management systems practiced in different locations. In the quantitative analysis of waste management, the parameters include public health collection, environmental controlled disposal and resource management—reuse, reduce and recycling and the qualitative indicators consolidates governance parameters like user and provider inclusivity; financial sustainability; and the national policy framework and local institutions (Wilson et al. 2013, 2015).

12.2.3 Matrix Method

The quantification method has been employed for the consideration of existing municipal solid waste management system (Rana et al. 2015). In this context, the 'wasteaware' benchmarks utilized grading system including low (*L*), low/medium (*L*/*M*), medium (*M*), medium/high (*M*/*H*) and high (*H*), a five points classification has been assigned to each of these benchmarks. The above grading systems (*L*, *L*/*M*, *M*, *M*/*H* and *H*) were utilized by assigning each of them a classification point such as ($L = 1$, $L/M = 2$, $M = 3$, $M/H = 4$, $H = 5$). The matrix method has been successfully used to evaluate the functioning of the MSW management in tri-city locations of Chandigarh, Mohali and Panchkula (Rana et al. 2015, 2017) and at selected study locations in Himachal Pradesh (Sharma et al. 2018).

12.3 Results and Discussions

12.3.1 Assessment of Existing Municipal Solid Waste (MSW) Management in Jalandhar City

Generation of MSW Jalandhar city lies in the area of 110 m^2 with a total number of 60 wards as reported by Census (2011). The estimated garbage generation is 400 ton per day in the city and approximately 350 ton of waste is collected and disposed of daily in the dumpsites. The solid waste is generated from residential, commercial, institutional, construction and demolition, industrial, agriculture, etc. and the sources of solid waste are rubbish, garbage, ashes, street waste, bulk waste and hazardous waste (Puri et al. 2008). The area of the city is scattered into three zones including residential zone (85%), industrial zone (10%) and mixed zone (5%). The physical characterization of municipal solid waste has been summarized in Table 12.4.

Table 12.4 Physical characterization of waste (Puri et al. 2008)

Sl. No.	Parameters	Range	Average
1.	Metal (ferrous)	0.00–1.00	0.01
2.	Metal (non-ferrous)	0.00–0.04	0.13
3.	Earth-ware stone	0.50–15.00	5.17
4.	Glass/ceramics	0.00–2.10	0.57
5.	Fine earth	19.92–25.72	24.15
6.	Paper/cardboard	0.2–10.80	3.43
7.	Wooden matter	0.00–0.30	0.09
8.	Rags	0.10–9.80	3.95
9.	Rubber/leather	0.00–4.00	1.31
10.	Plastics	3.20–14.5	7.42
11.	Organic matter	6.90–68.10	44.53

Collection of MSW The type of waste containers and the area of waste storage are mainly based on the frequency and method of solid waste collection (both inorganic and organic waste). It is reported that more than 450 collection bins have been placed roadside in the city and around 60 DP bins of 3.5 m^3 capacities are placed at sensitive littering points. The sweeping frequency of waste has been reported twice in a day under the supervision of ward supervisor. Individual municipal solid waste collectors are also involved and every house is charged a fee of rupee 50 per month for the collection of municipal solid waste. These waste collectors informally separate the waste into biodegradable, paper, rubber, plastics, glass and metals and then, waste is transferred to Sehaj Safai Kendra's (SSKs). The considerable downside of waste management in Jalandhar city is ill-suited collection of municipal solid waste. The solid waste generated in the city is stored in common bins without any prior segregation of waste. There is no provision of separate bins for the dry waste and the wet waste. The rate of waste generation is more and the dustbins for the collection of solid waste are less in number. The insufficient number of dustbins contributes to the littering and spilling of waste and hence contributes to insanitary conditions of the city. It is observed that during the survey of solid waste management plans in the city, there is no provision of daily door-to-door collection of waste. The solid waste is collected from the collection bins from different locations of the city and from the residential and commercial sectors of the city. It is recommended from World Health Organization that the waste is collected through cart pullers and handcarts. The cart pullers used to segregate the paper, plastic, polythene, metal, leather, etc. which is sold to the Kabariwala. In this way, the biodegradable and recycled waste may get separated from inert waste. This collection system is economically viable and also reduces the volume of solid waste in the dumping sites. But in actual practice, the waste is not sorted and segregated in accurate manner and almost all of the biodegradable waste is dumped in open land.

Transportation of MSW There is outrageous need of the expenditure on man-power, vehicles and other resources to improve the efficiency of solid waste management. The conditions of the transportation vehicles depend on the physical layout of the roads, cost of manpower available and maintenance provisions. The vehicles provided by municipal authority for the transportation of waste to the dump sites in Jalandhar includes tippers, loaders, bulldozers, compactor, three wheelers, tractor trolleys, dumper placer hydra cranes, etc. The transportation methodology is divided into three categories in the city including household waste transportation, commercial waste transportation and commercial routes being followed by the workers of municipal corporation of the city. The household waste is collected by waste pickers on rickshaw Rehra's and transported to secondary dumps. Finally, the secondary dumps loaded and transported to Wariana and Suchipind dumpsites. The commercial waste is collected by municipal corporation vehicles such as Tata Ace and Refuse Compactors. The vehicle named Tata Ace

Table 12.5 Number of machineries used for the transportations of municipal solid waste (city profile report of municipal corporation, Jalandhar)

Sl. No.	Name of machinery	Number of machinery
1.	Tippers	20
2.	JC/loaders	09
3.	Bulldozer tracked	02
4.	Three wheelers	27
5.	Tata Ace/Bolero/Ashok Leyland	20
6.	Tractor trolleys including hired	11 + 16 (Hired)
7.	Compactors	03 (Hired)
8.	Dumper placer	09

dumps the commercial waste at secondary collection points and then refuse compactors carry it to dumpsites for disposal. There are five commercial routes for the transportation of waste to the dumping lands. The name of machinery and number of machinery has been shown in Table 12.5.
In this context, it is critically observed from the survey that most of the vehicles are worn out and no maintenances had been carried out of these vehicles since the past years. Apart from this, one of the major drawbacks of transportation system is that waste is transported mostly in open trucks and vehicles which cause littering of waste here and there in the roads and thereby made habitat for mosquitoes (Rana et al. 2015).

Disposal of MSW The daily disposal of municipal solid waste is imperative due to the presence of high organic matter of municipal solid waste that may cause nuisance and unhygienic condition of the surroundings (Kumar et al. 2009). The waste collected from different sources from the Jalandhar city is disposed of in Wariana dumpsite (100 ton of solid waste per day) and in Suchipind dumpsite (250 ton of solid waste per day) that has been used for last 30 years. Presently, all types of solid waste consisting of industrial, biomedical, slaughterhouse and municipal solid waste are dumped on this landfill site. According to the management and handling Rules 2000, only inert waste should be disposed of in the landfills and the remaining waste should be transferred to the processing units. It has been already discussed that the disposal sites are used over 30 years old, and as such, no facility of leachate collection system, liner system and proper gas collection facilities has been constructed. Therefore, it is a threat to the surface and groundwater quality because of the permeation of leachate in the soil. Emission of landfill gases (LFGs) at the dumping site can be clearly observed causing pungent smell and affecting the health of the workers who work in the vicinity of the landfill site. However, no scientific observations for the right quantity of greenhouse gases produced are made to test the concentration of landfill gas (LFGs).

12.3.2 'Wasteaware' Benchmark Indicators

'Wasteaware' benchmark indicator is the index system to evaluate the pollution level by municipal solid waste (Rana et al. 2015). In this context, 'wasteaware' benchmark indicators which include qualitative and quantitative indicators have been addressed in Sect. 2.2 (Wilson et al. 2013, 2015). In this context, the benchmarks for Jalandhar city have been evaluated and are shown in Table 12.5 by adopting the procedure (Wilson et al. 2015). Apart from this, the generated benchmark for Jalandhar city has also been compared with the benchmarks of Chandigarh city. It is observed from Table 12.5 that overall municipal solid waste generated in Jalandhar city is substantially lower than the overall municipal solid waste generated in Chandigarh because of the difference in population of Chandigarh city is more than that of the Jalandhar city. The colour coding in the table indicated that red colour presented for low index, yellow colour for medium index and green colour for high index. In this context, it was observed from the evaluation of 'wasteaware' benchmark parameters that the collection efficiency and waste collection services under the category of qualitative indicators of Jalandhar city lies in low/medium index (*L*/*M*) as compared to Chandigarh city that is having collection efficiency lies in medium/high index (*M*/*H*) (Rana et al. 2015). Apart from this, for the Environmental control and 3R's facilities, both Jalandhar and Chandigarh city were classified under the category of the low index. The 'wasteaware' analysis also reveals that for the qualitative indicators including public health parameters and environmental control measures, Jalandhar city lies in low/medium index (*L*/*M*) and for the same qualitative parameters, Chandigarh city lies in medium index (Rana et al. 2015). The 'Wasteaware' benchmark indicators for Jalandhar city compared with Chandigarh city has been shown in Table 12.6.

Quantification of Indicators Using Matrix Method Matrix method is further used for the quantification of the 'weights' that has been allocated to both quantitative and qualitative parameters of 'wasteaware' benchmarks for Jalandhar and the evaluation comparison with Chandigarh city which has been summarized in Table 12.7 and summary of scores obtained through matrix method has been summarized in Table 12.8.

The overall score of analysis of Matrix method for Jalandhar city was reported 32% and similarly, the score for Chandigarh city was 46%. Hence, it is clearly showed that the quantification score of Jalandhar city was considerably lower than Chandigarh city (Rana et al. 2015). The matrix analysis reported that the management of municipal solid waste generated at study location Jalandhar can be categorized under low index category and the scores of Chandigarh city lies under low–medium index. Further analysis revealed that weightage obtained from quantitative parameters of 'wasteaware' analysis was reported (26%) for Jalandhar city, whereas it was slightly more for Chandigarh city (40%) because it is a planned and designed city and hence it has a marginal advantage in comparison to other Tier-II and Tier-III cities (Rana et al. 2015). Moreover, the score for governance factors of Jalandhar and Chandigarh were reported as 40 and 55% respectively.

Table 12.6 'Wasteaware' benchmark indicators for Jalandhar city

Sr. No.	Category	Indicator	Jalandhar City	Chandigarh City
Background information of the city				
1	Country Income Level	World Bank Indicator Level	Lower-Middle	Lower-Middle
		GNI per Capita	$1,140	$1,140
B2	Population of the City	Total Population of the City	8,73,725	1,055,450
B3	Waste Generation	MSW Generation (tons/year)	127750	135050
W1	Waste per Capita	MSW per capita (Kg per year)	146	128
W2	Waste Composition		3 key fractions – as % wt. of total waste generated	
W2. 1	Organic	Organics (food and green wastes)	44.53%	52%
W2. 2	Paper	Paper	3.43%	6%
W2. 3	Plastic	Plastic	7.42%	7%
1.1	Public health - Waste collection	Waste collection coverage	70% (L/M)	90% (M/H)
1C	-	Quality of waste collection service	70% (L/M)	90% (L/M)
2	Environmental control- waste treatment and disposal	Controlled treatment and disposal	10% (L)	30% (L)

(continued)

Table 12.6 (continued)

2E	-	Degree of environmental protection in waste treatment and disposal	0% (L)		0% (L)	
3	3Rs - reduce, reuse and recycling	Recycling rate	0% (L)		0% (L)	
3R		Quality of 3Rs provision	5% (L)		17% (L)	
6N	Sound institutions, proactive policies	Adequacy of national SWM framework	60% (L/M)		60% (L/M)	
6L	Degree of Institutional coherence		70% (L/M)		75 % (M)	
4U	User inclusivity	User inclusivity	68% (L/M)		75 % (M)	
4P	Provider inclusivity	Degree of provider inclusivity	65% (L/M)		78 % (M)	

12.4 Key Recommendations for Improvement of Municipal Solid Waste Management at the Selected Study Locations

12.4.1 Source Segregation

Source segregation is most important key parameter for the improvement of solid waste management system. Except for inert waste, rest of all the waste including paper, plastic, metal, glass and rubber is recyclable in nature. In this context, proper handling, collection and segregation of waste should be implemented in the city so that dry waste should be recycled properly. It is possible only because of community partnership and public–private ownership for the strategy of municipal solid

Table 12.7 Weightage assignment for evaluation using matrix method

Sl. No.	Category	Indicator	Jalandhar city	Chandigarh city
Quantitative indicators (public health, environmental control, 3R's)				
1.1	Public health	Waste collection coverage	70% (*L*/*M*) (2)	90% (*M*/*H*) (4)
1C	Waste collection	Waste collection services	70% (*L*/*M*) (2)	90% (*M*/*H*) (4)
2	Environment control facilities	Control treatment and disposal	10% (*L*) (1)	30% (*L*) (1)
2E	Waste treatment and disposal	Degree of environmental protection	0% (*L*) (1)	0% (*L*) (1)
3	3R's—reduce, reuse and recycling	Recycling rate	0% (*L*) (1)	0% (*L*) (1)
3R		Quality of 3R's provisions	5% (*L*) (1)	17% (*L*) (1)
Qualitative indicators (governance factors)				
4U	User inclusivity	User inclusivity	*L*/*M* (60%) (2)	*M* (75%) (3)
4P	Provider inclusivity	Provider inclusivity	*L*/*M* (70%) (2)	*M* (78%) (3)
6N	Sound, institutions proactive policies	Adequate national framework	*L*/*M* (60%) (2)	*L*/*M* (60%) (2)
6L	–	Degree of institutional coherence	*L*/*M* (65%) (2)	*M* (75%) (3)

waste management plans. Awareness programmes should be assembled in order to motivate the residents for source segregation of waste and promoted recycling and reuse of segregated waste material. At present, there is no recycling unit situated in Jalandhar city that is unfavourable practise. The public should be encouraged to manage two collection bins for wet, dry and recyclable waste so that the waste must be initially segregated at the household level before reaching to the dumpsites. The municipality should have commenced the provisions of closed-type garbage containers for the collection of waste so that littering and spilling of waste should be avoided.

12.4.2 Provision of Underground Collection Bins

It is critically suggested that the authorities of municipal corporation of the city should have focused on the issue of closed containers and underground bins.

Table 12.8 Summary of scores obtained through matrix method

Sl. No.	Category	Indicator	Jalandhar city	Chandigarh city
Quantitative indicators (public health, environmental control, 3R)				
1.1	Public health—waste collection	Waste collection coverage	2	4
1C		Quality of waste collection service	2	4
2	Environmental control—waste treatment and disposal	Controlled treatment and disposal	1	1
2E		Degree of environment protection in waste treatment and disposal	1	1
3	3R's—reduce, reuse and recycling	Recycling rate	1	1
3R		Quality of 3R's provision	1	1
Total score (quantitative indicators)			08	12
Maximum score			30	30
Weightage (%)			26	40
Qualitative indicators (governance factors)				
4U	User inclusivity	User inclusivity	2	3
4P	Provider inclusivity	provider inclusivity	2	3
6N	Sound institutions proactive policies	Adequacy of national SWM framework	2	2
6L	–	Degree of institutional coherence	2	3
Total score (quantitative indicators)			08	11
Maximum score			20	20
Weightage (%)			40	55
Total score (overall)			08 + 08 = 16	12 + 11 = 23
Total maximum score			30 + 20 = 50	30 + 20 = 50
Overall weightage (%)			32	46

There should be separate collection bins for dry waste (paper, plastic) and wet waste (organic waste). The non-biodegradable and dry waste such as paper, plastic, metal and glass should be recycled and sent to the authorized recyclers for its use in the manufacturing of new materials. The advantage of implementation of such strategy are better environment (no bad odour from smelly dirty bins), secured collection (no overflowing bins or stray animals feeding on waste), increase awareness among citizens, cost saving (no broken and dirty garbage bins) and moreover easy to install, collect and dispose garbage and hence, an effective alternative to present situation.

12.4.3 Composting/Vermicomposting

It is further reported from the literature study of characterization of municipal solid waste in Jalandhar that MSW is rich in organic waste. The past studies of characterization of waste in Jalandhar revealed that most of the waste is biodegradable in nature. In this context, composting and vermicomposting is the best alternative for the decomposition and stabilization of organic fraction of waste. The bio conversion of municipal solid waste into soil enriches the natural fertility of soil. In this context, a composting facility was operated by the M/S Punjab Grow more fertilizers Pvt. Ltd. since 2003 but at present the facility is non-working. (Personal Communication with the Municipal Engineer of Jalandhar). In this context, there is outrageous need of providing adequate training to the operating staff for reanimating of the existing compost plant.

12.4.4 Refused Derived Fuel Plant

Presently, there is no such waste treatment facility of municipal solid waste in Jalandhar city. The installation of RDF plant is one of the feasible alternatives that can be used as a waste processing facility. The literature study on characterization of solid waste in Jalandhar city revealed the composition of paper waste which varied in the range of 3–10%, plastic waste varied in the range of 6–14% and major fraction of organic waste varied in the range of 40–44% and is found suitable for the treatment of solid waste in the city (Puri et al. 2008; Sethi et al. 2013).

12.4.5 Construction of Sanitary Landfill

The survey of the study area revealed that the waste is disposed of in open land in an unscientific manner. The open dumping of waste may cause health hazard issues and having environmental pollution (Puri et al. 2008). In this context, it is strictly suggested to construct engineered landfill system with liner system, leachate collection and removal system, gas collection facility and final cover system. After sorting the biodegradable organic fraction for bioprocessing and recyclable waste to manufacturing units, only the inert material should be disposed of into sanitary landfills. It should be noted that compaction is the mandatory factor while deposition of waste in order to maintain the stability and increase the capacity of closure.

12.5 Conclusion

Solid waste management is the globally concerned occurrence in the present scenario. This paper revealed an expressive image of the present situation in municipal solid waste management under the perspective of the citizens and municipal authorities. There is a dreadful need to educate local authorities and citizens of the city to reinforce environmental sustainability, public health, reduction and segregation at the source, reuse and recycling of waste. Further, it has been observed that the lack of resources including infrastructure, suitable data and planning, financing issues are the major limitations in the municipal solid waste management system. The overall survey showed the per capita waste generation rate in Jalandhar city is 350–400 ton per day with the collection efficiency of 70% that proves ineffectual for the municipal solid waste management system. The paper also focussed on the 'wasteaware' benchmark indicators and the quantification analysis by matrix method system for the study region Jalandhar city and the evaluation comparison with Chandigarh city. The results clearly showed the poor performance of environmental control methods including the collection and treatment of waste, disposal of waste, 3R's facilities, etc. in Jalandhar city. In this context, some of the remedial measures were suggested that must be incorporated by municipal corporations of Jalandhar city for the intensification of solid waste management including sufficient number of collection bins to avoid spilling of waste, facilities of new and advanced machines for segregating and recycling facilities. It is further expected from the study that the adjoining land of 2.25 acres acquired and processes will be started very soon to develop it as sanitary landfill (SLF). Another MSW processing facility will be planned in the city catering to the requirement of 27 cluster urban local bodies (ULBs) including Jalandhar. It is critically observed that there is no such facility of liner system, leachate collection and transfer system, gas monitoring facilities and final cover system for the disposal of solid waste. Open dumping of waste creates annoyance for the health of people as well as aesthetic appearance of the environment. Hence, open dumps should be avoided and waste should be disposed of in sanitary engineered landfill systems.

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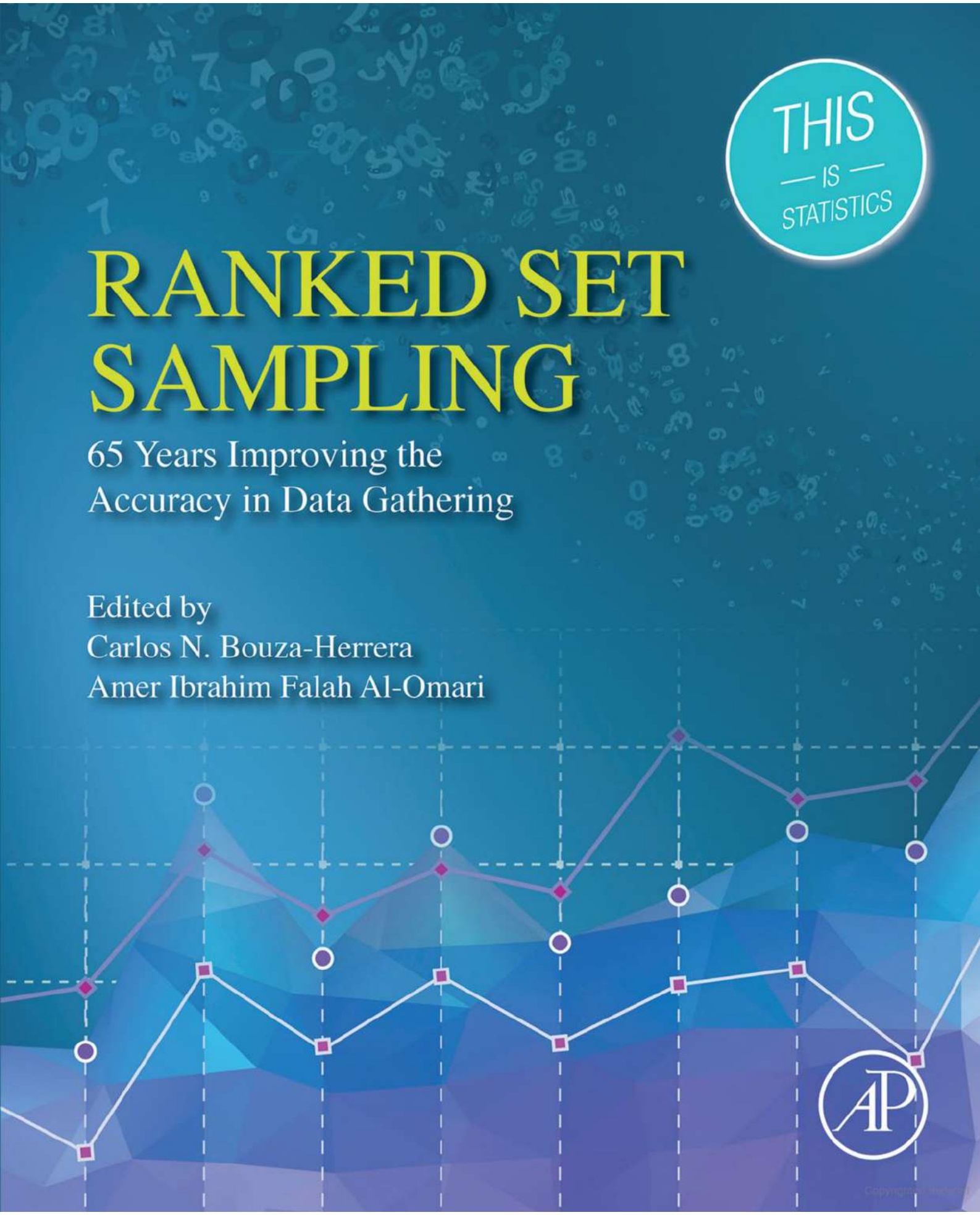

RANKED SET SAMPLING

65 Years Improving the Accuracy in Data Gathering

Edited by
Carlos N. Bouza-Herrera
Amer Ibrahim Falah Al-Omari

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CHAPTER

10

A NEW MORGENSTERN TYPE BIVARIATE EXPONENTIAL DISTRIBUTION WITH KNOWN COEFFICIENT OF VARIATION BY RANKED SET SAMPLING

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10.1 INTRODUCTION

Cost-effective sampling methods are of major concern in some experiments, especially when the measurement of the characteristics is costly, painful, or time-consuming. The concept of ranked set sampling (RSS) was first introduced by McIntyre (1952) as a process of increasing the precision of sample mean as an unbiased estimator of population mean. The method of RSS provides an effective way to achieve observational economy or to achieve relatively more precision per unit of sampling. RSS as described by McIntyre (1952) is applicable whenever ranking of a set of sampling units can be done easily by judgment method. For a detailed discussion on theory and application of RSS, see Chen et al. (2004). In certain situations one may prefer exact measurements of some easily measurable variable X associated with the study variable Y to rank the units of samples rather than ranking them by a crude judgment method. Suppose the variable of interest Y, is difficult or much more expensive to measure, but an auxiliary variable X correlated with Y is readily measureable and can be ordered exactly. In this case as an alternative to McIntyre's (1952) method of ranked set sampling, Stokes (1977) used an auxiliary variable for the ranking of sampling units.

If $X_{(r)r}$ is the observation measured on the auxiliary variable X from the unit chosen from the rth set then we write $Y_{[r]r}$ to denote the corresponding measurement made on the study variable Y on this unit, then $Y_{[r]r}, r = 1, 2, \ldots, n$ from the ranked set sample. Clearly $Y_{[r]r}$ is the concomitant of the rth order statistic arising from the rth sample.

In many areas, especially in physical science, it is common to find the population standard deviation is proportional to the population mean, that is, the coefficient of variation (CV) is constant (e.g., Sen, 1978; Ebrahimi, 1984, 1985; Singh, 1986). In such cases it is possible to find a more efficient estimator of the mean assuming that the coefficient of variation (CV) is known than by using the sample mean.

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Let X be a random variable having the two-parameter exponential distribution as

$$f_X(x) = \frac{1}{\sigma}\exp\left(-\frac{x-\theta}{\sigma}\right); x \geq \theta > 0, \sigma > 0. \tag{10.1}$$

Here θ is the location parameter (guarantee period) and σ is the scale parameter (measuring the mean life). Since $E(X) = \theta + \sigma$ and $Var(X) = \sigma^2$, therefore the $CV = \frac{\sigma}{\theta+\sigma}$. Using the fact that the CV is some known constant we get that $\sigma = a_1\theta$, where $a_1(>0)$ is known (see, Samanta, 1984, 1985; Joshi and Nabar, 1991) and therefore Eq. (10.1) reduces to

$$f_X(x) = \frac{1}{a_1\theta}\exp\left(-\frac{x-\theta}{a_1\theta}\right); x \geq \theta > 0, a_1 > 0, \tag{10.2}$$

which has mean $\theta(a_1 + 1)$ and variance $\theta^2 a_1^2$, therefore the $CV = \frac{a_1}{(a_1+1)}$ is the same for all $\theta(>0)$.

The cumulative density function (cdf) of Eq. (10.2) is given by

$$F_X(x) = 1 - \exp\left(-\frac{x-\theta}{a_1\theta}\right); x \geq \theta > 0, a_1 > 0. \tag{10.3}$$

Ali and Woo (2002) considered parametric estimation of a special case of the two-parameter exponential distribution in which both the threshold (location) and the scale parameters are equal. For $a_1 = 1$ the probability density function (pdf) $f_X(x)$ in Eq. (10.2) reduces to:

$$f_X(x) = \frac{1}{\theta}\exp\left(-\frac{x-\theta}{\theta}\right); x \geq \theta, \tag{10.4}$$

which is due to Ali and Woo (2002).

A general family of bivariate distributions is proposed by Morgenstern (1956) with specified marginal distributions $F_X(x)$ and $F_Y(y)$ as

$$F_{X,Y}(x,y) = F_X(x)F_Y(y)[1 + \alpha(1 - F_X(x))(1 - F_Y(y))]; -1 \leq \alpha \leq 1, \tag{10.5}$$

where α is the association parameter between X and Y and $F_{X,Y}(x,y)$ is the joint distribution function (df) and $F_X(x)$ and $F_Y(y)$ are the marginal distribution function (df) of X and Y respectively (see Johnson and Kotz, 1972).

Also, the probability density function (pdf) of the Morgenstern family of distribution can be given as

$$f_{X,Y}(x,y) = f_X(x)f_Y(y)[1 + \alpha(1 - 2F_X(x))(1 - 2F_Y(y))]; -1 \leq \alpha \leq 1. \tag{10.6}$$

The pdf of the concomitants of order statistics $Y_{[r]r}$ arising from MTBED is obtained as (see Scaria and Nair, 1999)

$$f_{Y_{[r]r}}(y) = f_Y(y)\left[1 + \alpha\left(\frac{n-2r+1}{n+1}\right)(1 - 2F_Y(y))\right]; -1 \leq \alpha \leq 1. \tag{10.7}$$

Now using Eqs. (10.2) and (10.3) in Eq. (10.6) we get a member of this family is Morgenstern type bivariate exponential distribution (MTBED) with the probability density function (pdf) as

$$f_{X,Y}(x,y) = \frac{\exp\left\{\left(-\frac{x-\theta_1}{a_1\theta_1}\right) + \left(-\frac{y-\theta_2}{a_2\theta_2}\right)\right\}\left[1 + \alpha\left(1 - 2\exp\left(-\frac{x-\theta_1}{a_1\theta_1}\right)\right)\left(1 - 2\exp\left(-\frac{y-\theta_2}{a_2\theta_2}\right)\right)\right]}{a_1a_2\theta_1\theta_2};$$

$$x \geq \theta_1, y \geq \theta_2, a_1, a_2 > 0, -1 \leq \alpha \leq 1. \tag{10.8}$$

Now the pdf of $Y_{[r]r}$ for $1 \le r \le n$ is given as (see Scaria and Nair, 1999)

$$f_{Y_{[r]r}}(y) = \frac{1}{a_2\theta_2}\exp\left(-\frac{y-\theta_2}{a_2\theta_2}\right)\left[1-\alpha\left(\frac{n-2r+1}{n+1}\right)\left(1-2\exp\left(-\frac{y-\theta_2}{a_2\theta_2}\right)\right)\right]; \tag{10.9}$$

$$y \ge \theta_2, a_2 > 0, \ -1 \le \alpha \le 1.$$

The mean and variance of $Y_{[r]r}$ for $1 \le r \le n$ are respectively given by

$$E\left(Y_{[r]r}\right) = \theta_2\xi_r \quad \text{and} \quad Var\left(Y_{[r]r}\right) = \theta_2^2\delta_r, \tag{10.10}$$

where

$$\xi_r = \left[1 + a_2\left(1 - \frac{\alpha}{2}\left(\frac{n-2r+1}{n+1}\right)\right)\right]$$

and

$$\delta_r = a_2^2\left[1 - \frac{\alpha}{2}\left(\frac{n-2r+1}{n+1}\right) - \frac{\alpha^2}{4}\left(\frac{n-2r+1}{n+1}\right)^2\right].$$

Stokes (1995) has considered the estimation of parameters of location-scale family of distributions using RSS. Lam et al. (1994, 1995) have obtained the BLUEs of location and scale parameters of exponential distribution and logistic distribution. Stokes (1980) has considered the method of estimation of correlation coefficient of bivariate normal distribution using RSS. Modarres and Zheng (2004) have considered the problem of estimation of the dependence parameter using RSS. A robust estimate of correlation coefficient for bivariate normal distribution has been developed by Zheng and Modarres (2006). Stokes (1977) has suggested the ranked set sample mean as an estimator for the mean of the study variate Y, when an auxiliary variable X is used for ranking the sample units, under the assumption that (X, Y) follows a bivariate normal distribution. Estimation of a parameter of Morgenstern type bivariate exponential distribution by using RSS was considered by Chacko and Thomas (2008). Barnett and Moore (1997) have improved the estimator of Stokes (1977) by deriving the best linear unbiased estimator (BLUE) of the mean of the study variate Y, based on ranked set sample obtained on the study variate Y. Lesitha et al. (2010) have considered application of RSS in estimating parameters of Morgenstern type bivariate logistic distribution. Tahmasebi and Jafari (2012) have considered upper RSS. For current references in this context the reader is referred to Sharma et al. (2016), Bouza (2001, 2002, 2005), Samawi and Muttlak (1996), Demir and Singh (2000); Singh and Mehta (2013, 2014a,b, 2015, 2016a,b,c, 2017), Mehta and Singh (2014, 2015), and Mehta (2017).

The remaining part of the chapter is organized as follows: Section 10.2.1 proposes an unbiased estimator $\hat{\theta}_2$ of the parameter θ_2 involved in Eq. (10.8) using ranked set sample mean along with its variance. In Section 10.2.2, we have derived BLUE θ_2^* of θ_2, when the association parameter α is known. We have also given the variance of BLUE θ_2^*. Section 10.2.3 deals with the problem of estimating the parameter θ_2 based on unbalanced multistage RSS. We have derived BLUE $\hat{\theta}_2^{n(r)}$ of θ_2 and obtained its variance. In Sections 10.2.4 and 10.2.5, we have discussed the problem of estimating the parameter θ_2 based on unbalanced single-stage and steady-state RSS, respectively, which are particular cases of the studies presented in Section 10.3.1. Section 10.3.2 compares the performance of the different estimators proposed in the chapter through a numerical illustration. In Section 10.4 we conclude the chapter with final remarks.

10.2 EXPERIMENTAL METHODS AND MATERIALS

10.2.1 RANKED SET SAMPLE MEAN AS AN ESTIMATOR OF θ_2

Let (X, Y) be a bivariate random variable which follows an MTBED with pdf defined by Eq. (10.8). Suppose RSS in the sense of Stokes (1977) has been carried out. Let $X_{(r)r}$ be the observation measured on the auxiliary variate X in the rth unit of the RSS and let $Y_{[r]r}$ be the measurement made on the Y variate of the same unit $r = 1, 2, \ldots, n$. Then clearly $Y_{[r]r}$ is distributed as the concomitant of rth order statistics of a random sample of n arising from Eq. (10.8). By using the expressions for mean and variances of concomitants of order statistics arising from MTBED obtained in Eq. (10.10), we propose an estimator $\hat{\theta}_2$ of θ_2 involved in Eq. (10.8) and proved that it is an unbiased estimator of θ_2.

Theorem 1.1: *Let $Y_{[r]r}, r = 1, 2, \ldots, n$ be the ranked set sample observations on a study variate Y obtained out of ranking made on an auxiliary variate X, when (X, Y) follows MTBED as defined in Eq. (10.8). Then the ranked set sample mean given by*

$$\hat{\theta}_2 = \frac{1}{n(a_2+1)} \sum_{r=1}^{n} Y_{[r]r}, \tag{10.11}$$

is an unbiased estimator of θ_2 and its variance is given by

$$Var\left(\hat{\theta}_2\right) = \frac{a_2^2\theta_2^2}{n(a_2+1)^2}\left[1 - \frac{\alpha^2}{4n}\sum_{r=1}^{n}\left(\frac{n-2r+1}{n+1}\right)^2\right]. \tag{10.12}$$

Proof: *Taking expectations of both sides of Eq. (10.11) we have*

$$E\left(\hat{\theta}_2\right) = \frac{1}{n(a_2+1)}\sum_{r=1}^{n} E\left(Y_{[r]r}\right) = \frac{\theta_2}{n(a_2+1)}\sum_{r=1}^{n}\left[1 + a_2\left(\frac{n-2r+1}{n+1}\right)\right]. \tag{10.13}$$

It is clear to note that

$$\sum_{r=1}^{n}(n-2r+1) = 0. \tag{10.14}$$

Using Eq. (10.14) in Eq. (10.13) we get

$$E\left(\hat{\theta}_2\right) = \theta_2.$$

Thus $\hat{\theta}_2$ is an unbiased estimator of θ_2.
The variance of $\hat{\theta}_2$ is given by

$$Var\left(\hat{\theta}_2\right) = \frac{1}{n^2(a_2+1)^2}\sum_{r=1}^{n} Var\left(Y_{[r]r}\right).$$

Now using Eq. (10.10) and Eq. (10.14) in the above sum we get,

$$\mathrm{Var}\left(\hat{\theta}_2\right) = \frac{a_2^2\theta_2^2}{n(a_2+1)^2}\left[1 - \frac{\alpha^2}{4n}\sum_{r=1}^{n}\left(\frac{n-2r+1}{n+1}\right)^2\right].$$

Thus the theorem is proved.♦

10.2.2 BEST LINEAR UNBIASED ESTIMATOR OF θ_2

In this section we provide a better estimator of θ_2 than that of $\hat{\theta}_2$ by deriving the BLUE θ_2^* of θ_2 provided the parameter α is known. Let $X_{(r)r}$ be the observation measured on the auxiliary variable X in the rth unit of ranked set samples and let $Y_{[r]r}$ be measurement made on the Y variable of the same unit, $r = 1, 2, \ldots, n$. Let $\mathbf{Y}_{[n]} = \left(Y_{[1]1}, Y_{[2]2}, \ldots, Y_{[n]n}\right)'$ and if the parameter α involved in ξ_r and δ_r is known, then proceeding as in David and Nagaraja (2003, p.185) the BLUE θ_2^* of θ_2 is obtained as

$$\theta_2^* = \left(\xi' G^{-1}\xi\right)^{-1}\xi' G^{-1}\mathbf{Y}_{[n]} \tag{10.15}$$

and

$$\mathrm{Var}\left(\theta_2^*\right) = \left(\xi' G^{-1}\xi\right)^{-1}\theta_2^2, \tag{10.16}$$

where $\xi = \left(\xi_1, \xi_2, \ldots, \xi_n\right)'$ and $G = diag(\delta_1, \delta_2, \ldots, \delta_n)$. On substituting the values of ξ and G in Eqs. (10.15) and (10.16) and simplifying we have

$$\theta_2^* = \frac{\sum_{r=1}^{n}\left(\xi_r/\delta_r\right)Y_{[r]r}}{\sum_{r=1}^{n}\left(\xi_r^2/\delta_r\right)} \tag{10.17}$$

and

$$\mathrm{Var}\left(\theta_2^*\right) = \frac{\theta_2^2}{\sum_{r=1}^{n}\left(\xi_r^2/\delta_r\right)}. \tag{10.18}$$

10.2.3 ESTIMATION OF θ_2 BASED ON UNBALANCED MULTISTAGE RANKED SET SAMPLING

Al-Saleh and Al-Kadiri (2000) have extended first the usual concept of RSS to double-stage ranked set sampling (DSRSS) with the objective of increasing the precision of certain estimators of the population when compared with those obtained based on usual RSS or using random sampling. Al-Saleh and Al-Omari (2002) have further extended DSRSS to multistage ranked set sampling (MSRSS) and shown that there is an increase in the precision of estimators obtained based on MSRSS when compared with those based on usual RSS and DSRSS. The MSRSS (in r stages) procedure is described below:

(1) Randomly select n^{r+1} sample units from the target population, where r is the number of stages of MSRSS.

(2) Allocate the n^{r+1} selected units randomly into n^{r-1} sets, each of size n^2.

(3) For each set in step (2), apply the procedure of RSS method to obtain a (judgment) ranked set, of size n; this step yields n^{r-1} (judgment) ranked sets, of size n each.
(4) Arrange n^{r-1} ranked sets of size n each, into n^{r-2} sets of n^2 units each and without doing any actual quantification, apply ranked set sampling method on each set to yield n^{r-2} second stage ranked sets of size n each.
(5) This process is continued, without any actual quantification, until we end up with the rth stage (judgment) ranked set of size n.
(6) Finally, the n identified elements in step (5) are now quantified for the variable of interest.

Instead of the judgment method of ranking at each stage if there exists an auxiliary variate on which one can make measurement very easily and exactly and if the auxiliary variate is highly correlated with the variable under study, then we can apply ranking based on these measurements to obtain the ranked set units at each stage of MSRSS. Then, on the finally selected units, one can make measurement on the study variable.

In this section we deal with the MSRSS by assuming that the random variable (X, Y) has an MTBED as defined in Eq. (10.8), where Y is the study variable and X is an auxiliary variable. In Section 10.2.2, we have considered a method for estimating θ_2 using the $Y_{[r]r}$ measured on the study variate Y on the unit having rth smallest value observed on the auxiliary variable X, of the rth sample $r = 1, 2, \ldots, n$, and hence the RSS considered there was balanced.

Abo-Eleneen and Nagaraja (2002) have shown that, in a bivariate sample of size n arising from MTBED, the concomitant of largest-order statistic possesses the maximum Fisher information on θ_2 whenever $\alpha > 0$ and the concomitant of smallest order statistic possesses the maximum Fisher information on θ_2 whenever $\alpha < 0$. Hence, in this section, first we considered $\alpha > 0$ and carry out an unbalanced MSRSS with the help of measurements made on an auxiliary variate to choose the ranked set and then estimate θ_2 involved in MTBED based on the measurements made on the study variable. At each stage and from each set we choose a unit of a sample with the largest value on the auxiliary variable as the units of ranked sets with an objective of exploiting the maximum Fisher information on the ultimately chosen ranked set sample.

Let $U_i^{(r)}, i = 1, 2, \ldots, n$ be the units chosen by the (r stage) MSRSS. Since the measurement of an auxiliary variable on each unit $U_i^{(r)}, i = 1, 2, \ldots, n$ has the largest value, we may write $Y_{[n]i}^{(r)}, i = 1, 2, \ldots, n$ to denote the value measured on the variable of primary interest on $U_i^{(r)}, i = 1, 2, \ldots, n$. Then it is easy to see that each $Y_{[n]i}^{(r)}$ is the concomitant of the largest-order statistic of n^r independently and identically distributed bivariate random variables with MTBED. Moreover $Y_{[n]i}^{(r)}, i = 1, 2, \ldots, n$ are also independently distributed with *pdf* given by (see Scaria and Nair, 1999)

$$f_{[n]i}^{(r)}(y) = \frac{1}{a_2\theta_2}\exp\left(-\frac{y-\theta_2}{a_2\theta_2}\right)\left[1+\alpha\left(\frac{n^r-1}{n^r+1}\right)\left(1-2\exp\left(-\frac{y-\theta_2}{a_2\theta_2}\right)\right)\right]; \tag{10.19}$$

$$y \geq \theta_2, a_2 > 0, \ -1 \leq \alpha \leq 1.$$

Thus the mean and variance of $Y_{[n]i}^{(r)}, i = 1, 2, \ldots, n$ are given below

$$E\left(Y_{[n]i}^{(r)}\right) = \theta_2\left[1 + a_2\left\{1 + \frac{\alpha}{2}\left(\frac{n^r-1}{n^r+1}\right)\right\}\right] = \theta_2\xi_{n^r}, \tag{10.20}$$

$$Var\left(Y_{[n]i}^{(r)}\right) = \theta_2^2 a_2^2\left[1 + \frac{\alpha}{2}\left(\frac{n^r-1}{n^r+1}\right) - \frac{\alpha^2}{4}\left(\frac{n^r-1}{n^r+1}\right)^2\right] = \theta_2^2\delta_{n^r}, \tag{10.21}$$

where

$$\xi_{n^r} = \left[1 + a_2\left\{1 + \frac{\alpha}{2}\left(\frac{n^r-1}{n^r+1}\right)\right\}\right] \tag{10.22}$$

and

$$\delta_{n^r} = a_2^2\left[1 + \frac{\alpha}{2}\left(\frac{n^r-1}{n^r+1}\right) - \frac{\alpha^2}{4}\left(\frac{n^r-1}{n^r+1}\right)^2\right]. \tag{10.23}$$

Let $\mathbf{Y}_{[n]}^{(r)} = \left(Y_{[n]1}^{(r)}, Y_{[n]2}^{(r)}, \ldots, Y_{[n]n}^{(r)}\right)'$, then by using Eqs. (10.20) and (10.21) we get the mean vector and dispersion matrix of $\mathbf{Y}_{[n]}^{(r)}$ as

$$E\left(\mathbf{Y}_{[n]}^{(r)}\right) = \theta_2\xi_{n^r}\mathbf{1} \tag{10.24}$$

and

$$D\left(\mathbf{Y}_{[n]}^{(r)}\right) = \theta_2^2\delta_{n^r}\mathbf{I}, \tag{10.25}$$

where $\mathbf{1}$ is the column vector of n ones and $\mathbf{I}$ is a unit matrix of order n.

If $\alpha > 0$ involved in ξ_{n^r} and δ_{n^r} is known then Eqs. (10.24) and (10.25) together define a generalized Gass−Markov setup and hence the BLUE of θ_2 is obtained as

$$\hat{\theta}_2^{n(r)} = \frac{1}{n\xi_{n^r}}\sum_{i=1}^{n} Y_{[n]i}^{(r)} \tag{10.26}$$

with variance given by

$$Var\left(\hat{\theta}_2^{n(r)}\right) = \frac{\theta_2^2\delta_{n^r}}{n\left(\xi_{n^r}\right)^2}. \tag{10.27}$$

10.2.4 ESTIMATION OF θ_2 BASED ON UNBALANCED SINGLE-STAGE RANKED SET SAMPLING

If we take $r = 1$ in the MSRSS method described above, then we get the usual single-stage unbalanced RSS. By putting $r = 1$ in Eqs. (10.26) and (10.27) we get the BLUE $\hat{\theta}_2^{n(1)}$ of θ_2 based on single-stage unbalanced ranked set sampling as

$$\hat{\theta}_2^{n(1)} = \frac{1}{n\xi_n}\sum_{i=1}^{n} Y_{[n]i} \tag{10.28}$$

with variance

$$\mathrm{Var}\left(\hat{\theta}_2^{n(1)}\right) = \frac{\theta_2^2\delta_n}{n\left(\xi_n\right)^2}, \tag{10.29}$$

where, we write $Y_{[n]i}$ instead of $Y^{(1)}_{[n]i}$ and it represents the measurement on the study variable of the unit selected in the RSS. Also ξ_n and δ_n are obtained by putting $r=1$ in Eqs. (10.22) and (10.23), respectively i.e.,

$$\xi_n = \left[1 + a_2\left\{1 + \frac{\alpha}{2}\left(\frac{n-1}{n+1}\right)\right\}\right] \tag{10.30}$$

and

$$\delta_n = a_2^2\left[1 + \frac{\alpha}{2}\left(\frac{n-1}{n+1}\right) - \frac{\alpha^2}{4}\left(\frac{n-1}{n+1}\right)^2\right]. \tag{10.31}$$

10.2.5 ESTIMATION OF θ_2 BASED ON UNBALANCED STEADY-STATE RANKED SET SAMPLING

Al-Saleh (2004) has considered the steady-state RSS by letting r go to $+\infty$. For the steady-state RSS the problem considered in having the asymptotic distribution of $Y^{(r)}_{[n]i}$ is given by

$$f^{(\infty)}_{[n]i}(y) = \frac{1}{a_2\theta_2}\exp\left(-\frac{y-\theta_2}{a_2\theta_2}\right)\left[1 + \alpha\left(1 - 2\exp\left(-\frac{y-\theta_2}{a_2\theta_2}\right)\right)\right]; \tag{10.32}$$

$$y \geq \theta_2, a_2 > 0, \ -1 \leq \alpha \leq 1.$$

From the definition of unbalanced MSRSS it follows that $Y^{(\infty)}_{[n]i}, i = 1, 2, \ldots, n$ are independent and identically distributed random variables each with *pdf* as defined in Eq. (10.32). Then $Y^{(\infty)}_{[n]i}, i = 1, 2, \ldots, n$ may be regarded as an unbalanced steady-state ranked set sample of size n. The mean and variance of $Y^{(\infty)}_{[n]i}, i = 1, 2, \ldots, n$ are given below

$$E\left(Y^{(r)}_{[n]i}\right) = \theta_2\left[1 + a_2\left\{1 + \frac{\alpha}{2}\right\}\right], \tag{10.33}$$

$$\mathrm{Var}\left(Y^{(r)}_{[n]i}\right) = \theta_2^2 a_2^2\left[1 + \frac{\alpha}{2} - \frac{\alpha^2}{4}\right]. \tag{10.34}$$

Let $\mathbf{Y}^{(\infty)}_{[n]} = \left(Y^{(\infty)}_{[n]1}, Y^{(\infty)}_{[n]2}, \ldots, Y^{(\infty)}_{[n]n}\right)'$. Then the BLUE $\hat{\theta}_2^{n(\infty)}$ based on $\mathbf{Y}^{(\infty)}_{[n]}$ and the variance of $\hat{\theta}_2^{n(\infty)}$ is obtained by taking the limits as $r \to \infty$ in Eqs. (10.26) and (10.27), respectively, and are given by

$$\hat{\theta}_2^{n(\infty)} = \frac{1}{n\left[1 + a_2\left(1 + \frac{\alpha}{2}\right)\right]}\sum_{i=1}^{n} Y^{(\infty)}_{[n]i} \tag{10.35}$$

and

$$\mathrm{Var}\left(\hat{\theta}_2^{n(\infty)}\right) = \theta_2^2\frac{a_2^2\left(1 + \frac{\alpha}{2} - \frac{\alpha^2}{4}\right)}{n\left[1 + a_2\left(1 + \frac{\alpha}{2}\right)\right]}. \tag{10.36}$$

Remark 1: *As mentioned earlier for MTBED the concomitant of smallest-order statistic possesses the maximum Fisher information on* θ_2 *whenever* $\alpha < 0$. *Therefore when* $\alpha < 0$ *we consider an*

unbalanced MSRSS in which at each stage and from each set we choose a unit of a sample with the smallest value on the auxiliary variable as the units of ranked sets with an objective of exploiting the maximum Fisher information on the ultimately chosen ranked set sample.

Let $Y_{[1]i}^{(r)}, i = 1, 2, \ldots, n$, *be the value measured on the variable of primary interest on the units selected at the rth stage of the unbalanced MSRSS. Then it is easily to see that each* $Y_{[1]i}^{(r)}, i = 1, 2, \ldots, n$ *is the concomitant of the smallest-order statistic of* n^r *independently and identically distributed bivariate random variables with MTBED. Moreover* $Y_{[1]i}^{(r)}, i = 1, 2, \ldots, n$ *are also independently distributed with pdf given by*

$$f_{[1]i}^{(r)}(y) = \frac{1}{a_2\theta_2}\exp\left(-\frac{y-\theta_2}{a_2\theta_2}\right)\left[1-\alpha\left(\frac{n^r-1}{n^r+1}\right)\left(1-2\exp\left(-\frac{y-\theta_2}{a_2\theta_2}\right)\right)\right]; \quad y \geq \theta_2, a_2 > 0, -1 \leq \alpha \leq 1. \tag{10.37}$$

Clearly from Eqs. (10.19) and (10.37) we have

$$f_{[1]i}^{(r)}(y;\alpha) = f_{[n]i}^{(r)}(y;-\alpha) \tag{10.38}$$

and hence $E\left(Y_{[n]i}^{(r)}\right)$ *for* $\alpha > 0$ *and* $E\left(Y_{[1]i}^{(r)}\right)$ *for* $\alpha < 0$ *are identically equal. Similarly,* $Var\left(Y_{[n]i}^{(r)}\right)$ *for* $\alpha > 0$ *and* $Var\left(Y_{[1]i}^{(r)}\right)$ *for* $\alpha < 0$ *are identically equal. Consequently, if* $\hat{\theta}_2^{1(1)}$ *is the BLUE of* θ_2, *involved in MTBED for* $\alpha < 0$, *based on the unbalanced MSRSS observations* $Y_{[1]i}^{(r)}, i = 1, 2, \ldots, n$ *then the coefficients of* $Y_{[1]i}^{(r)}, i = 1, 2, \ldots, n$ *in the BLUE* $\hat{\theta}_2^{1(1)}$ *for* $\alpha < 0$ *is the same as the coefficients of* $Y_{[n]i}^{(r)}, i = 1, 2, \ldots, n$ *in the BLUE* $\hat{\theta}_2^{n(r)}$ *for* $\alpha > 0$. *Further we have* $Var\left(\hat{\theta}_2^{1(1)}\right) = Var\left(\hat{\theta}_2^{n(r)}\right)$ *and hence* $Var\left(\hat{\theta}_2^{1(1)}\right) = Var\left(\hat{\theta}_2^{n(1)}\right)$ *and* $Var\left(\hat{\theta}_2^{1(\infty)}\right) = Var\left(\hat{\theta}_2^{n(\infty)}\right)$, *where* $\hat{\theta}_2^{1(1)}$ *are the BLUE of* θ_2 *for* $\alpha < 0$ *based on the usual unbalanced single stage RSS observations* $Y_{[n]i}, i = 1, 2, \ldots, n$ *and* $\hat{\theta}_2^{1(\infty)}$ *are the BLUE of* θ_2 *for* $\alpha < 0$ *based on the unbalanced steady-state RSS observations* $Y_{[n]i}^{(\infty)}, i = 1, 2, \ldots, n$.

Remark 2: *If we have a situation with* α *unknown, we introduce an estimator (moment type) for* α *as follows. For MTBED the correlation coefficient between the two variables is given by* $\rho = \frac{\alpha}{4}$. *If* q *is the sample correlation coefficient between* $X_{(i)i}$ *and* $Y_{[i]i}, i = 1, 2, \ldots, n$ *then the moment type estimator for* α *is obtained by equating with the population correlation coefficient* ρ *and is obtained as (see Chacko and Thomas, 2008*):

$$\hat{\alpha} = \begin{cases} -1 & \text{if } q < -1/4 \\ 4q & \text{if } -\frac{1}{4} \leq q \leq \frac{1}{4} \\ 1 & \text{if } q > 1/4 \end{cases}. \tag{10.39}$$

10.3 OBSERVATIONS, RESULTS, AND DISCUSSION

10.3.1 RELATIVE EFFICIENCY

We have obtained the relative efficiencies $e_1 = RE\left(\theta_2^*, \hat{\theta}_2\right) = \frac{\mathrm{Var}(\hat{\theta}_2)}{\mathrm{Var}(\theta_2^*)}, e_2 = RE\left(\hat{\theta}_2^{n(1)}, \hat{\theta}_2\right) = \frac{\mathrm{Var}(\hat{\theta}_2)}{\mathrm{Var}\left(\hat{\theta}_2^{n(1)}\right)}$ and $e_3 = RE\left(\hat{\theta}_2^{n(\infty)}, \hat{\theta}_2\right) = \frac{Var(\hat{\theta}_2)}{Var\left(\hat{\theta}_2^{n(\infty)}\right)}$ of $\theta_2^*, \hat{\theta}_2^{n(1)}$ and $\hat{\theta}_2^{n(\infty)}$ relative to $\hat{\theta}_2$ respectively, for $n = 2(2)20, \alpha = 0.25(0.25)1.00$ and $a_2 = 1(1)5$ and these are presented in Table 10.1.

Table 10.1 The Values of $e_i's, i = 1, 2, 3$

		$a_2 = 1$			$a_2 = 2$			$a_2 = 3$		
n	α	e_1	e_2	e_3	e_1	e_2	e_3	e_1	e_2	e_3
2	0.25	1.0008	1.0005	1.0160	1.0000	1.0138	1.0559	1.0004	1.0210	1.0766
	0.50	1.0016	1.0008	1.0581	1.0009	1.0280	1.1383	1.0004	1.0415	1.1793
	0.75	1.0041	1.0013	1.1241	1.0023	1.0416	1.2463	1.0014	1.0617	1.3093
	1.00	1.0075	1.0016	1.2150	1.0037	1.0537	1.3824	1.0022	1.0803	1.4703
4	0.25	1.0000	1.0034	1.0143	1.0009	1.0281	1.0549	1.0000	1.0401	1.0751
	0.50	1.0033	1.0118	1.0521	1.0018	1.0595	1.1316	1.0014	1.0842	1.1729
	0.75	1.0083	1.0235	1.1095	1.0047	1.0946	1.2304	1.0037	1.1307	1.2928
	1.00	1.0224	1.0388	1.1880	1.0125	1.1311	1.3517	1.0083	1.1782	1.4369
6	0.25	1.0000	1.0052	1.0135	1.0000	1.0343	1.0540	1.0000	1.0489	1.0743
	0.50	1.0024	1.0182	1.0487	1.0027	1.0762	1.1296	1.0022	1.1052	1.1704
	0.75	1.0126	1.0397	1.1049	1.0070	1.1225	1.2235	1.0044	1.1652	1.2852
	1.00	1.0316	1.0628	1.1760	1.0190	1.1730	1.3382	1.0138	1.2299	1.4230
8	0.25	1.0000	1.0060	1.0127	1.0000	1.0375	1.0530	1.0000	1.0536	1.0736
	0.50	1.0033	1.0225	1.0470	1.0037	1.0863	1.1285	1.0014	1.1172	1.1687
	0.75	1.0135	1.0481	1.1004	1.0075	1.1387	1.2190	1.0045	1.1853	1.2805
	1.00	1.0355	1.0771	1.1680	1.0236	1.1992	1.3312	1.0170	1.2615	1.4154
10	0.25	1.0000	1.0079	1.0135	1.0023	1.0417	1.0545	1.0000	1.0571	1.0736
	0.50	1.0082	1.0283	1.0487	1.0023	1.0920	1.1270	1.0018	1.1249	1.1674
	0.75	1.0127	1.0532	1.0967	1.0071	1.1495	1.2161	1.0056	1.2001	1.2791
	1.00	1.0402	1.0890	1.1650	1.0248	1.2151	1.3248	1.0195	1.2812	1.4090
12	0.25	1.0000	1.0063	1.0111	1.0000	1.0431	1.0540	1.0000	1.0603	1.0743
	0.50	1.0049	1.0312	1.0487	1.0028	1.0966	1.1265	1.0000	1.1291	1.1653
	0.75	1.0152	1.0593	1.0967	1.0114	1.1597	1.2167	1.0067	1.2093	1.2767
	1.00	1.0486	1.0987	1.1640	1.0269	1.2271	1.3210	1.0211	1.2974	1.4068
14	0.25	1.0000	1.0101	1.0143	1.0000	1.0436	1.0530	1.0000	1.0614	1.0736
	0.50	1.0057	1.0292	1.0445	1.0032	1.1005	1.1265	1.0025	1.1358	1.1674
	0.75	1.0179	1.0613	1.0940	1.0099	1.1663	1.2161	1.0052	1.2156	1.2743
	1.00	1.0506	1.1048	1.1620	1.0315	1.2394	1.3216	1.0219	1.3085	1.4041

Table 10.1 The Values of $e_i's, i = 1, 2, 3$ ***Continued***

		$a_2 = 1$			$a_2 = 2$			$a_2 = 3$		
n	α	e_1	e_2	e_3	e_1	e_2	e_3	e_1	e_2	e_3
16	0.25	1.0065	1.0122	1.0160	1.0036	1.0465	1.0549	1.0000	1.0628	1.0736
	0.50	1.0066	1.0300	1.0436	1.0037	1.1034	1.1265	1.0029	1.1374	1.1653
	0.75	1.0204	1.0676	1.0967	1.0076	1.1681	1.2122	1.0060	1.2227	1.2748
	1.00	1.0507	1.1091	1.1600	1.0280	1.2430	1.3158	1.0252	1.3176	1.4025
18	0.25	1.0000	1.0077	1.0111	1.0000	1.0465	1.0540	1.0000	1.0635	1.0732
	0.50	1.0074	1.0314	1.0436	1.0000	1.1027	1.1234	1.0033	1.1415	1.1666
	0.75	1.0153	1.0678	1.0940	1.0128	1.1753	1.2150	1.0067	1.2257	1.2725
	1.00	1.0574	1.1151	1.1610	1.0362	1.2533	1.3190	1.0248	1.3225	1.3988
20	0.25	1.0000	1.0064	1.0095	1.0000	1.0453	1.0521	1.0000	1.0648	1.0736
	0.50	1.0082	1.0376	1.0487	1.0046	1.1056	1.1244	1.0036	1.1425	1.1653
	0.75	1.0169	1.0728	1.0967	1.0095	1.1772	1.2133	1.0075	1.2295	1.2720
	1.00	1.0545	1.1183	1.1600	1.0302	1.2525	1.3120	1.0236	1.3289	1.3982

		$a_2 = 4$			$a_2 = 5$		
n	α	e_1	e_2	e_3	e_1	e_2	e_3
2	0.25	1.0000	1.0249	1.0887	1.0000	1.0277	1.0970
	0.50	1.0003	1.0498	1.2043	1.0003	1.0551	1.2210
	0.75	1.0006	1.0737	1.3477	1.0006	1.0818	1.3738
	1.00	1.0016	1.0964	1.5244	1.0012	1.1073	1.5611
4	0.25	1.0000	1.0474	1.0873	1.0000	1.0526	1.0957
	0.50	1.0006	1.0986	1.1975	1.0006	1.1082	1.2139
	0.75	1.0026	1.1523	1.3306	1.0018	1.1668	1.3561
	1.00	1.0066	1.2072	1.4896	1.0055	1.2265	1.5250
6	0.25	1.0000	1.0580	1.0870	1.0000	1.0635	1.0948
	0.50	1.0010	1.1223	1.1948	1.0009	1.1336	1.2110
	0.75	1.0039	1.1915	1.3233	1.0036	1.2094	1.3493
	1.00	1.0101	1.2642	1.4744	1.0093	1.2885	1.5107
8	0.25	1.0000	1.0639	1.0866	1.0012	1.0705	1.0951
	0.50	1.0013	1.1357	1.1929	1.0012	1.1486	1.2096
	0.75	1.0039	1.2150	1.3195	1.0024	1.2333	1.3440
	1.00	1.0136	1.2986	1.4661	1.0125	1.3251	1.5019
10	0.25	1.0000	1.0669	1.0856	1.0000	1.0733	1.0935
	0.50	1.0016	1.1446	1.1918	1.0015	1.1588	1.2093
	0.75	1.0033	1.2291	1.3156	1.0045	1.2507	1.3424
	1.00	1.0153	1.3212	1.4602	1.0141	1.3491	1.4959
12	0.25	1.0000	1.0700	1.0859	1.0000	1.0767	1.0938
	0.50	1.0019	1.1512	1.1914	1.0018	1.1660	1.2089
	0.75	1.0039	1.2405	1.3143	1.0054	1.2625	1.3408
	1.00	1.0185	1.3392	1.4582	1.0151	1.3671	1.4926

(*Continued*)

Table 10.1 The Values of $e_i's, i = 1, 2, 3$ *Continued*

		$a_2 = 4$			$a_2 = 5$		
n	α	e_1	e_2	e_3	e_1	e_2	e_3
14	0.25	1.0000	1.0718	1.0856	1.0000	1.0796	1.0945
	0.50	1.0022	1.1560	1.1910	1.0000	1.1698	1.2071
	0.75	1.0069	1.2503	1.3148	1.0042	1.2710	1.3392
	1.00	1.0168	1.3504	1.4543	1.0155	1.3793	1.4889
16	0.25	1.0000	1.0730	1.0853	1.0000	1.0807	1.0938
	0.50	1.0026	1.1604	1.1914	1.0000	1.1737	1.2068
	0.75	1.0052	1.2539	1.3109	1.0048	1.2771	1.3376
	1.00	1.0192	1.3620	1.4543	1.0177	1.3898	1.4871
18	0.25	1.0000	1.0750	1.0859	1.0000	1.0820	1.0938
	0.50	1.0029	1.1624	1.1903	1.0026	1.1782	1.2079
	0.75	1.0059	1.2617	1.3131	1.0054	1.2840	1.3384
	1.00	1.0186	1.3680	1.4509	1.0171	1.3982	1.4857
20	0.25	1.0000	1.0740	1.0839	1.0000	1.0844	1.0951
	0.50	1.0000	1.1647	1.1899	1.0029	1.1806	1.2075
	0.75	1.0033	1.2627	1.3092	1.0030	1.2852	1.3344
	1.00	1.0207	1.3750	1.4504	1.0190	1.4049	1.4843

It is observed from Table 10.1 that

- for fixed a_2, the values of $e_i's, i = 1, 2, 3$ increase as n increase;
- for fixed n, the value of $e_i's, i = 1, 2, 3$ increase as α increases;
- the values of $e_i's, i = 1, 2, 3$ greater than "unity" for all values of (n, α, a_2), which follows that the estimators $\theta_2^*, \hat{\theta}_2^{n(1)}$ and $\hat{\theta}_2^{n(\infty)}$ are more efficient than unbiased estimator $\hat{\theta}_2$;
- when n is fixed, larger gain in efficiencies are observed for large values of α and all values of a_2;
- the values of $e_i's, i = 2, 3$ increase as the value of a_2 increases. It follows that the larger gain in efficiency by using $\hat{\theta}_2^{n(1)}$ and $\hat{\theta}_2^{n(\infty)}$ over $\hat{\theta}_2$ can be obtained when the population is more heterogeneous. No trend is observed for e_1 as a_2 increases.

Therefore we conclude that the BLUE of steady-state RSS $\hat{\theta}_2^{n(\infty)}$ of θ_2 is a better estimator of $\hat{\theta}_2$, θ_2^* and $\hat{\theta}_2^{n(1)}$, respectively.

10.4 CONCLUSION

In this chapter, taking the motivation from Ebrahimi (1984, 1985), we have developed a new Morgenstern type bivariate exponential distribution (MTBED) with known coefficients of variation (CV) using the results due to Morgenstern (1956) and Scaria and Nair (1999). The mean and

variance of newly developed MTBED with known CV have also been obtained. We have discussed the problem of estimating parameter θ_2 in MTBED in the presence of known CV. For estimating the parameter θ_2 of MTBED, we have derived an unbiased estimator $\hat{\theta}_2$ using ranked set sample mean and the BLUE θ_2^* based on RSS and their variances are given. We have further addressed the problem of estimating θ_2 using unbalanced RSS and its special cases known as unbalanced single-stage and steady-state RSS are also discussed. The reflective performance of the various proposed estimators of the parameter θ_2 are evaluated through numerical illustration and finally obtained that the BLUE of the steady-state RSS $\hat{\theta}_2^{n(\infty)}$ is more efficient among the estimators discussed in the chapter.

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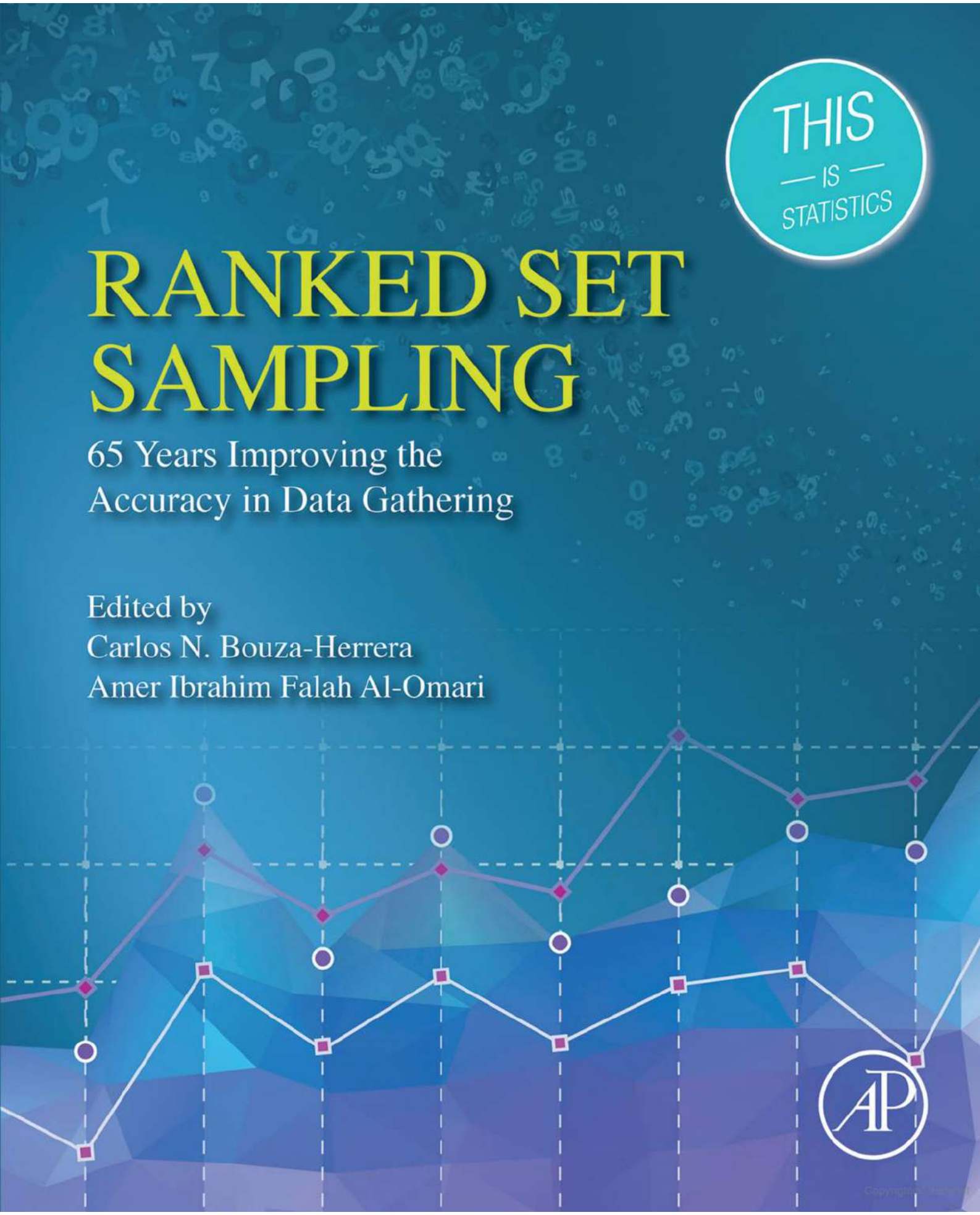

RANKED SET SAMPLING

65 Years Improving the Accuracy in Data Gathering

Edited by
Carlos N. Bouza-Herrera
Amer Ibrahim Falah Al-Omari

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CHAPTER

11

SHRINKAGE ESTIMATORS OF SCALE PARAMETER TOWARDS AN INTERVAL OF MORGENSTERN TYPE BIVARIATE UNIFORM DISTRIBUTION USING RANKED SET SAMPLING

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11.1 INTRODUCTION

Ranked set sampling (RSS) is a method of sampling that can be advantageous when quantification of all sampling units is costly but a small set of units can be easily ranked, according to the character under investigation, without actual quantification. The technique was first introduced by McIntyre (1952) for estimating mean pasture and forage yields. The theory and applications of RSS are given by Chen et al. (2004). Suppose the variable of interest, Y, is difficult or much too expensive to measure, but an auxiliary variable X correlated with Y is readily measureable and can be ordered exactly. In this case, as an alternative to McIntyre's (1952) method of ranked set sampling, Stokes (1977) used an auxiliary variable for the ranking of sampling units. If $X_{(r)r}$ is the observation measured on the auxiliary variable X from the unit chosen from the rth set then we write $Y_{[r]r}$ to denote the corresponding measurement made on the study variable Y on this unit, then $Y_{[r]r}, r = 1, 2, \ldots, n$, from the ranked set sample. Clearly, $Y_{[r]r}$ is the concomitant of the rth order statistic arising from the rth sample. Stokes (1995) has obtained the estimation of parameters of the location-scale family of distribution by RSS. Lam et al. (1994) used RSS to estimate the two-parameter exponential distribution. Al-Saleh and Ananbeh (2005, 2007) estimated the means of the bivariate normal distribution using moving extremes RSS with a concomitant variable. Al-Saleh and Diab (2009) considered estimation of the parameters of Downton's bivariate exponential distribution using an RSS scheme. Barnett and Moore (1997) derived the best linear unbiased estimator (BLUE) for the mean of Y, based on a ranked set sample obtained using an auxiliary variable X for ranking the sample units.

In the estimation of an unknown parameter there often exists some prior knowledge about the parameter which one would like to utilize in order to get a better estimate. The Bayesian approach is a well-known example in which prior knowledge about the parameter is available in the form of

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prior distribution. For current references in this context the reader is referred to Sharma et al. (2016), Bouza (2001, 2002, 2005), Samawi and Muttlak (1996), Demir and Singh (2000), Singh and Mehta (2013, 2014a,b, 2015, 2016a,b,c, 2017), Mehta and Singh (2015, 2014), and Mehta (2017).

The organization of this chapter is as follows. Section 11.2 introduces the general distribution theory, properties of Farlie−Gumbel−Morgenstern (FGM) distribution/Morgenstern distribution and a brief review of the estimators of the scale parameter θ_2 envisaged by Tahmasebi and Jafari (2012). In Section 11.3, some improved shrinkage toward interval estimators are described on the lines of Singh et al. (1973), Searls and Intarapanich (1960), Searls (1964), Jani (1991), and Kourouklis (1994), the expressions of bias and mean squared error (MSE) are obtained and compared with usual unbiased estimators. In Section 11.4, we have computed the relative efficiencies of different estimators numerically to evaluate their performance. Section 11.5 concludes the chapter with some final remarks.

11.2 REVIEW OF RSS IN FGM FAMILY OF DISTRIBUTION

A general family of bivariate distributions is proposed by Morgenstern (1956) with specified marginal distributions $F_X(x)$ and $F_Y(y)$ as

$$F_{X,Y}(x,y) = F_X(x)F_Y(y)[1+\alpha(1-F_X(x))\,(1-F_Y(y))];\ -1 \le \alpha \le 1, \tag{11.1}$$

where α is the association parameter between X and Y.

A member of this family is Morgenstern type bivariate uniform distribution (MTBUD) with the probability density function (pdf)

$$f_{X,Y}(x,y) = \frac{1}{\theta_1\theta_2}\left[1+\alpha\left(1-\frac{2x}{\theta_1}\right)\left(1-\frac{2y}{\theta_2}\right)\right];0<x<\theta_1,0<y<\theta_2. \tag{11.2}$$

The pdf of $Y_{[r]r}$ for $1 \le r \le n$ is given by [see Scaria and Nair (1999)]

$$g_{Y_{[r]r}}(y) = \int f_{Y|X}(y|x)\,f_r(x)\,dx = \frac{1}{\theta_2}\left[1+\alpha\left(\frac{n-2r+1}{n+1}\right)\left(1-\frac{2y}{\theta_2}\right)\right];\ 0<y<\theta_2,$$

where $f_r(x)$ is the density function of $X_{(r)r}$, i.e.,

$$f_r(x) = \frac{n!}{(r-1)!(n\text{-}r)!}\left[\frac{x^{r-1}(\theta_1-x)^{n-r}}{\theta_1^n}\right];\ 0<x<\theta_1,$$

and therefore, the mean and variance of $Y_{[r]r}$ for $1 \le r \le n$ are, respectively, given by

$$E\left[Y_{[r]r}\right] = \theta_2\beta_r \quad \text{and} \quad \mathrm{Var}\left[Y_{[r]r}\right] = \theta_2^2\lambda_r, \tag{11.3}$$

where

$$\beta_r = \frac{1}{2}\left[1-\frac{\alpha}{3}\left(\frac{n-2r+1}{n+1}\right)\right] \quad \text{and} \quad \lambda_r = \frac{1}{12}\left[1-\frac{\alpha^2}{3}\left(\frac{n-2r+1}{n+1}\right)^2\right]$$

Let $Y_{[r]r}, r = 1,2,\ldots,n$, be the RSS observations made on the units of the ranked set sampling regarding the study variable Y, which is correlated with the auxiliary variable X, when (X,Y) follows

MTBUD as defined in Eq. (11.2). Then an unbiased estimator for θ_2 based on RSS mean in Eq. (11.3) is given as [see Tahmasebi and Jafari (2012)]

$$t_1 = \hat{\theta}_{2,\mathrm{RSS}} = \frac{2}{n}\sum_{r=1}^{n} Y_{[r]r},$$

and its variance is

$$\mathrm{Var}(t_1) = \frac{\theta_2^2}{3n}\left[1 - \frac{\alpha^2}{3n}\sum_{r=1}^{n}\left(\frac{n-2r+1}{n+1}\right)^2\right] = \theta_2^2 V_1, \tag{11.4}$$

where

$$V_1 = \frac{1}{3n}\left[1 - \frac{\alpha^2}{3n}\sum_{r=1}^{n}\left(\frac{n-2r+1}{n+1}\right)^2\right].$$

When the parameter α is known, Tahmasebi and Jafari (2012) have suggested a BLUE θ_2^* of θ_2, which is more efficient than the estimator $\hat{\theta}_{2,\mathrm{RSS}}$ and is given as:

$$t_2 = \theta_2^* = \sum_{r=1}^{n}\left(\frac{\beta_r}{\lambda_r}\right)\left(\sum_{i=1}^{n}\left(\frac{\beta_i^2}{\lambda_i}\right)\right)^{-1} Y_{[r]r},$$

whose variance is

$$\mathrm{Var}(t_2) = \theta_2^2\left(\sum_{r=1}^{n}\left(\frac{\beta_r^2}{\lambda_r}\right)\right)^{-1} = \theta_2^2 V_2, \tag{11.5}$$

where

$$V_2 = \left(\sum_{r=1}^{n}\left(\frac{\beta_r^2}{\lambda_r}\right)\right)^{-1}.$$

Further, Tahmasebi and Jafari (2012) derived BLUE of θ_2 based on the upper ranked set sample (URSS) as

$$t_3 = \tilde{\theta}_2 = \frac{1}{n\beta_n}\sum_{r=1}^{n} Y_{[n]r},$$

and its variance is given by

$$\mathrm{Var}(t_3) = \theta_2^2\frac{\lambda_n}{n\beta_n^2} = \theta_2^2 V_3, \tag{11.6}$$

where

$$V_3 = \frac{\lambda_n}{n\beta_n^2}.$$

Using the extreme ranked set sampling (ERSS) method, Tahmasebi and Jafari (2012) also derived different estimators for θ_2 with concomitant variable for n. Below we have used the same notations ERSS_1, ERSS_2 and ERSS_3 as defined in Tahmasebi and Jafari (2012), pp. 134−135).

If n is even then the estimator of the θ_2 using ERSS_1 is defined as

$$t_4 = \hat{\theta}_{2,\text{ERSS}_1} = \frac{2}{n}\sum_{r=1}^{n/2} Y_{[1]2r-1} + Y_{[n]2r},$$

and its variance is given by

$$\text{Var}(t_4) = \frac{\theta_2^2}{3n}\left[1 - \frac{\alpha^2}{3}\left(\frac{n-1}{n+1}\right)^2\right] = \theta_2^2 V_4, \tag{11.7}$$

where

$$V_4 = \frac{1}{3n}\left[1 - \frac{\alpha^2}{3}\left(\frac{n-1}{n+1}\right)^2\right].$$

If n is odd then the estimators of θ_2 using ERSS_2 and ERSS_3 are obtained as

$$t_5 = \hat{\theta}_{2,\text{ERSS}_2} = \frac{2\left(Y_{[1]1} + Y_{[n]2} + Y_{[1]3} + \ldots + Y_{[n](n-1)} + \dfrac{\left(Y_{[1]n} + Y_{[n]n}\right)}{2}\right)}{n},$$

and

$$t_6 = \hat{\theta}_{2,\text{ERSS}_3} = \frac{2\left(Y_{[1]1} + Y_{[n]2} + Y_{[1]3} + \ldots + Y_{[n](n-1)} + Y_{\left[\frac{n+1}{2}\right]n}\right)}{n}.$$

The variances of the estimators t_5 and t_6 are, respectively, given by

$$\text{Var}(t_5) = \frac{\theta_2^2}{3n}\left[1 - \frac{\alpha^2(n-1)^3}{3n(n+1)^2} - \frac{1}{2n} + \frac{\alpha^2(2-n)}{6n(n+2)}\right] = \theta_2^2 V_5, \tag{11.8}$$

$$\text{Var}(t_6) = \frac{\theta_2^2}{3n}\left[1 - \frac{\alpha^2(n-1)^3}{3n(n+1)^2}\right] = \theta_2^2 V_6, \tag{11.9}$$

where

$$V_5 = \frac{1}{3n}\left[1 - \frac{\alpha^2(n-1)^3}{3n(n+1)^2} - \frac{1}{2n} + \frac{\alpha^2(2-n)}{6n(n+2)}\right],$$

and

$$V_6 = \frac{1}{3n}\left[1 - \frac{\alpha^2(n-1)^3}{3n(n+1)^2}\right].$$

Al-Saleh and Ananbeh (2007) proposed the concept of moving extreme ranked set sampling (MERSS) with a concomitant variable for the estimation of the means of the bivariate normal distribution. Now, suppose that the random vector (X, Y) has an MTBUD as defined in Eq. (11.2). An unbiased estimator of θ_2 based on MERSS is given by [see Tahmasebi and Jafari (2012)]

$$t_7 = \hat{\theta}_{2,\text{MERSS}} = \frac{1}{n}\sum_{r=1}^{n}\left(Y_{[1]r} + Y_{[n]r}\right),$$

and its variance is

$$\mathrm{Var}(t_7) = \frac{\theta_2^2}{6n}\left[1 - \frac{\alpha^2}{3n}\left(\frac{n-1}{n+1}\right)^2\right] = \theta_2^2 V_7, \tag{11.10}$$

where

$$V_7 = \frac{1}{6n}\left[1 - \frac{\alpha^2}{3n}\left(\frac{n-1}{n+1}\right)^2\right].$$

11.3 THE SUGGESTED FAMILY OF ESTIMATORS FOR THE SCALE PARAMETER θ_2 BASED ON THE A PRIORI INTERVAL

The arithmetic mean (AM), the geometric mean (GM), and the harmonic mean (HM) are measures of location, which are used for suggesting different classes of shrinkage estimators for scale parameter θ_2. Let the prior information of θ_2 be available in the form of an interval whose end points are θ_{21} and θ_{22}, such that $\theta_{21} < \theta_{22}$. We define the following families of shrinkage estimators $\psi_{\theta_2}^{(i)}$ $(i = 1, 2, 3)$ of θ_2 as

$$\psi_{\theta_2}^{(i)} = \delta t_j + (1-\delta) AGH(l,k) = \delta\left[t_j - AGH(l,k)\right] + AGH(l,k), \tag{11.11}$$

where $t_j, j = 1, 2, \ldots, 7$ is an unbiased estimator of the parameter θ_2, δ is a scalar such that $0 \le \delta \le 1$, and $AGH(l,k) = (\theta_{21}\theta_{22})^l \left(\frac{\theta_{21}+\theta_{22}}{2}\right)^k$ for $i = 1, 2, 3$ corresponding to (l,k) which should be taken as $(0,1)$, $\left(\frac{1}{2}, 0\right)$ and $(1, -1)$ in $AGH(l,k)$. It is interesting to note that for different values of i we have formed the following classes of estimators:

i. For $i = 1$ and $(l,k) = (0,1)$, we get the class of estimators as

$$\psi_{\theta_2}^{(1)} = \delta\left[t_j - AGH(0,1)\right] + AGH(0,1) = \delta\left[t_j - \left(\frac{\theta_{21}+\theta_{22}}{2}\right)\right] + \left(\frac{\theta_{21}+\theta_{22}}{2}\right), \tag{11.12}$$

ii. For $i = 2$ and $(l,k) = \left(\frac{1}{2}, 0\right)$, we obtain the class of estimators as

$$\psi_{\theta_2}^{(2)} = \delta\left[t_j - AGH\left(\frac{1}{2}, 0\right)\right] + AGH\left(\frac{1}{2}, 0\right) = \delta\left[t_j - \sqrt{\theta_{21}\theta_{22}}\right] + \sqrt{\theta_{21}\theta_{22}}, \tag{11.13}$$

iii. For $i = 3$ and $(l,k) = (1, -1)$, we get the class of estimators as

$$\psi_{\theta_2}^{(3)} = \delta\left[t_j - AGH(1,-1)\right] + AGH(1,-1) = \delta\left[t_j - \left(\frac{2\theta_{21}\theta_{22}}{\theta_{21}+\theta_{22}}\right)\right] + \left(\frac{2\theta_{21}\theta_{22}}{\theta_{21}+\theta_{22}}\right). \tag{11.14}$$

The bias and MSE of $\psi_{\theta_2}^{(i)}$ $(i = 1, 2, 3)$ are, respectively, given by

$$B\left[\psi_{\theta_2}^{(i)}\right] = \theta_2(1-\delta)\left(\lambda_{(i)} - 1\right) \tag{11.15}$$

$$\mathrm{MSE}\left[\psi_{\theta_2}^{(i)}\right] = \theta_2^2\left[V_j\delta^2 + (1-\delta)^2\left(\lambda_{(i)} - 1\right)^2\right], \tag{11.16}$$

where $\lambda_{(i)} = \frac{AGH(l,k)}{\theta_2}$.

The minimum mean squared error (MMSE) estimators of the parameter θ_2 based on $t_j, j = 1, 2, \ldots, 7$ are given as

$$T_j^* = \frac{\theta_2}{(1+V_j)}, j = 1, 2, \ldots, 7, \tag{11.17}$$

in the class of estimator $T_j = t_j A_j, j = 1, 2, \ldots, 7$, where $A_j^{'}s, j = 1, 2, \ldots, 7$ are suitably chosen constants such that the MSE of $T_j^{'}s, j = 1, 2, \ldots, 7$ are minimum.

The bias and MSE of $T_j^*s, j = 1, 2, \ldots, 7$ are, respectively, given by

$$B\left(T_j^*\right) = -\theta_2\left(\frac{V_j}{1+V_j}\right), \tag{11.18}$$

$$\text{MSE}\left(T_j^*\right) = \theta_2^2\left(\frac{V_j}{1+V_j}\right). \tag{11.19}$$

Comparisons of the proposed shrinkage estimators $\psi_{\theta_2}^{(i)}$ $(i = 1, 2, 3)$ with that of corresponding usual unbiased estimators $t_j^{'}s, j = 1, 2, \ldots, 7$ are given in Theorem 1.1.

Theorem 1.1: *The proposed shrinkage estimators* $\psi_{\theta_2}^{(i)}$ $(i = 1, 2, 3)$ *are better than the corresponding usual unbiased estimators* $t_j^{'}s, j = 1, 2, \ldots, 7$ *if*

$$\frac{\left\{\left(\lambda_{(i)}-1\right)^2 - V_j\right\}}{\left\{\left(\lambda_{(i)}-1\right)^2 + V_j\right\}} < \delta < 1.$$

Proof: *From Eqs. (11.4)–(11.10) and (11.16), we have that*

$$Var\left(t_j\right) - MSE\left[\psi_{\theta_2}^{(i)}\right] > 0, \quad i = 1, 2, 3, \quad j = 1, 2, \ldots, 7 \text{ if}$$

$$\theta_2^2 V_j - \theta_2^2 V_j \delta^2 - (1-\delta)^2\left(\lambda_{(i)}-1\right)^2\theta_2^2 > 0,$$

i.e., if $V_j\left(1-\delta^2\right) > (1-\delta)^2\left(\lambda_{(i)}-1\right)^2$, *i.e., if* $V_j(1+\delta) > (1-\delta)\left(\lambda_{(i)}-1\right)^2$,

Now

$$(1-\delta) > 0 \Rightarrow 1 > \delta \Rightarrow \delta < 1 \tag{11.20}$$

and $V_j + \delta\left\{V_j + \left(\lambda_{(i)}-1\right)^2\right\} > \left(\lambda_{(i)}-1\right)^2$, *or* $\delta\left\{V_j + \left(\lambda_{(i)}-1\right)^2\right\} > \left\{\left(\lambda_{(i)}-1\right)^2 - V_j\right\}$, *i.e., if*

$$\delta > \frac{\left\{\left(\lambda_{(i)}-1\right)^2 - V_j\right\}}{\left\{\left(\lambda_{(i)}-1\right)^2 + V_j\right\}}. \tag{11.21}$$

From Eqs. (11.20) and (11.21) we have

$$\frac{\left\{\left(\lambda_{(i)}-1\right)^2 - V_j\right\}}{\left\{\left(\lambda_{(i)}-1\right)^2 + V_j\right\}} < \delta < 1. \tag{11.22}$$

Hence the theorem.♦

Comparisons of the proposed shrinkage estimators $\psi_{\theta_2}^{(i)}$ $(i=1,2,3)$ with that of corresponding MMSE estimators $T_j^*s, j=1,2,\ldots,7$ are given in Theorem 1.2.

Theorem 1.2: *The proposed shrinkage estimators* $\psi_{\theta_2}^{(i)}$ $(i=1,2,3)$ *are better than the corresponding MMSE estimators* $T_j^*s, j=1,2,\ldots,7$ *if*

$$\left\{\frac{(\lambda_{(i)}-1)^2}{(\lambda_{(i)}-1)^2+V_j}-\frac{V_j\sqrt{\left\{1-(\lambda_{(i)}-1)^2\right\}}}{\sqrt{(1+V_j)\left\{(\lambda_{(i)}-1)^2+V_j\right\}}}\right\}<\delta<\left\{\frac{(\lambda_{(i)}-1)^2}{(\lambda_{(i)}-1)^2+V_j}+\frac{V_j\sqrt{\left\{1-(\lambda_{(i)}-1)^2\right\}}}{\sqrt{(1+V_j)\left\{(\lambda_{(i)}-1)^2+V_j\right\}}}\right\} \tag{11.23}$$

Proof: *From Eqs. (11.16) and (11.19), we have that*

$$MSE\left(T_j^*\right)-MSE\left[\psi_{\theta_2}^{(i)}\right]>0,\ \ i=1,2,3,\ \ j=1,2,\ldots,7 \text{ if}$$

$$\theta_2^2\frac{V_j}{1+V_j}-\theta_2^2V_j\delta^2-(1-\delta)^2(\lambda_{(i)}-1)^2\theta_2^2>0,$$

i.e., if $-\frac{V_j}{1+V_j}+V_j\delta^2+\left(1+\delta^2-2\delta\right)\left(1-\delta^2\right)(\lambda_{(i)}-1)^2<0,$

i.e., if $\delta^2\left[-V_j+(\lambda_{(i)}-1)^2\right]-2\delta(\lambda_{(i)}-1)^2-\frac{V_j}{1+V_j}+(\lambda_{(i)}-1)^2>0,$

On solving the above quadratic equation with respect to δ *we have*

$$\left\{\frac{(\lambda_{(i)}-1)^2}{(\lambda_{(i)}-1)^2+V_j}-\frac{V_j\sqrt{\left\{1-(\lambda_{(i)}-1)^2\right\}}}{\sqrt{(1+V_j)\left\{(\lambda_{(i)}-1)^2+V_j\right\}}}\right\}<\delta<\left\{\frac{(\lambda_{(i)}-1)^2}{(\lambda_{(i)}-1)^2+V_j}+\frac{V_j\sqrt{\left\{1-(\lambda_{(i)}-1)^2\right\}}}{\sqrt{(1+V_j)\left\{(\lambda_{(i)}-1)^2+V_j\right\}}}\right\}.$$

Hence the theorem.♦

11.4 RELATIVE EFFICIENCY

We note here that among these seven estimators $t_j,\ j=1,2,\ldots,7$ discussed above, the estimator t_2 is the best as we have observed numerically. Keeping this in view we have made an effort to compare the estimators $\psi_{\theta_2}^{(i)}$ $(i=1,2,3)$ formulated based on the BLUE with that of the BLUE t_2 and its MMSE estimator T_2^* by using following the formula:

$$e_1^{(i)}=RE\left(\psi_{\theta_2}^{(i)},t_2\right)=\frac{V_2}{\left\{V_2\delta^2+(1-\delta)^2(\lambda_{(i)}-1)^2\right\}},\ \ i=1,2,3, \tag{11.24}$$

$$e_2^{(i)}=RE\left(\psi_{\theta_2}^{(i)},T_2^*\right)=\frac{V_2}{(1+V_2)\left\{V_2\delta^2+(1-\delta)^2(\lambda_{(i)}-1)^2\right\}},\ \ i=1,2,3. \tag{11.25}$$

The values of $e_1^{(i)}$ and $e_2^{(i)}$, $i=1,2,3$ are shown in Table 11.1 for $n=5(5)20$, $\alpha=0.25(0.25)1.00$ and different values of $\psi_1=\frac{\theta_{21}}{\theta_2}=0.5(0.1)0.9$, $\psi_2=\frac{\theta_{22}}{\theta_2}=1.1(0.1)1.5$ and $\delta=0.25(0.25)0.75$.

Table 11.1 The Values of $e_1^{(i)}$ and $e_2^{(i)'}s$, $i = 1, 2, 3$ for Different Values of n, (ψ_1, ψ_2), δ and Fixed $\alpha = 0.25$

		(0.5,1.1)			(0.6,1.2)			(0.7,1.3)			(0.8,1.4)			(0.9,1.5)		
$(\psi_1,\psi_2)\rightarrow$ $n\downarrow$	δ	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$
5	0.25	2.4869	1.5882	1.1211	6.7842	3.8922	2.4869	16.0000	12.4488	7.6179	6.7842	10.9450	15.3735	2.4869	3.5095	5.1297
	0.50	2.4942	1.9918	1.6164	3.4754	2.9726	2.4942	4.0000	3.8771	3.5642	3.4754	3.8047	3.9820	2.4942	2.8665	3.2377
	0.75	1.6660	1.5987	1.5275	1.7485	1.7120	1.6660	1.7778	1.7715	1.7540	1.7485	1.7677	1.7769	1.6660	1.7030	1.7325
10	0.25	1.3465	0.8344	0.5801	4.3002	2.2128	1.3465	16.0000	10.1822	4.9940	4.3002	8.3114	14.7926	1.3465	1.9684	3.0509
	0.50	1.8106	1.3248	1.0117	3.0715	2.3637	1.8106	4.0000	3.7612	3.2132	3.0715	3.6272	3.9640	1.8106	2.2321	2.7181
	0.75	1.5672	1.4520	1.3385	1.7200	1.6508	1.5672	1.7778	1.7653	1.7307	1.7200	1.7577	1.7760	1.5672	1.6340	1.6893
15	0.25	0.9231	0.5658	0.3912	3.1475	1.5458	0.9231	16.0000	8.6137	3.7144	3.1475	6.6992	14.2539	0.9231	1.3677	2.1709
	0.50	1.4210	0.9924	0.7363	2.7516	1.9618	1.4210	4.0000	3.6520	2.9250	2.7516	3.4654	3.9463	1.4210	1.8276	2.3422
	0.75	1.4794	1.3299	1.1911	1.6925	1.5938	1.4794	1.7778	1.7592	1.7080	1.6925	1.7478	1.7751	1.4794	1.5704	1.6482
20	0.25	0.7023	0.4281	0.2952	2.4822	1.1878	0.7023	16.0000	7.4640	2.9569	2.4822	5.6110	13.7531	0.7023	1.0479	1.6850
	0.50	1.1695	0.7933	0.5787	2.4921	1.6767	1.1695	4.0000	3.5490	2.6843	2.4921	3.3175	3.9287	1.1695	1.5472	2.0577
	0.75	1.4010	1.2268	1.0730	1.6658	1.5406	1.4010	1.7778	1.7530	1.6860	1.6658	1.7380	1.7742	1.4010	1.5115	1.6090
		(0.5,1.1)			(0.6,1.2)			(0.7,1.3)			(0.8,1.4)			(0.9,1.5)		
$(\psi_1,\psi_2)\rightarrow$ $n\downarrow$	δ	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$
5	0.25	2.3324	1.4895	1.0514	6.3627	3.6504	2.3324	15.0058	11.6753	7.1446	6.3627	10.2649	14.4182	2.3324	3.2915	4.8109
	0.50	2.3392	1.8680	1.5160	3.2595	2.7879	2.3392	3.7515	3.6362	3.3428	3.2595	3.5683	3.7345	2.3392	2.6884	3.0365
	0.75	1.5625	1.4993	1.4326	1.6398	1.6056	1.5625	1.6673	1.6615	1.6450	1.6398	1.6579	1.6665	1.5625	1.5971	1.6248
10	0.25	1.3033	0.8077	0.5615	4.1625	2.1420	1.3033	15.4877	9.8562	4.8341	4.1625	8.0453	14.3189	1.3033	1.9054	2.9532
	0.50	1.7526	1.2823	0.9794	2.9731	2.2880	1.7526	3.8719	3.6408	3.1103	2.9731	3.5110	3.8371	1.7526	2.1606	2.6311
	0.75	1.5170	1.4055	1.2957	1.6649	1.5979	1.5170	1.7209	1.7088	1.6753	1.6649	1.7014	1.7191	1.5170	1.5817	1.6352
15	0.25	0.9032	0.5536	0.3828	3.0796	1.5124	0.9032	15.6550	8.4279	3.6343	3.0796	6.5547	13.9465	0.9032	1.3382	2.1241
	0.50	1.3904	0.9710	0.7204	2.6922	1.9194	1.3904	3.9137	3.5733	2.8620	2.6922	3.3907	3.8612	1.3904	1.7881	2.2917
	0.75	1.4475	1.3012	1.1654	1.6560	1.5594	1.4475	1.7394	1.7212	1.6712	1.6560	1.7101	1.7368	1.4475	1.5365	1.6126
20	0.25	0.6909	0.4211	0.2904	2.4419	1.1684	0.6909	15.7399	7.3427	2.9088	2.4419	5.5197	13.5295	0.6909	1.0309	1.6576
	0.50	1.1505	0.7804	0.5693	2.4516	1.6494	1.1505	3.9350	3.4913	2.6407	2.4516	3.2636	3.8648	1.1505	1.5220	2.0242
	0.75	1.3782	1.2069	1.0555	1.6387	1.5155	1.3782	1.7489	1.7245	1.6586	1.6387	1.7098	1.7454	1.3782	1.4870	1.5829
(For Fixed $\alpha = 0.50$)																
		(0.5, 1.1)			(0.6, 1.2)			(0.7, 1.3)			(0.8, 1.4)			(0.9, 1.5)		
$(\psi_1,\psi_2)\rightarrow$ $n\downarrow$	δ	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$
5	0.25	2.4473	1.5612	1.1014	6.7101	3.8365	2.4473	16.0000	12.3960	7.5421	6.7101	10.8790	15.3620	2.4473	3.4577	5.0636
	0.50	2.4763	1.9728	1.5981	3.4667	2.9580	2.4763	4.0000	3.8748	3.5568	3.4667	3.8012	3.9816	2.4763	2.8510	3.2259
	0.75	1.6640	1.5956	1.5234	1.7479	1.7108	1.6640	1.7778	1.7714	1.7535	1.7479	1.7675	1.7769	1.6640	1.7016	1.7316

Table 11.1 The Values of $e_1^{(i)}$ and $e_2^{(i)'}s$, $i = 1, 2, 3$ for Different Values of $n, (\psi_1, \psi_2), \delta$ and Fixed $\alpha = 0.25$ *Continued*

(For Fixed $\alpha = 0.50$)

$(\psi_1,\psi_2) \rightarrow$ $n \downarrow$	δ	$(0.5, 1.1)$			$(0.6, 1.2)$			$(0.7, 1.3)$			$(0.8, 1.4)$			$(0.9, 1.5)$		
		$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$
10	0.25	1.3178	0.8160	0.5671	4.2267	2.1684	1.3178	16.0000	10.0950	4.9137	4.2267	8.2176	14.7661	1.3178	1.9282	2.9933
	0.50	1.7873	1.3040	0.9941	3.0546	2.3409	1.7873	4.0000	3.7559	3.1982	3.0546	3.6192	3.9632	1.7873	2.2089	2.6976
	0.75	1.5628	1.4457	1.3307	1.7187	1.6480	1.5628	1.7778	1.7650	1.7296	1.7187	1.7572	1.7759	1.5628	1.6308	1.6873
15	0.25	0.9014	0.5523	0.3818	3.0844	1.5110	0.9014	16.0000	8.5136	3.6432	3.0844	6.6014	14.2144	0.9014	1.3366	2.1242
	0.50	1.3981	0.9737	0.7213	2.7299	1.9366	1.3981	4.0000	3.6440	2.9051	2.7299	3.4537	3.9449	1.3981	1.8026	2.3177
	0.75	1.4732	1.3214	1.1812	1.6904	1.5896	1.4732	1.7778	1.7587	1.7063	1.6904	1.7471	1.7750	1.4732	1.5657	1.6451
20	0.25	0.6850	0.4173	0.2877	2.4281	1.1594	0.6850	16.0000	7.3603	2.8946	2.4281	5.5163	13.7023	0.6850	1.0227	1.6461
	0.50	1.1480	0.7769	0.5659	2.4675	1.6514	1.1480	4.0000	3.5385	2.6612	2.4675	3.3026	3.9268	1.1480	1.5225	2.0316
	0.75	1.3932	1.2168	1.0619	1.6630	1.5352	1.3932	1.7778	1.7524	1.6837	1.6630	1.7370	1.7741	1.3932	1.5056	1.6050

$(\psi_1,\psi_2) \rightarrow$ $n \downarrow$	δ	$(0.5, 1.1)$			$(0.6, 1.2)$			$(0.7, 1.3)$			$(0.8, 1.4)$			$(0.9, 1.5)$		
		$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$
5	0.25	2.2979	1.4659	1.0342	6.3005	3.6023	2.2979	15.0234	11.6394	7.0817	6.3005	10.2150	14.4243	2.2979	3.2467	4.7546
	0.50	2.3251	1.8524	1.5006	3.2551	2.7774	2.3251	3.7558	3.6383	3.3397	3.2551	3.5692	3.7386	2.3251	2.6769	3.0290
	0.75	1.5624	1.4982	1.4304	1.6412	1.6064	1.5624	1.6693	1.6633	1.6465	1.6412	1.6596	1.6684	1.5624	1.5977	1.6259
10	0.25	1.2765	0.7905	0.5494	4.0944	2.1006	1.2765	15.4992	9.7791	4.7599	4.0944	7.9604	14.3039	1.2765	1.8679	2.8996
	0.50	1.7314	1.2632	0.9630	2.9590	2.2676	1.7314	3.8748	3.6383	3.0981	2.9590	3.5059	3.8392	1.7314	2.1397	2.6132
	0.75	1.5139	1.4004	1.2891	1.6649	1.5964	1.5139	1.7221	1.7098	1.6755	1.6649	1.7022	1.7204	1.5139	1.5798	1.6345
15	0.25	0.8825	0.5406	0.3737	3.0195	1.4792	0.8825	15.6633	8.3344	3.5665	3.0195	6.4625	13.9153	0.8825	1.3084	2.0795
	0.50	1.3687	0.9532	0.7061	2.6724	1.8959	1.3687	3.9158	3.5673	2.8440	2.6724	3.3810	3.8619	1.3687	1.7647	2.2690
	0.75	1.4422	1.2936	1.1563	1.6548	1.5561	1.4422	1.7404	1.7217	1.6704	1.6548	1.7103	1.7377	1.4422	1.5328	1.6105
20	0.25	0.6741	0.4107	0.2832	2.3896	1.1410	0.6741	15.7465	7.2437	2.8487	2.3896	5.4289	13.4851	0.6741	1.0065	1.6200
	0.50	1.1298	0.7646	0.5570	2.4284	1.6252	1.1298	3.9366	3.4824	2.6191	2.4284	3.2503	3.8646	1.1298	1.4984	1.9994
	0.75	1.3711	1.1976	1.0450	1.6367	1.5109	1.3711	1.7496	1.7246	1.6570	1.6367	1.7095	1.7460	1.3711	1.4817	1.5796

(For Fixed $\alpha = 0.75$)

$(\psi_1,\psi_2) \rightarrow$ $n \downarrow$	δ	$(0.5, 1.1)$			$(0.6, 1.2)$			$(0.7, 1.3)$			$(0.8, 1.4)$			$(0.9, 1.5)$		
		$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$
5	0.25	2.3798	1.5155	1.0682	6.5822	3.7413	2.3798	16.0000	12.3033	7.4110	6.5822	10.7637	15.3415	2.3798	3.3693	4.9504
	0.50	2.4451	1.9399	1.5667	3.4513	2.9324	2.4451	4.0000	3.8708	3.5437	3.4513	3.7949	3.9810	2.4451	2.8238	3.2051
	0.75	1.6605	1.5901	1.5161	1.7469	1.7087	1.6605	1.7778	1.7712	1.7527	1.7469	1.7672	1.7768	1.6605	1.6991	1.7301
10	0.25	1.2687	0.7846	0.5449	4.0995	2.0921	1.2687	16.0000	9.9403	4.7742	4.0995	8.0524	14.7182	1.2687	1.8592	2.8941
	0.50	1.7466	1.2680	0.9636	3.0245	2.3007	1.7466	4.0000	3.7462	3.1714	3.0245	3.6047	3.9617	1.7466	2.1679	2.6610
	0.75	1.5549	1.4344	1.3167	1.7163	1.6429	1.5549	1.7778	1.7645	1.7276	1.7163	1.7564	1.7759	1.5549	1.6252	1.6836

(*Continued*)

Table 11.1 **The Values of $e_1^{(i)}$ and $e_2^{(i)'}s$, $i = 1, 2, 3$ for Different Values of n, (ψ_1, ψ_2), δ and Fixed $\alpha = 0.25$** ***Continued***

(For Fixed $\alpha = 0.75$)

$(\psi_1,\psi_2)\rightarrow$ $n\downarrow$	δ	(0.5, 1.1)			(0.6, 1.2)			(0.7, 1.3)			(0.8, 1.4)			(0.9, 1.5)		
		$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$
15	0.25	0.8643	0.5290	0.3655	2.9750	1.4511	0.8643	16.0000	8.3359	3.5193	2.9750	6.4294	14.1425	0.8643	1.2830	2.0434
	0.50	1.3578	0.9413	0.6953	2.6910	1.8921	1.3578	4.0000	3.6292	2.8694	2.6910	3.4323	3.9425	1.3578	1.7586	2.2742
	0.75	1.4617	1.3062	1.1634	1.6866	1.5820	1.4617	1.7778	1.7578	1.7032	1.6866	1.7457	1.7749	1.4617	1.5572	1.6395
20	0.25	0.6553	0.3989	0.2749	2.3342	1.1106	0.6553	16.0000	7.1766	2.7864	2.3342	5.3502	13.6097	0.6553	0.9793	1.5790
	0.50	1.1105	0.7483	0.5438	2.4235	1.6066	1.1105	4.0000	3.5192	2.6197	2.4235	3.2755	3.9234	1.1105	1.4791	1.9853
	0.75	1.3791	1.1989	1.0420	1.6579	1.5253	1.3791	1.7778	1.7512	1.6795	1.6579	1.7351	1.7739	1.3791	1.4947	1.5976

$(\psi_1,\psi_2)\rightarrow$ $n\downarrow$	δ	(0.5, 1.1)			(0.6, 1.2)			(0.7, 1.3)			(0.8, 1.4)			(0.9, 1.5)		
		$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$
5	0.25	2.2390	1.4258	1.0050	6.1927	3.5199	2.2390	15.0531	11.5752	6.9724	6.1927	10.1267	14.4336	2.2390	3.1699	4.6574
	0.50	2.3004	1.8251	1.4739	3.2471	2.7589	2.3004	3.7633	3.6417	3.3340	3.2471	3.5703	3.7454	2.3004	2.6567	3.0154
	0.75	1.5622	1.4960	1.4264	1.6435	1.6075	1.5622	1.6726	1.6664	1.6490	1.6435	1.6626	1.6717	1.5622	1.5986	1.6277
10	0.25	1.2305	0.7610	0.5285	3.9762	2.0292	1.2305	15.5189	9.6414	4.6306	3.9762	7.8102	14.2756	1.2305	1.8033	2.8070
	0.50	1.6941	1.2299	0.9346	2.9335	2.2315	1.6941	3.8797	3.6336	3.0761	2.9335	3.4963	3.8425	1.6941	2.1027	2.5810
	0.75	1.5081	1.3913	1.2771	1.6647	1.5935	1.5081	1.7243	1.7114	1.6757	1.6647	1.7036	1.7225	1.5081	1.5763	1.6330
15	0.25	0.8469	0.5183	0.3581	2.9151	1.4219	0.8469	15.6777	8.1680	3.4485	2.9151	6.2999	13.8576	0.8469	1.2572	2.0023
	0.50	1.3305	0.9223	0.6813	2.6368	1.8540	1.3305	3.9194	3.5561	2.8116	2.6368	3.3632	3.8631	1.3305	1.7232	2.2284
	0.75	1.4323	1.2799	1.1400	1.6526	1.5501	1.4323	1.7420	1.7224	1.6689	1.6526	1.7105	1.7391	1.4323	1.5259	1.6065
20	0.25	0.6453	0.3929	0.2708	2.2989	1.0938	0.6453	15.7578	7.0680	2.7442	2.2989	5.2692	13.4036	0.6453	0.9644	1.5551
	0.50	1.0937	0.7370	0.5356	2.3868	1.5823	1.0937	3.9394	3.4660	2.5800	2.3868	3.2260	3.8640	1.0937	1.4567	1.9553
	0.75	1.3582	1.1808	1.0262	1.6328	1.5022	1.3582	1.7509	1.7247	1.6540	1.6328	1.7089	1.7471	1.3582	1.4721	1.5734

(For Fixed $\alpha = 1.00$)

$(\psi_1,\psi_2)\rightarrow$ $n\downarrow$	δ	(0.5, 1.1)			(0.6, 1.2)			(0.7, 1.3)			(0.8, 1.4)			(0.9, 1.5)		
		$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$
5	0.25	2.2820	1.4494	1.0202	6.3926	3.6023	2.2820	16.0000	12.1617	7.2159	6.3926	10.5892	15.3097	2.2820	3.2405	4.7840
	0.50	2.3982	1.8908	1.5201	3.4276	2.8935	2.3982	4.0000	3.8645	3.5234	3.4276	3.7851	3.9801	2.3982	2.7826	3.1733
	0.75	1.6550	1.5817	1.5050	1.7454	1.7053	1.6550	1.7778	1.7709	1.7515	1.7454	1.7666	1.7768	1.6550	1.6954	1.7278
10	0.25	1.1966	0.7387	0.5125	3.9092	1.9795	1.1966	16.0000	9.6998	4.5645	3.9092	7.7988	14.6414	1.1966	1.7576	2.7468
	0.50	1.6845	1.2137	0.9179	2.9769	2.2384	1.6845	4.0000	3.7308	3.1290	2.9769	3.5815	3.9592	1.6845	2.1048	2.6040
	0.75	1.5422	1.4165	1.2948	1.7124	1.6348	1.5422	1.7778	1.7636	1.7244	1.7124	1.7550	1.7757	1.5422	1.6161	1.6778

Table 11.1 **The Values of $e_1^{(i)}$ and $e_2^{(i)'}s$, $i = 1, 2, 3$ for Different Values of $n, (\psi_1, \psi_2), \delta$ and Fixed $\alpha = 0.25$** ***Continued***

(For Fixed $\alpha = 1.00$)

$(\psi_1,\psi_2) \rightarrow$ $n \downarrow$	δ	(0.5, 1.1)			(0.6, 1.2)			(0.7, 1.3)			(0.8, 1.4)			(0.9, 1.5)		
		$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$	$e_1^{(1)}$	$e_1^{(2)}$	$e_1^{(3)}$
15	0.25	0.8096	0.4948	0.3417	2.8115	1.3626	0.8096	16.0000	8.0600	3.3336	2.8115	6.1659	14.0261	0.8096	1.2039	1.9236
	0.50	1.2967	0.8925	0.6566	2.6295	1.8235	1.2967	4.0000	3.6054	2.8126	2.6295	3.3979	3.9384	1.2967	1.6909	2.2062
	0.75	1.4434	1.2819	1.1354	1.6805	1.5696	1.4434	1.7778	1.7564	1.6981	1.6805	1.7434	1.7747	1.4434	1.5436	1.6305
20	0.25	0.6115	0.3719	0.2562	2.1945	1.0385	0.6115	16.0000	6.8933	2.6248	2.1945	5.0973	13.4598	0.6115	0.9152	1.4796
	0.50	1.0538	0.7056	0.5109	2.3543	1.5381	1.0538	4.0000	3.4880	2.5540	2.3543	3.2319	3.9178	1.0538	1.4128	1.9135
	0.75	1.3564	1.1705	1.0108	1.6497	1.5093	1.3564	1.7778	1.7492	1.6726	1.6497	1.7320	1.7736	1.3564	1.4772	1.5857
$(\psi_1,\psi_2) \rightarrow$ $n \downarrow$	δ	(0.5, 1.1)			(0.6, 1.2)			(0.7, 1.3)			(0.8, 1.4)			(0.9, 1.5)		
		$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$	$e_2^{(1)}$	$e_2^{(2)}$	$e_2^{(3)}$
5	0.25	2.1530	1.3675	0.9626	6.0315	3.3988	2.1530	15.0960	11.4746	6.8082	6.0315	9.9909	14.4447	2.1530	3.0574	4.5137
	0.50	2.2627	1.7840	1.4342	3.2340	2.7300	2.2627	3.7740	3.6461	3.3243	3.2340	3.5712	3.7552	2.2627	2.6254	2.9940
	0.75	1.5614	1.4924	1.4199	1.6468	1.6090	1.5614	1.6773	1.6708	1.6525	1.6468	1.6668	1.6764	1.5614	1.5996	1.6301
10	0.25	1.1627	0.7178	0.4980	3.7986	1.9235	1.1627	15.5476	9.4255	4.4355	3.7986	7.5783	14.2274	1.1627	1.7079	2.6691
	0.50	1.6368	1.1794	0.8920	2.8928	2.1751	1.6368	3.8869	3.6253	3.0405	2.8928	3.4802	3.8472	1.6368	2.0453	2.5304
	0.75	1.4986	1.3764	1.2581	1.6640	1.5886	1.4986	1.7275	1.7138	1.6757	1.6640	1.7054	1.7255	1.4986	1.5704	1.6304
15	0.25	0.7943	0.4855	0.3352	2.7586	1.3369	0.7943	15.6988	7.9083	3.2708	2.7586	6.0498	13.7621	0.7943	1.1812	1.8874
	0.50	1.2722	0.8757	0.6442	2.5800	1.7892	1.2722	3.9247	3.5375	2.7596	2.5800	3.3339	3.8643	1.2722	1.6591	2.1646
	0.75	1.4162	1.2577	1.1140	1.6488	1.5401	1.4162	1.7443	1.7234	1.6662	1.6488	1.7106	1.7413	1.4162	1.5145	1.5998
20	0.25	0.6029	0.3666	0.2525	2.1636	1.0239	0.6029	15.7743	6.7961	2.5878	2.1636	5.0254	13.2699	0.6029	0.9023	1.4587
	0.50	1.0389	0.6956	0.5037	2.3211	1.5164	1.0389	3.9436	3.4388	2.5180	2.3211	3.1863	3.8626	1.0389	1.3928	1.8865
	0.75	1.3373	1.1540	0.9965	1.6264	1.4880	1.3373	1.7527	1.7246	1.6490	1.6264	1.7076	1.7486	1.3373	1.4564	1.5633

11.5 CONCLUSION

It is observed from Table 11.1 that:

- when $(\psi_1, \psi_2) \in (0.7, 1.3)$ the proposed classes of estimators $\psi_{\theta_2}^{(i)}$ $(i = 1, 2, 3)$ is always better than the usual unbiased estimator t_2 and MMSE estimator T_2^*;
- the gain in efficiency by using $\psi_{\theta_2}^{(i)}$ $(i = 1, 2, 3)$ over MMSE estimator T_2^* is fewer than by using $\psi_{\theta_2}^{(i)}$ $(i = 1, 2, 3)$ over the BLUE t_2;
- for $(\psi_1, \psi_2) \in (0.7, 1.3)$, the developed class of estimators $\psi_{\theta_2}^{(1)}$ (based on AM) is the best (best in the sense of having smaller MSE) among $\psi_{\theta_2}^{(i)} (i = 1, 2, 3)$, while for $(\psi_1, \psi_2) \in (0.9, 1.5)$ the developed class of estimator $\psi_{\theta_2}^{(3)}$ (based on HM) is the best among $\psi_{\theta_2}^{(i)}$ $(i = 1, 2, 3)$.

In general the proposed estimator $\psi_{\theta_2}^{(1)}$ is recommended when $(\psi_1, \psi_2) \in (0.5, 1.3)$ and $\psi_{\theta_2}^{(3)}$ is recommended when $(\psi_1, \psi_2) \in (0.8, 1.5)$ and the sample size n is small. In practice, when the observations are expensive such small sizes may be all that are available, particularly in defense weapon testing problems.

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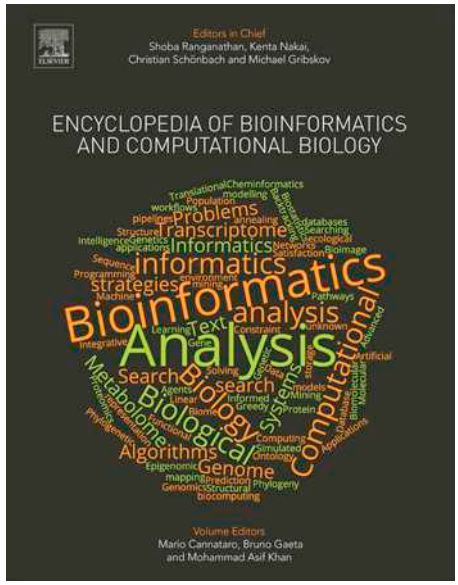

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Disease Biomarker Discovery

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Metabolic Networks: A Background for Biomarkers

Network biology is a branch of science that deals with the interactions among biomolecules that include genes, transcripts, proteins, metabolites, etc. With the advent of system biology, networks are being used widely across many branches of biology (proteomics, genomics, transcriptomics, and metabolomics) as a convenient representation of the interaction between specific biological elements. These graphical representations denote the molecular-level blueprint of interactions and mechanisms of regulation inside a cell. These biological networks include gene regulatory network, transcriptomic network, protein–protein interaction network, and metabolic network. The network biology approach helped to cover the overall aspects of the necessary facets that need to be considered while finding the probable therapeutic intervention for the particular disease type. The interaction data come through the high-throughput methods that are gathered from individual studies and large-scale screens that finally get assembled into a topological form (i.e., network format) that holds significant biological properties. In a recent scenario, more attention has been given to the gene and protein networks to study a complex form of diseases (Shukla and Singh, 2017). Although it has been found that the metabolic networks seem to play a significant role in the complex disease regulation like in case of cancer's Warburg effect (Vander Heiden *et al.*, 2009), which signifies uncontrolled cell division even in anaerobic conditions that involve numerous metabolites and the reaction mechanisms. The metabolic network comprises of metabolites and enzymes that take the role of nodes and the reactions describing their transformations and is represented as directed edges in **Fig. 1** (Bourqui *et al.*, 2007).

Biochemical reactions happening inside a metabolic network allow an organism to grow, reproduce, and respond to the environment and maintain its structure (Xu *et al.*, 2016). In a biochemical pathway, the metabolic network centralizes its attention towards mass flow that generates essential components like amino acids, sugars, and lipids, and the energy required by the biochemical reactions (Zhu *et al.*, 2007). In a metabolic network, it's not only metabolites that perform the overall metabolism but there are genes and proteins too that commence their task in regulatory mechanisms; this is what makes the metabolic networks more efficient from the disease perspective and their immediate applications too for therapeutic interventions (Berkhout *et al.*, 2013). This shows that metabolic networks typically show the representation of not only metabolites but also for genes and proteins and therefore provide wide perspective in disease studies. In a cell, metabolism holds chemical processes by which cells break down food and nutrients into usable building blocks and then reassemble those building blocks to form the biological molecules known as metabolites (DeBerardinis and Thompson, 2012). The metabolites consumed are called the substrates of the reaction; however those produced are called the products. Most metabolic reactions do not occur spontaneously, or we can say that they occur at a very low rate; therefore enzymes are used to enhance the pace of the reaction to get it completed (Cooper, 2000). This breakdown and reassembly in a pathway entails a set of successive chemical reactions that convert initial inputs into useful end products via a series of steps and this complete set of reactions in the pathway forms the metabolic network (Sridharan *et al.*, 2015). To understand the interacting mechanism in a network it's necessary to understand the architecture of the network topology. In a metabolic network, nodes represent the chemicals produced and consumed by the reactions that include small molecules (i.e. carbohydrates, lipids, amino acids, and nucleotides), and the edges denote the metabolic flow or the regulatory effects of a specific reaction (Lee *et al.*, 2008). Understanding the complex network often requires a bottom-up approach that carries its path towards systems biology perspective (Shahzad and Loor, 2012). Thus there is need to examine a system, not only in terms of individual components but as a whole, which can be done by considering the elementary constituents individually as well as when they are connected. Numerous components of a system and their interactions are best characterized as networks and they are mainly represented as graphs where thousands of nodes are connected with thousands of vertices (Cho *et al.*, 2012).

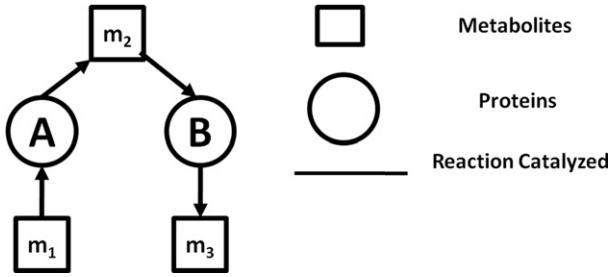

Fig. 1 Basic metabolic network.

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Network analysis has suggested that biological networks have two imperative structural properties (Mahadevan and Palsson, 2005). First, it has been shown that several of these networks, including metabolic networks, are scale-free and possess a "small world" property (Barabasi and Oltvai, 2004). Second, scale-free networks are suggested to have high error tolerance and low attack tolerance (Crucitti *et al.*, 2004). In general, interactions in a network between biological entities (genes, transcripts, proteins, metabolites, etc.) can be classified on the basis of the nature of the interaction into two broad categories, i.e., influence networks and the flow networks. For influence networks, the nature of interactions are "influence-based" such as protein–protein interaction or signaling networks, i.e., connections mark the presence or absence of the reaction (Mahadevan and Palsson, 2005). This class might be extended with the case where the type of interaction is important in addition to presence or absence of the interaction, e.g., gene regulatory networks where transcription factors can either activate or repress gene expression. While in flow networks, where a specific variable like mass or energy flow may be conserved at each node, such as metabolic networks. However, it should be noted that the fundamental properties of biological networks in these two classes can be significantly different (Barabasi and Oltvai, 2004). It has been seen widely that along with the complete network graph, the subgraphs are also seen to play an essential functional role like network motifs (that represent most frequently occurring subgraph) and studies have shown the structural organization of the feedback loops (**Fig. 2**). Similarly, single-input and multiple-input motifs (**Fig. 2**) (Sehgal *et al.*, 2015) can influence the dynamics and the regulation of metabolic pathways (Beber *et al.*, 2012). For effective analysis it's important to model the network graphs correctly for which there are a wide variety of approaches depending on the features of interest through which network dynamics can be modeled, like for small networks with explicit kinetics, which can be modeled with differential equations, while for larger networks dynamics can be accessed by flux balance analysis or stochastic kinetic modeling (Boccaletti *et al.*, 2006). Also, for the case where only stoichiometric information is available, more basic approaches like network expansion or Petri nets can be utilized (Peleg *et al.*, 2005).

Varieties of graph representations are available in network biology but studies have shown that bipartite graph (**Fig. 3**) (two nodes represent metabolites with edges joining each metabolite to the reaction) is the most correct representation of the metabolic network (Veeramani and Bader, 2010). The edges in the representative graphs are directed because some metabolites (the substrates) go into the reaction and some (the products) come out of it. Metabolic networks are represented through nodes as metabolites and the links as reactions that are catalyzed by specific gene products; this representation is different from protein–protein interaction networks, where the nodes are the gene products and the links correspond to interactions. The analysis of protein–protein interaction networks has suggested that the deletion of the most highly connected proteins correlates well with a lethal phenotype (Mahadevan and Palsson, 2005). In contrast, a node in metabolic networks cannot be deleted by genetic techniques, but links can (Jeong *et al.*, 2001).

Now the question comes as to how the resultant computational network are formed and how their global representation is possible. The answer lies in the computer readable file formats for the biological networks, i.e., Systems Biology Markup Language (SBML), a global format which could be utilized for the reusability of network models. It is a XML-like machine-readable language that is proficient to represent models to be analyzed by a computer. SBML can represent metabolic networks, cell signaling pathways, regulatory networks, and many other kinds of systems (Hucka *et al.*, 2003). An increasing number of diseases are now

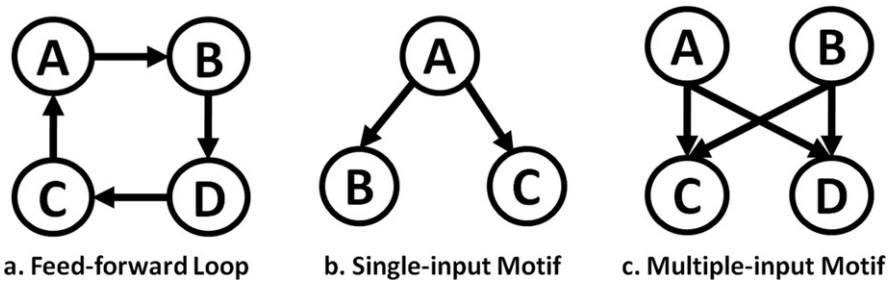

Fig. 2 Most frequent regulatory motif.

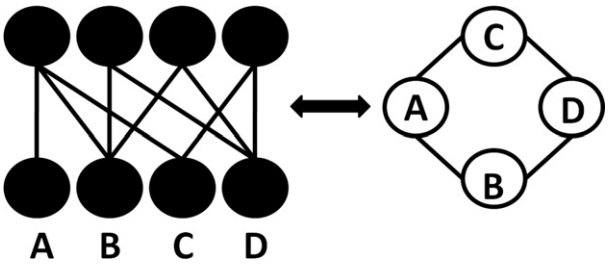

Fig. 3 Bipartite graph with corresponding simple representation.

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seen to be a result of drastic perturbations of cellular functions that involve large sets of genes, where connections are complicated to understand. Diseases in particular like cancer, CVD, or diabetes causes huge perturbations in cell metabolism. Therefore, the study of metabolic networks primary perturbation in interactions and fluxes can aid better understanding of the physiopathology of such diseases. It notably permits an understanding of how and why alteration in activity or expression levels of a few enzymes can transmit substantial perturbations into entire cellular functions. Therefore these metabolites could have been proposed as putative biomarkers for the human diseases.

Metabolome Analysis: Computational Protocols and Methods

The metabolome comprises of the biochemical composition of the small-molecule metabolites present in a cell that are involved in the metabolic reaction mechanism and required for the maintenance, growth, and normal functioning of the cell (Mohney and Milburn, 2015). The metabolome was first described by Oliver and colleagues in 1998 (Oliver *et al.*, 1998), during their pioneering work on yeast metabolism that therefore confers the discipline of metabolomics; that follows the analysis of the metabolome. Metabolomics is sometimes also called metabonomics or metabolic profiling (Lindon *et al.*, 2011). Various experimental, statistical, and computational approaches have been discovered so far to perform the metabolome analysis. The most commonly used experimental techniques in metabolomics are mass spectrometry (MS), i.e., gas chromatography (GC–MS) or liquid chromatography (LC-MS), and nuclear magnetic resonance spectroscopy (NMR) spectra (Zhang *et al.*, 2012). Along with this statistical approaches have been devised to perform the analysis and it comprises of various standard analysis methods such as t-test and ANOVA, as well as more sophisticated methodologies such as univariate and multivariate analysis methods (Bartel *et al.*, 2013).

Also, bioinformatic approaches fall into the scenario due to the boom in high-throughput data and this includes databases for the data retrieval as well as web servers for carrying out the analysis (Maudsley *et al.*, 2011). Tremendous efforts have been implemented to archive all types of biological data, i.e., genes, proteins, gene products, metabolites, etc. With the advent of the genomic era, the amount of biochemical knowledge has exploded in the last two decades, which has necessitated its storage in large databases. Variety of top-down (gene to protein to metabolite) and bottom-up (chemical entity to biological function) approaches have been implied resulting in a rich expanse of metabolic knowledge from the biochemical network (Cakir and Khatibipour, 2014). Bioinformatics is a pioneer in preserving the data obtained through the experimental or natural resources and also provided the numerous tools for the analysis purpose. The databases provide the contextual biochemical basis for metabolomics data interpretation. By providing information regarding metabolites like defining which enzymatic reactions consume or produce them, and which pathways they're involved in, researchers can use this data to interpret their experiments towards a higher level of annotation.

METLIN, was the first metabolomics database, was established in 2004 (Smith *et al.*, 2005). Thereby in 2005, the Human Metabolome Project was launched to find and catalog all of the metabolites in human tissue and biofluids. This metabolite information is kept in the Human Metabolome Database, which produced its first draft in 2007 (Wishart *et al.*, 2007). There are many databases containing metabolomics data, and each has different information, ranging from NMR and MS spectra to metabolic pathways. Additionally, and more specifically to the development of metabolomics, mass spectral databases like the Golm Metabolome Database (Hummel *et al.*, 2007), which links mass spectrum and chromatographic retention time to specific compounds, have been developed. Some tools designed for higher level metabolomic analysis can take GC–MS spectra as input and use them for the identification stages of metabolomics. The purpose of metabolic databases is to organize the metabolites in a way that helps researchers in an easy identification and analysis. The information found in metabolite databases has continuously been updated to provide state-of-the-art data to the scientific community. Metabolomics is a new field and therefore new approaches are still being discovered and the existing ones are still improving. These databases are embraced with various types of information including concentration, anatomical location, and related disorders.

Other databases are MassBank (Horai *et al.*, 2008), lipid metabolites and pathways strategy (LIPID-MAPS) (LIPID), Madison metabolomics consortium database, and Kyoto Encyclopedia of Genes and Genomes (KEGG) (Kanehisa and Goto, 2000). The major database till now is the KEGG, which is divided into several subdatabases with LIGAND, REACTION PAIR and PATHWAY being the most relevant to metabolomics (Booth *et al.*, 2013). In KEGG however there is a dauntingly large sum, i.e., 10,664 reactions and 18,107 metabolites (Kanehisa and Goto, 2000). These databases have been undergoing continuous updation and annotation for and so contain a great deal of valuable information. KEGG and MetaCyc (Karp *et al.*, 2002) are currently the largest (most number of organisms) and most in-depth comprehensive databases available. There are other databases too as Reactome (Joshi-Tope *et al.*, 2005), Model SEED (Devoid *et al.*, 2013), and BiGG (Schellenberger *et al.*, 2010), that can be more useful than the large databases if a specific organism is desired. The KEGG and MetaCyc databases each contain a generalized conserved set of pathways based on metabolic pathways. For KEGG, organism-specific annotations are available to query while for MetaCyc, individual "Cyc" databases have been generated for a number of organisms, some are just computationally derived while others are extensively manually curated such as AraCyc for *Arabidopsis* (Mueller *et al.*, 2003) and EcoCyc for *E.coli* strain *K-12 MGI655* (Karp *et al.*, 2014). A more recent development is the cheminformatic databases like PubChem (Wang *et al.*, 2009) and ChEBI (Degtyarenko *et al.*, 2007), which provide a chemically ontological approach to catalog small molecules that are active in biological systems. These databases, therefore, can provide fruitful information regarding the metabolic datasets. Finally, it is important to note that these databases can be cross-referenced and linked to each other as well as against more widely known databases such as the well-known Chemical Abstract Service (CAS) among many others. Along with the above mentioned

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Table 1 Selected databases and tools w.r.t metabolomics

Databases		
BioCyc	Collection of 10992 Pathway/Genome Databases (PGDBs)	http://biocyc.org
BiGG Models	Knowledgebase of genome-scale metabolic network reconstructions.	http://bigg.ucsd.edu/
BMRB	Repository for data from nuclear magnetic resonance spectroscopy (NMR) spectroscopy on proteins, peptides, nucleic acids, and other biomolecules	http://www.bmrb.wisc.edu/
BRENDA	Comprehensive enzyme repository, provide metabolic pathway details	http://www.brenda-enzymes.info/index.php
ChEBI	Freely available dictionary of molecular entities focused on "small" chemical compounds	https://www.ebi.ac.uk/chebi/
DIMEdb	Database of biologically relevant metabolite structures and annotations	http://dimedb.ibers.aber.ac.uk/
DRUGBANK	Unique bioinformatics and cheminformatics resource that combines detailed drug (i.e., chemical, pharmacological, and pharmaceutical) data with comprehensive drug target (i.e., sequence, structure, and pathway) information	https://www.drugbank.ca/
ECMDB	Contains extensive metabolomic data and metabolic pathway diagrams about *Escherichia coli (strain K12, MG1655)*	http://ecmdb.ca/
GMD	Facilitates the search for and dissemination of reference mass spectra from biologically active metabolites quantified using gas chromatography coupled to mass spectrometry (MS)	http://gmd.mpimp-golm.mpg.de/
HMDB	Archive information about small-molecule metabolites found in the human body	http://www.hmdb.ca/
KEGG	Resource for understanding high-level functions and utilities of the biological system, such as the cell, the organism and the ecosystem, from molecular-level information	http://www.genome.jp/kegg/pathway.html
MANET	Maps evolutionary relationships of molecule (metabolic, protein) architectures directly onto biological networks	http://manet.illinois.edu/
MassBank	Contains high resolution mass spectral data	http://massbank.eu/MassBank/
MetaboLights	Database for metabolomics experiments and derived information	http://www.ebi.ac.uk/metabolights/
MetaNetX	Automated model construction and genome annotation for large-scale metabolic networks	http://www.metanetx.org/
Reactome	Navigable map of human biological pathways, ranging from metabolic processes to hormonal signaling	http://www.reactome.org
SMPDB	Support pathway elucidation and pathway discovery in metabolomics, transcriptomics, proteomics and systems biology	http://smpdb.ca/
YMDB	Manually curated database of small-molecule metabolites found in or produced by *Saccharomyces cerevisiae*	http://www.ymdb.ca/
Computational analysis tools		
Arcadia	Visualization tool for metabolic pathways	http://arcadiapathways.sourceforge.net/
CellNetAnalyzer	MATLAB toolbox providing a various (partially unique) computational methods and algorithms for exploring structural and functional properties of metabolic, signaling, and regulatory networks	http://www.mpi-magdeburg.mpg.de/projects/cna/cna.html
GLAMM	Unified web interface for visualizing metabolic networks, reconstructing metabolic networks from annotated genome data, visualizing experimental data in the context of metabolic networks, and investigating the construction of novel, transgenic pathways	http://glamm.lbl.gov/
IMPaLA	Perform pathway overrepresentation and enrichment analysis with expression and/or metabolite data	http://impala.molgen.mpg.de
iPath	Web-based tool for the visualization, analysis and customization of the various pathways maps	http://pathways.embl.de
JDesigner	Graphical modeling environment for biochemical reaction networks	http://jdesigner.sourceforge.net/Site/JDesigner.html
KaPPA-View	Web-based analysis tool for integration of transcript and metabolite data on plant metabolic pathway	http://kpv.kazusa.or.jp/en/
LIPID MAPS	Online tools for lipid research	http://www.lipidmaps.org/tools/index.html
MapMan	A user-driven tool to display genomics data sets onto diagrams of metabolic pathways and other biological processes	http://mapman.gabipd.org/web/guest/mapman
MetaMapp	Mapping and visualizing metabolomic data by integrating information from biochemical pathways and chemical and mass spectral similarity	http://uranus.fiehnlab.ucdavis.edu:8080/MetaMapp/homePage
MetPA	A web-based metabolomics tool for pathway analysis and visualization	http://metpa.metabolomics.ca
MassTRIX	Annotate metabolites in high precision MS data	http://masstrix3.helmholtz-muenchen.de/masstrix3/
MetaboAnalyst	Web server designed to permit comprehensive metabolomic data analysis, visualization and interpretation	http://www.metaboanalyst.ca/MetaboAnalyst/
MetaPath Online	For the analysis of metabolic networks	https://scopes.biologie.hu-berlin.de/

(*Continued*)

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Table 1 Continued

Databases		
Meta P-server	A web based, easy-to-use analysis tool for the statistical analysis of metabolomics data	http://metabolomics.helmholtz-muenchen.de/metap2/
MetExplore	Find information about metabolite relationships in metabolic networks	http://metexplore.toulouse.inra.fr/metexplore/
Metscape	A plug-in for Cytoscape, used to visualize and interpret metabolomic data in the context of human metabolic networks	http://metscape.ncibi.org
MGV	A versatile generic graph viewer for multiomics data also it offers a comprehensive set of tools for analysis and visualization of graphs.	http://www.microarray-analysis.org/mayday
MPEA	Metabolite pathway enrichment analysis	http://ekhidna.biocenter.helsinki.fi/poxo/mpea/
MSEA	A web-based tool to identify biologically meaningful patterns in quantitative metabolomic data	http://www.msea.ca
Omix	Network drawing tool along with programmable visualization framework	http://www.omix-visualization.com/?from=http://www.13cflux.net#sthash.vLyVKteK.dpbs
Paintomics	A web based tool for the joint visualization of transcriptomics and metabolomics data	http://www.paintomics.org
TICL	A web tool for network-based interpretation of compound lists inferred by high-throughput metabolomics	http://mips.helmholtz-muenchen.de/proj/cmp/home.html
Vanted	Network visualization and analysis tool for creating and editing the network and mapping experimental data onto networks	https://immersive-analytics.infotech.monash.edu/vanted/

Table 2 PAM50 genes list

PAM50 genes				
ACTR3B	CDCA1 (NUF2)	FOXA1	MDM2	PGR
ANLN	CDH3	FOXC1	MELK	PHGDH
BAG1	CENPF	GPR160	MIA	PTTG1
BCL2	CEP55	GRB7	MKI67	RRM2
BIRC5	CXXC5	KIF2C	MLPH	SFRP1
BLVRA	EGFR	KNTC2(NDC80)	MMP11	SLC39A6
CCNB1	ERBB2	KRT14	MYBL2	TMEM45B
CCNE1	ESR1	KRT17	MYC	TYMS
CDC20	EXO1	KRT5	NAT1	UBE2C
CDC6	FGFR4	MAPT	ORC6L(ORC6)	UBE2T

databases there are different types of databases built so far only the selected ones based upon accuracy and applications are mentioned in alphabetical order in **Table 1**.

Similarly, there are many computational tools available for the metabolic data handling like for building, editing, enrichment, and interpreting metabolic network models, including Arcadia (Villeger *et al.*, 2010), GLAMM (Bates *et al.*, 2011), CellNetAnalyzer (Klamt and von Kamp, 2011), MetaMapp (Barupal *et al.*, 2012), MetPA (Xia and Wishart, 2010a), Vanted (Rohn *et al.*, 2012) for network visualization. Likewise there are tools for drawing a network, Omix (Droste *et al.*, 2013) which have been widely used for creating a network model. TICL (Antonov *et al.*, 2009) is used for the interpretation of compound lists that are inferred by high-throughput metabolomics. Enrichment analysis could be done with the help of MSEA (Xia and Wishart, 2010b), MPEA (Kankainen *et al.*, 2011). MassTRIX (Suhre and Schmitt-Kopplin, 2008) performs the annotating metabolites in high precision MS data. There are other tools also, which have been mentioned in **Table 2** along with their descriptions.

Biomarker Discovery: A Challenge and Plausible Solutions Through Bioinformatics

Biomarkers are measured indicators of biological and pathogenic conditions or pharmacological responses to a therapeutic intervention (Strimbu and Tavel, 2010). Based on pathophysiological, epidemiological, therapeutic, or other scientific evidence they are intended to be useful in terms of clinical significance (i.e., to know whether they will benefit or harm) (Baumgartner *et al.*, 2011; Downing, 2001). Biomarkers have a generous impact on the care of patients; for those who are suspected to have the disease or those who have or have no visible disease symptoms (Baumgartner *et al.*, 2011). For a long time biomarkers have served as a plausible diagnostic key to unraveling disease conditions, especially in case of cancers. Depending on the condition type they can be categorized as diagnostic, prognostic, and screening biomarkers (Madu and Lu, 2010). Currently, screening biomarkers are of high interest due to their ability to predict future events, but there are only a few accepted biomarkers for disease screening available today (Melander *et al.*, 2009). Therefore it is necessary to have considerable search, verification, biological and

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biochemical interpretation, and independent validation of disease biomarkers, which requires advancement in high-throughput technologies. To achieve this goal there is necessity to have interdisciplinary expertise, which requires the teamwork of clinicians, biologists, biochemists, and bioinformaticians to carry out biomarker cohort studies with professional planning, implementation, and control. Bioinformatics plays a key role in the biomarker discovery process via bridging the gap between initial discovery phases such as experimental design, clinical study execution, and bioanalytics, including sample preparation, separation, high-throughput profiling, and independent validation of identified candidate biomarkers (Baumgartner *et al.*, 2011) (**Fig. 4**).

It is well known that a disease or a phenotype is rarely a consequence of an abnormality of a single gene or its expression but instead reflects the interactions of various processes in a complex network; such network could combine multiple genes (proteins) and metabolites. For example, plants can produce numerous metabolites to handle different environmental conditions however the biosynthetic pathways for most of these compounds have not yet been revealed (Schlapfer *et al.*, 2017). From these facts, the need for a disease signature, a set of compounds generally presented as a network, becomes evident. Such disease-specific signature could be helpful in understanding all its mechanisms and evolution and in an earlier diagnosis. Multiple works and frameworks aimed to either use genes expression or metabolic data to extract a set of disease-relevant compounds; it's safe to say biomarkers (Strimbu and Tavel, 2010). Identifying such crucial biomarkers responsible for disease characteristics and revealing its mechanisms can be used to infer its evolution and development and offers better targets for drug development, treatment individualization, and dose regimen. These biomarkers are selected by analytic methods or pathway and network-centric methods (Wang *et al.*, 2015). A typical case would be gene expression data of two pairs of samples in both disease and normal states help in discovering genes and metabolites which can be potential biomarkers (Li *et al.*, 2013; Shlomi, 2010; Li *et al.*, 2012). Cancer is a heterogeneous disease, for instance, breast cancer. Biomarkers at the DNA, RNA, and protein levels were developed to better understand the biology of breast cancer, leading to the possibility to classify the disease into subtypes and subgroups, which may lead to new therapeutic opportunities (Le Du *et al.*, 2013). Many tests are available for the diagnosis and each one is based on a set of genes; we can list some of most known ones such as PAM50. PAM50 stands for Prediction Analysis of Microarray 50 (Sweeney *et al.*, 2014), fifty genes were probed like *ACTR3B*, *ANLN*, *BAG1*, *BCL2*, *BIRC5*, etc. Elaborating a set of biomarkers allowed the development of many tools online (cbioportal (Gao *et al.*, 2013)) and offline, in libraries and packages. These tools offer the possibility of analyzing targeted datasets and understanding the disease stage. Machine learning tools are also a very effective way of dealing with such complex diseases, predicting treatment effectiveness and new treated disease trajectory. Since these, new models have been well designed, which fully explains the relationship between each biomarker.

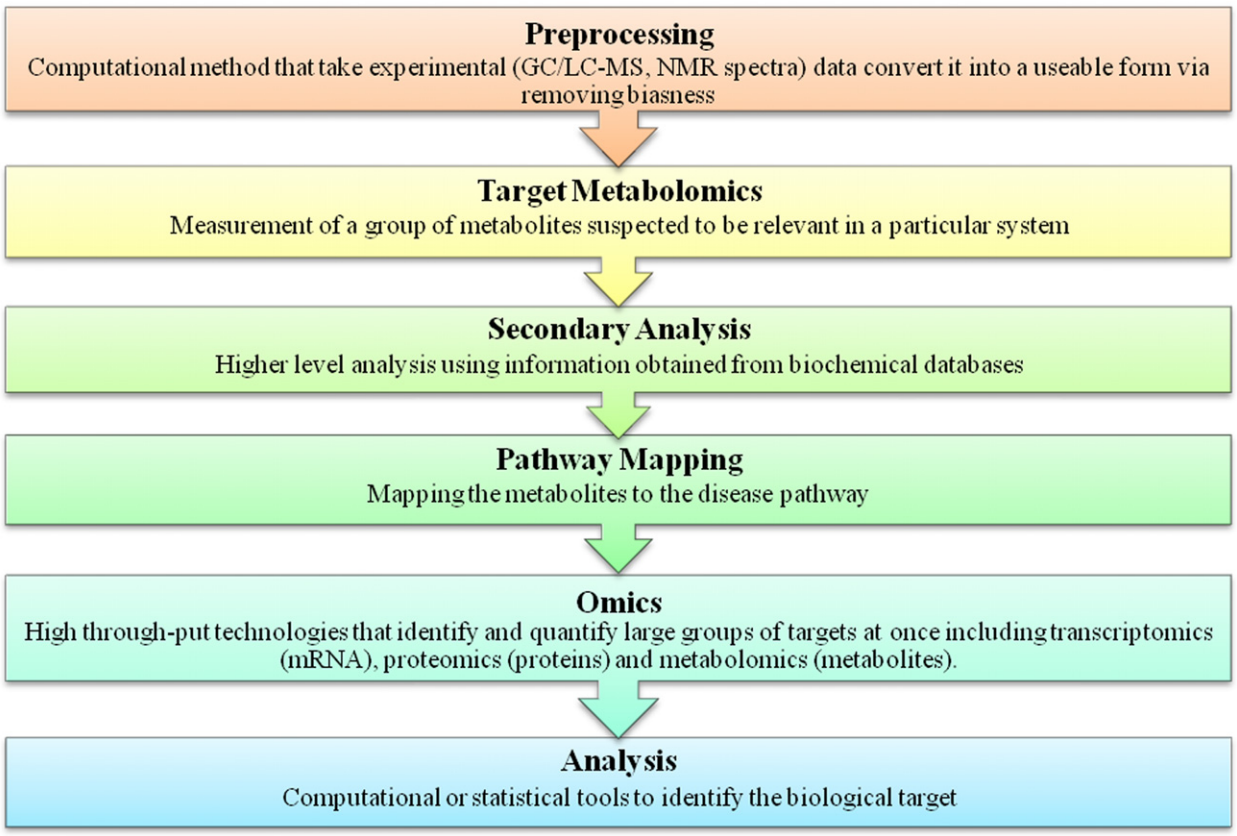

Fig. 4 Computational pipeline for metabolome analysis.

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Gene Expression and Metabolic Network: Applications in Biomarker Discovery for Complex Diseases

DNA microarray technologies permit systematic approaches to the biological discovery that have a profound impact on biological research, pharmacology, and medicine (Yousef *et al.*, 2014). The ability to obtain quantitative information from the complete transcription profile of cells provides a powerful means to explore basic biology, disease diagnosis, drug development, mold therapeutics to specific pathologies, and generate databases (Young, 2000). Gene expression studies bridge the gap between DNA information and its trait information by dissecting the biochemical pathways into intermediate components, that is, between genotype and phenotype (Xiong *et al.*, 2001). The gene expression studies, therefore, open new avenues for identifying complex disease genes and biomarkers for disease diagnosis and also for assessing drug efficacy and toxicity. One particularly powerful application of gene expression analyses is in biomarker discovery, which can be used for disease risk assessment, early detection, prognosis, predicting response to therapy, and preventive measures.

For years, scientists studied one gene at a time and genes were indeed studied in isolation from the larger context of other involved genes. Nowadays, genomics via high-throughput techniques helps to study the genome of organisms as a whole thus allowing a wide picture of gene characteristics. One of the most popular high-throughput techniques are arrays, which are an orderly arrangement of a large number of samples allowing large-scale studies (Yousef *et al.*, 2014). This gave rise to the genomic era, which emerged from the sequencing of genomes from many organisms. The development of the first arrays started many years ago to study a large number of genes at a time (Hergenhahn *et al.*, 2003) and has widely expanded since then. Today the approach is also applicable to RNA probes, proteins, antibodies, and even biological samples allowing new types of research (Yousef *et al.*, 2014). Currently, other types of high-throughput techniques are also developing, for instance, to study the transcripts and metabolites.

Today, genomics has induced two new paradigms in biology; the first paradigm is a new approach that allows the study of the complex network through which genes and proteins communicate. It is attained via an amalgamation of the researcher having expertise in the field of biology, engineering, chemistry, and computer science; this multidisciplinary approach allows the development of systems biology. The second paradigm is a direct consequence of information derived from genomics studies where raw data needs to be analyzed and then to be used in the systemic approach. This led the development of bioinformatics,

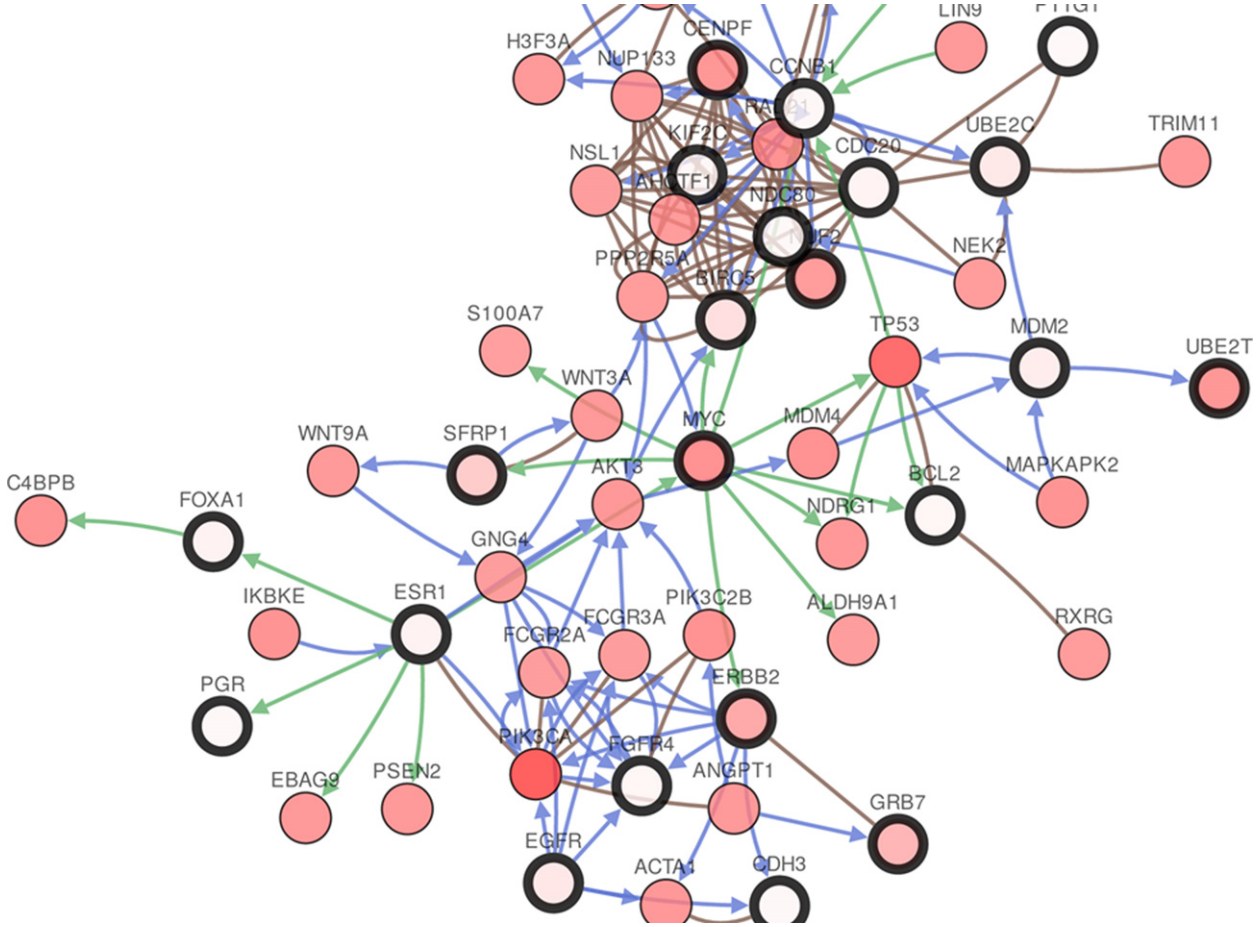

Fig. 5 Network interaction of the PAM50 genes set.

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which requires the use of computers to manage biological information. The practical applications of gene expression analyses are numerous and only beginning to be realized. One particularly powerful application of gene expression analyses is in biomarker identification, which can be used for disease risk assessment, early detection, prognosis, prediction response to therapy, and preventative measures.

Therefore approaches to cancer biomarker discovery comprise genomics, epigenomics, transcriptomics, and proteomic analyses. Current efforts in the laboratory focus on the identification of biomarkers in chronic lymphocytic leukemia, lung cancer, and colon cancer (McDermott *et al.*, 2013). Along with the mRNA other small RNAs are also known to be a predictive indicator in disease studies; and it has been found that alterations in gene expression patterns due to dysregulation of miRNAs is a common cause in tumorigenesis (Chen *et al.*, 2012). High concentrations of cell-free miRNAs that originate from the primary tumor have been found in the plasma of cancer patients, and several lines of evidence indicate that plasma miRNAs are associated with specific vesicles called exosomes (Yang *et al.*, 2016). This led to the discovery of new biomarkers that comprises plasma miRNAs and seems to be promising in disease prognosis (Jeffrey, 2008). Recent discovery of quantifiable circulating cancer-associated miRNAs exposes the immense potential of their use as novel minimally invasive biomarkers for breast and other cancers (Heneghan *et al.*, 2009).

Discovery of Biomarkers Through Computational Pipeline: A Cancer Based Study

The classification of samples from gene expression datasets usually involves a small number of samples. The problem of selecting those biomarker genes that are vital for differentiating the different sample classes being compared poses a challenging problem in

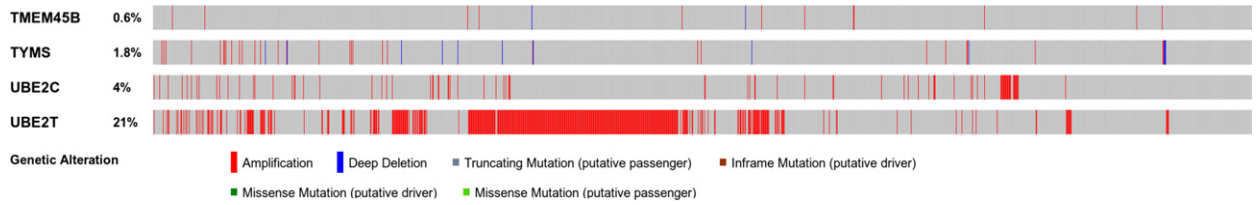

Fig. 6 Oncoprint for only four biomarkers.

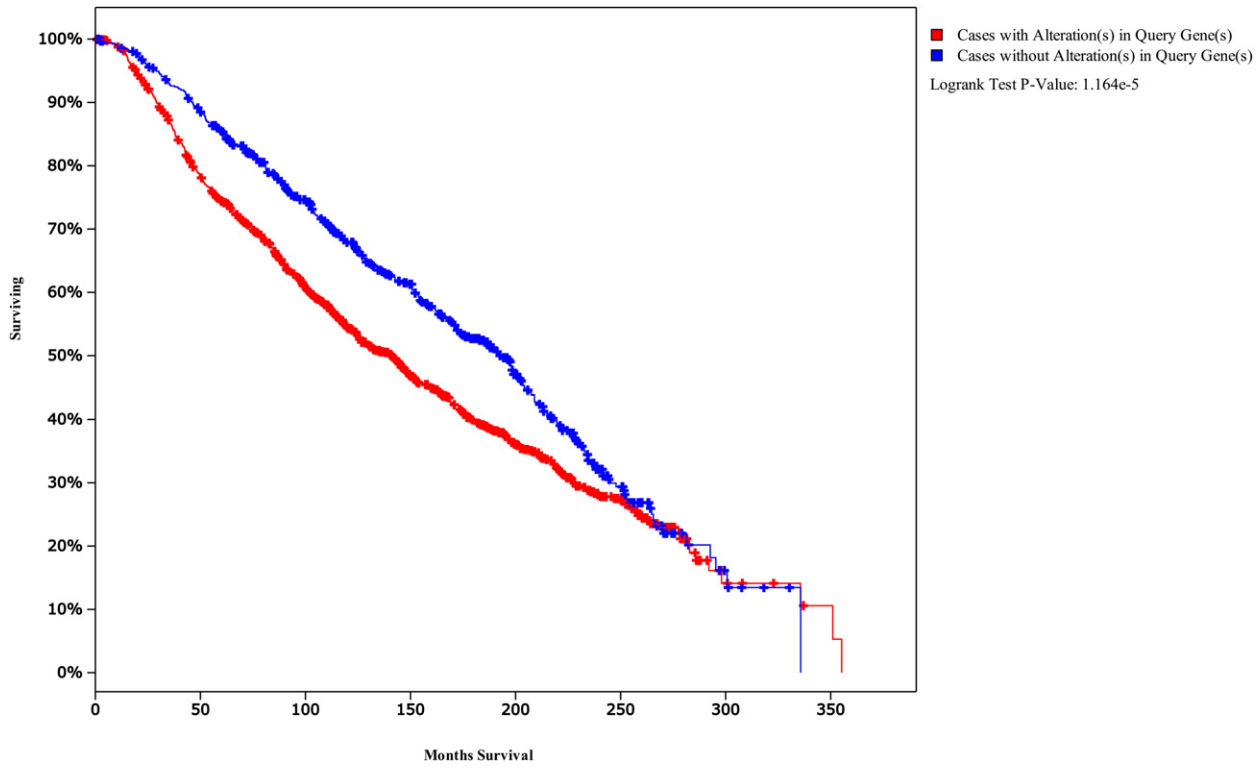

Fig. 7 Survival study.

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case of the high dimensional data analysis. A variety of methods to address this problem have been implemented and these methods can be divided into two main categories: (1) Filtering based methods and (2) model-based or wrapper approaches (Wang *et al.*, 2005; Inza *et al.*, 2004). The filter method (Ben-Bassat, 1982) assesses the goodness of the proposed feature subset looking only at the intrinsic characteristics of the data, based on the relation of each single gene with the class label by the calculation of simple statistics computed from the empirical distribution. This approach is extensively used as a feature subset selection method in the microarray (Aris and Recce, 2002). While in the wrapper approach (Kohavi and John, 1997), which is a very powerful machine learning application, search is conducted in the space of genes, evaluating the goodness of each found gene subset by the estimation of the accuracy percentage of the specific classifier to be used.

One of the most important properties that should be considered for the biomarkers is the robustness. It is an important issue for the successful discovery of biomarkers, as it may greatly influence subsequent biological validations. In addition, a more robust set of markers may strengthen the confidence of an expert in the results of a selection method (Abeel *et al.*, 2010). Robustness, a property that allows a system to maintain its functions under certain external and internal perturbations, is a ubiquitously observed feature of biological systems (Kitano, 2004). Studying the relationship between the topology and robustness of

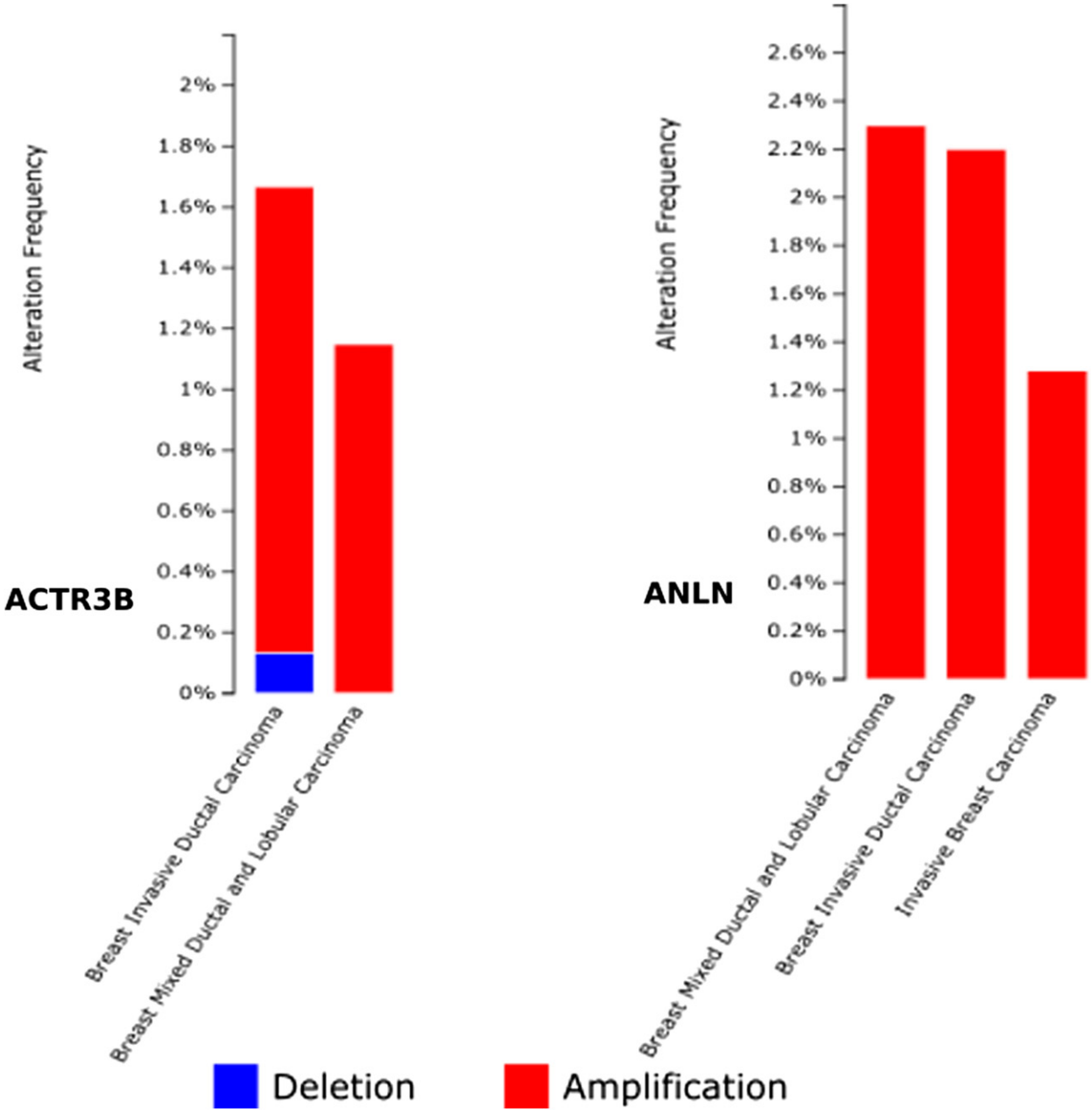

Fig. 8 Breast cancer histogram with subtypes.

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metabolic networks may help to understand the functional organization principle of cells and could have important implications for disease studies (Schuster and Holzhütter, 1995) and drug target identifications (Bakker *et al.*, 2000).

The robustness of the metabolic network with respect to specific enzymes can be qualitatively estimated by the preservation or decay of the network after removal of the nodes or edges corresponding to these enzymes. The following topological features of metabolic networks may ensure the robustness of metabolism; these are (1) modularity, which contributes to the robustness of networks by decreasing the cross talk between different functional modules, detaining perturbations and damages to separable parts and preventing deleterious effects from spreading to the whole system (Stelling *et al.*, 2004); (2) bow-tie structure, which aids in forming a robust conserved core because it is the most tightly connected part of the network and there are multiple routes between any pair of nodes. Such connecting patterns provide an advantage in generating a coordinated response to various stimuli and increases the robustness of the whole system (Kitano, 2004); and (3) scale-free topology; the key feature of scale-free networks is the high-degree of error tolerance; that is, the ability of their nodes to communicate is unaffected by the failure of some randomly chosen nodes (Crucitti *et al.*, 2004). Thus the scale-free nature of metabolic networks indicates its high resistance towards random perturbations and thus could explain why some enzyme dysfunction at the metabolic level is without substantial phenotypic effect (Barabasi and Albert, 1999). The studies have shown that the scale-free networks are extremely vulnerable to attacks, i.e., the removal of a few hub nodes that play a crucial role in maintaining a network's connectivity will destroy the whole network (Crucitti *et al.*, 2004). Studies conducted by Mahadevan and Palsson showed that low-degree nodes are almost as likely to be critical to the overall network functions as high-degree nodes (Mahadevan and Palsson, 2005) by calculating the number of lethal reactions among all the reactions connected to every metabolite in the substrate graph of metabolic networks.

To show an example of analysis using biomarkers a dataset from (Pereira *et al.*, 2016) was used. It presents a somatic mutation profiling study of 2433 breast cancers, which approved the classification of the tumors into 10 integrative clusters (IntClusts).

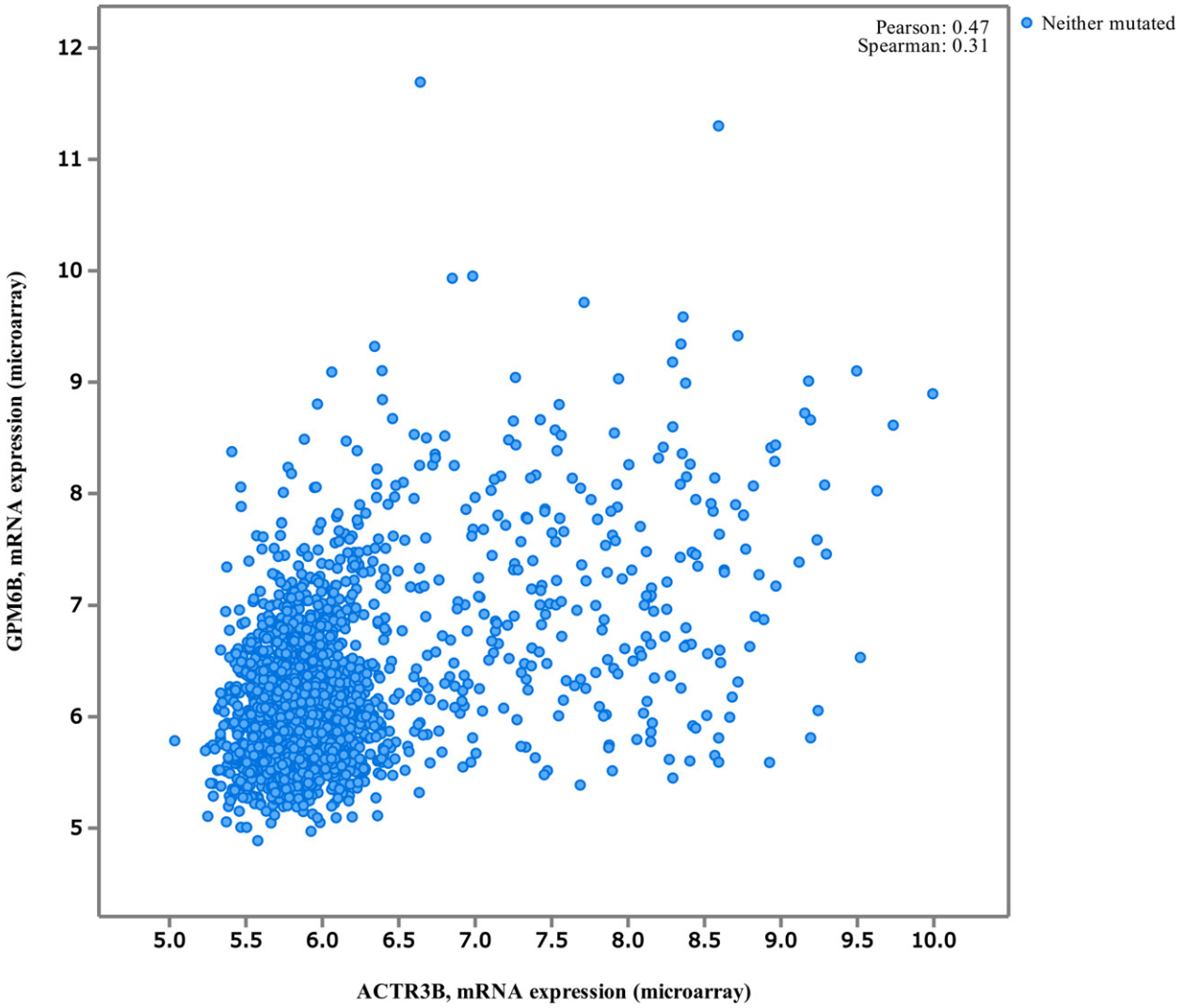

Fig. 9 Coexpression of two biomarkers, ACTR3B & GPM6B.

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During this study (Pereira *et al.*, 2016) CNAs (copy number aberrations) were the main driver in an unsupervised clustering approach due to their influence on genes expression. The current analysis used the dataset above against the fifty genes found in PAM50 (**Table 2**). These genes served as a gene set for the cbioportal, so the mutations profiling could be performed. Figures below show different knowledges extracted, cancer types, and mutation happening along genes, genes with similar or exclusive expression, and finally survival estimation. Gene networks present an excellent input for models analysis using algorithmic methods such as Bayesian networks, leading to inferring and predicting the cancer evolution, trajectory, and progression (Caravagna *et al.*, 2016). **Fig. 5** shows the interaction of the PAM50 gene set where nodes are representing genes and edges (arrows) denote the interactions between them.

Thereby an oncoprint of four biomarkers (TMEM45B, TYMS, UBE2C, UBE2T) has been captured (**Fig. 6**) that shows the type of mutation occurring to the gene set.

After this, a survival study has been conducted (**Fig. 7**), which is performed for the p-value of 1.164e-5 and red color denotes the alteration in query gene while blue color shows the query gene without alteration. It has been noticed that the cases with alterations have higher survival rate than the nonaltered ones.

Then alteration frequency of ACTR3B and ANLN were determined through the histogram (**Fig. 8**) that denotes the alteration and the deletion frequency. Finally Pearson and Spearsman correlation coefficient induced shows the coexpression of the two biomarkers, that is, ACTR3B & GPM6B (**Fig. 9**).

Concluding Remarks

The advent of high-throughput technologies, and as a result, the generation of various kinds of omics data, has challenged both the experimental or computational scientific communities. Therefore an "omics cascade" came into the scenario where the genotype to the phenotype can be connected through various intermediate steps for better understanding the disease biology and their overall impact on the phenotypic observations at the physical or organism level. Understanding the genotype to phenotype scenario and its consequences will provide an edge towards better implementation of computational methods for their experimental validations. It will be an added advantage for the scientific community to amalgamate the computational and experimental procedures for the betterment of mankind. It is anticipated that this comprehensive text will provide systematic and ordered information on the metabolic world with its exact connection to the biomarker identification procedure.

See also: Biological Database Searching. Identification and Extraction of Biomarker Information. Integrative Analysis of Multi-Omics Data. Natural Language Processing Approaches in Bioinformatics

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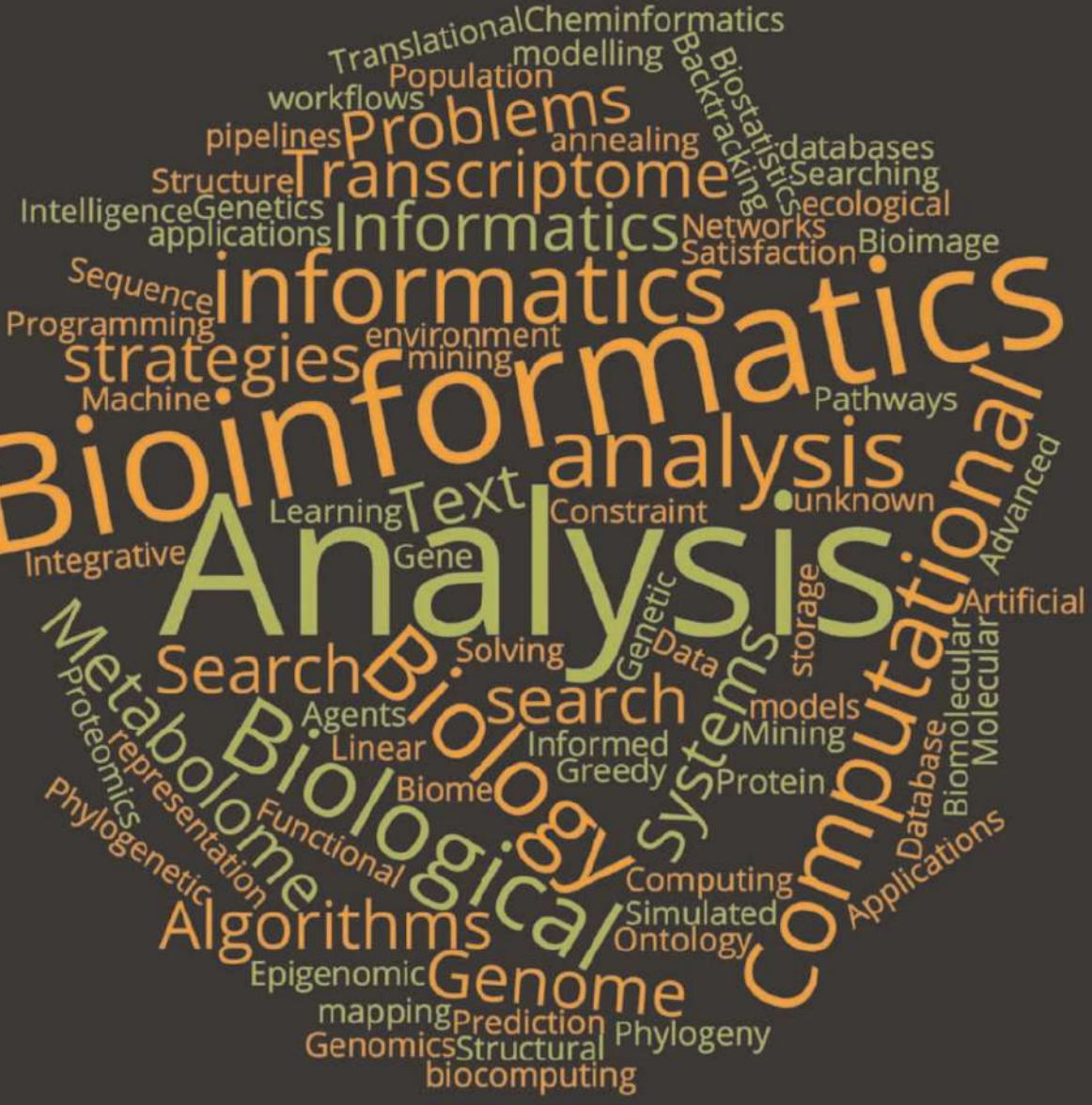

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Methods

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Phylogenetic Analysis: Gene Duplication and Speciation

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Background

Significant progress has been made in the past few decades in understanding Darwin's theory of the origin of species. Different genomic methods have helped to understand the genetic variations and gene flow that makes new species (Magadum *et al.*, 2013; Shapiro *et al.*, 2016). Although new methods have not changed the previous speculations about how species formed, they have quickened the pace of information gathering (Reams and Roth, 2015). Compiling studies on hereditary investigations would be useful to answer queries of the upcoming generations on the relative occurrence and significance of various procedures that occur during speciation (Liu *et al.*, 2016).

Many 20th century biologists viewed genes as traits of species, exquisitely tuned to current utility. This resulted in the assumption that each species should possess different genes. Gene duplication was recognized, but was implicitly assumed to have occurred recently (Rose and Oakley, 2007). Many biologists now assume that most genes have their origins in gene duplication events, which happen throughout evolutionary history. As a result, many genes form families that have persisted for hundreds of millions of years.

Gene duplication events and results of such events play a crucial role in determination of the function of novel genes. There have been various models and theories that have emerged to support the concept of gene copies (Liu *et al.*, 2016; Singh *et al.*, 2009). However, a clear picture of gene duplication events is still not clear and needs more information to come to any conclusion. Different prediction software and tools based models such as hidden Markov models give insight to evolutionary functional properties and dynamics (Singh and Pardasani, 2009). Hence, understanding the gene duplication events and speciation is an essential step towards understanding and identifying the major mechanisms that are involved in the evolution (Seehausen *et al.*, 2014).

Gene Duplication

The evolutionary understanding of gene duplication events was first performed by Haldane and John (1932), who suggested that a redundant duplicate(s) of a gene may acquire divergent mutations and eventually emerge as a new gene. A gene duplication event was first noted by Bridges (1936) in the Bar locus in *Drosophila*. A substantial increase in the number of copies of a DNA segment can be brought by various types of gene duplication (White, 1977; Raj Singh, 2008). There are various studies where gene duplication and deletion events are being systematically observed (Ma *et al.*, 2014; Schacherer *et al.*, 2004; Simillion *et al.*, 2002; Stephens, 1951). Many types of duplications are recognized: First, partial gene duplication; second, complete gene duplication; third, partial chromosomal duplication; fourth, complete chromosomal duplication; fifth, genome duplication (Innan and Kondrashov, 2010; Conant and Wolfe, 2008; Panchy *et al.*, 2016). The first four are treated as regional duplicates as they do not alter the haploid set of chromosomes. The main reason for gene duplication includes uneven crossing over (Iñiguez and Hernández, 2017; Levasseur and Pontarotti, 2011; Qian and Zhang, 2014). Uneven crossing over in two nonaligned sequences gives a duplicated region on one chromosome along with deletion on second on the basis of the size of the nonaligned region. DNA sequence duplication in tandem results in a progressive increase in uneven crossing over, which ultimately increases the number of duplicate copies (Mendivil Ramos and Ferrier, 2012).

Partial Gene Duplication

Tandem duplication events in DNA sequences may provide information about genetic evolution events in terms of the complete gene while tandem duplication in a small region, or maybe in part of gene, ultimately results in mutations and is the cause of various diseases (Hu and Worton, 1992; Hu *et al.*, 1988). The duplication arrangement can be understood by taking the inference from molecular information lying in the sequence (Toll-Riera *et al.*, 2011). For instance, structure level changes induced by changes in nucleotide and amino acid sequence level influences the protein evolution. Toll-Riera *et al.* (2011) have demonstrated this by considering a large dataset of human and mouse orthologs protein and later mapping with PDB structures. Evidence from literature suggests that duplication may arise from either homologous (Alu-Alu) recombination or nonhomologous recombination, the latter possibly mediated by topoisomerases. For the dystrophin gene, in which most duplications have been identified, these recombination events are intrachromosomal, which suggests that unequal sister chromatid exchange is the major mechanism (Toll-Riera *et al.*, 2011).

Domain Duplication and Gene Elongation

A domain is a well-defined region within a protein that either performs a specific function within a protein, such as substrate binding, or constitutes a stable, independently folding, compact structural unit within the protein that can be distinguished from

all the other parts" (Li and Makova, 2001). Theoretically, several possible relationships may be envisioned between the structural domains and the arrangements of the exons in the gene, e.g., in many globular proteins, a more or less exact correspondence exists between exons of gene and the structural domains of the protein product. Alternate splicing is one of the main reasons for exon shuffling in a duplication event as there are always chances for repetition of a similar exon set again. In a considerable number of cases, several adjacent models were found to be encoded by the same exon (Li and Makova, 2001).

The vertebrate hemoglobin α and β chains, consist of four domains, whereas their genes consist of only three exons, the second of which encodes two adjacent domains. In *Caenorhabditis elegans*, a globin-encoding gene, during the evolution of a globin gene family from a four exon ancestral gene, several lineages lost some or all of their three introns, thereby, generating panoply of exon–intron permutations (Vogel *et al.*, 2005). In the majority of cases, a domain duplication at the protein level indicates that an exon duplication has occurred at the DNA level. Moreover, many proteins of present day organisms show internal repeats often correspond to functional or structural domains within the proteins. A survey of modern genes in eukaryotes shows that the internal duplications have occurred frequently in evolution. This gene duplication is one of the most important steps in the evolution of complex genes from the simple ones (Vogel *et al.*, 2005).

Theoretically, elongation of genes can also occur by other means; for example, a mutation change converting a stop codon into a sense codon can also elongate the gene, which could be a part of recoding event (Singh and Pardasani, 2009). Similarly, either insertion of a foreign DNA segment into an exon or the occurrence of a mutation obliterating a splicing site will achieve same result. These types of molecular changes most probably disrupt the function of the elongated gene. In the vast majority of cases, such molecular changes have been found to be associated with pathological manifestations. By contrast, duplication of a structural domain is less likely to be problematic. Indeed, such a duplication can sometimes even enhance the function of the protein produced for example by increasing the number of active sites (a quantitative change), thus enabling the gene to perform its function more rapidly and efficiently or by having a synergistic effect yielding a new function (a qualitative change) (Nacher *et al.*, 2010).

Emergence of novel function can be derived from partial gene as divergence in the sequence may lead to different functions. Complete gene duplication produces two identical paralogous copies (Nacher *et al.*, 2010). Duplicated genes can be divided into two types – Variant and invariant repeats. Invariant repeats are identical or nearly identical in sequence to one another. Variant repeats are copies of a gene that, although similar to each other, differ in their sequences to a lesser or greater extent. All the genes that belong to a certain group of repeated sequences in a genome are referred to as a gene or a multigene family. Functional and nonfunctional members of a gene family may reside in close proximity to one another on the same chromosome or they may be located on different chromosomes. A member of a gene family that is located alone at a different genomic location than the other members of the family is called an orphan. The term *superfamily* was coined by Dayhoff in order to distinguish closely related proteins from distantly related ones (Dayhoff and Schwartz, 1978). Proteins that exhibit at least 50% similarity to each other at the amino acid level are considered as members of a superfamily, for example, α and β globins are classified into two separate families and together with myoglobin they form the globin superfamily (Li and Makova, 2001). An important feature associated with gene duplication is that as long as two or more copies of a gene exist in proximity to each other, the process of gene duplication can be greatly accelerated in this region, and numerous copies may be produced. There may be two reasons for the general positive correlation between genome size and number of copies of RNA specifying genes. Either a large genome requires large quantities of RNA, or the number of RNA-specifying genes is simply a passive consequence of genome enlargement by duplication. Highly repetitive genes, like rRNA genes, are generally very similar to each other (Li and Makova, 2001).

One factor responsible for homogeneity may be purifying selection. In addition to invariant repeats, the genomes of higher organisms contain numerous multigene families whose members have diverged to various extents such as genes coding for isozymes, such as lactate dehydrogenase, aldolase, creatine kinase, carbonic anhydrase, and pyruvate kinase. Isozymes are enzymes that catalyze the same biochemical reaction but may differ from one another in tissue specificity, developmental regulation, electrophoretic mobility, or biochemical properties. Isozymes are encoded by different loci, usually duplicated genes, as opposed to allozymes, which are distinct forms of the same enzyme encoded by different alleles at a single locus (Li and Makova, 2001; Vogel *et al.*, 2005).

Exon Shuffling

There are three types of exon shuffling: (1) Exon duplication, (2) exon insertion, and (3) exon deletion. Exon duplication refers to the duplication of one or more exons in a gene and so is a type of internal duplication (Patthy, 1999). Exon insertion is the process by which structural or functional domains are exchanged between proteins or inserted into a protein. Exon deletion results in the removal of a segment of amino acids from the protein. All types of shuffling have occurred in the evolutionary process of creating new genes (Kolkman and Stemmer, 2001; Patthy, 1999). Exon shuffling could be represented through various phases as shown in **Fig. 1**.

Mosaic or Chimeric Proteins

A mosaic or chimeric protein is a protein encoded by a gene that contains regions that are also found in other genes (Nicolson, 2015; Singer and Nicolson, 1972). The existence of such proteins indicates that exon shuffling has occurred during the evolutionary history of their genes. The first described mosaic protein was tissue plasminogen activator (Iñiguez and Hernández, 2017). For an exon to be inserted, deleted, or duplicated without causing a frameshift in the reading frame, certain phase limitations of the exonic structure of the gene must be respected. Mosaic proteins can be made when two adjacent genes are transcribed together and are therefore made into the same protein.

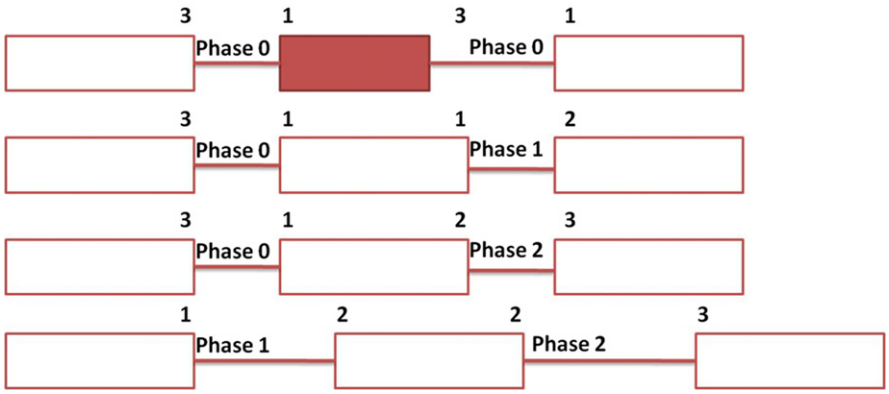

Fig. 1 Schematic representationof exon shuffling. Numbers above the box represents the position of nucleotide.

To understand this, we need to consider introns in terms of their possible positions relative to the coding regions (Nicolson, 2014). Introns residing between coding regions are classified into three types according to the way in which the coding region is interrupted (Jeon, 2004). An intron is of phase 0 if it lies between two codons, of phase 1 if it lies between the first and second nucleotide of a codon, and of phase 2 if it lies between the second and third nucleotides of a codon. Exons are grouped into classes according to the phases of their flanking introns. Here are four middle exons, said to be (0–0), (0–1), (0–2), and (1–2) exons. An exon that is flanked by introns of the same phase at both ends is called a symmetrical exon, otherwise it is asymmetrical. The first exon (middle) is a symmetrical exon, represented by black box. The length of a symmetrical exon is always a multiple of three nucleotides. Only symmetrical exons can be duplicated in tandem or deleted without affecting the reading frame.

Duplication or deletion of asymmetrical exons would disrupt the reading frame downstream. Similarly, only symmetrical exons can be inserted into introns, but with the restriction of, a 0–0 exon can only be inserted in phase-0-introns, a 1–1 exon is inserted into phase 1 introns, and 2–2 exons into phase-2 introns for avoiding frameshifts. All the exons coding for the modules of mosaic proteins are symmetrical. Since nonrandom intron phase usage is a necessary consequence of exon duplication or insertion, this property may be used as a diagnostic feature of gene assembly through exon shuffling. In terms of splicing, introns are classified into two categories, self-splicing and spliceosomal (Wang *et al.*, 2013). The vast majority of introns in eukaryotic nuclear genes are spliceosomal. Self-splicing introns play a vital role in their own removal, some regions of the introns are involved in self-complimentary interactions important for forming the 3-D structure possessing splicing activity. Exon shuffling probably did not play a role in the formation of genes in the early stages of evolution. Exon shuffling came to full bloom with the evolution of spliceosomal introns, which do not play a role in their self excision. These introns contain mainly nonessential parts and therefore could accommodate quantities of "foreign" DNA (Wang *et al.*, 2013).

Exonization and Pseudoexonization

Exonization is the process through which an intronic sequence becomes an exon. An exon created by exonization must abide by the same rules of exon insertion (Schmitz and Brosius, 2011). The opposite process is called pseudoexonization. It occurs when nonfunctionalization affects a single exon rather than the entire gene. The result is the creation of a pseudoexon, and the most obvious consequence of such a process is gene abridgement (as opposed to gene elongation). Pseudoexons are often created by the nonfunctionalization of internal gene duplications, for example, the aggrecan gene in rat contains 18 repeated exons and one pseudoexon. Some complex biological functions that require several enzymes may be specified by genes encoding different combinations of protein modules. In some species we may find single-module proteins, while in others we may find different combinations of multimodular proteins, for example, genes in a multistep process in the synthesis of fatty acids from Acetyl Co-A require seven enzymatic activities and an acyl–carrier protein. In fungi, these activities are distributed between two nonidentical polypeptides encoded by two unlinked intronless genes, FAS1 and FAS2. FAS1 encodes two and FAS2 encodes five enzymatic activities. In most bacteria, however, these functions are carried on by discrete monofunctional proteins (Schweizer and Hofmann, 2004).

In animals, key functions associated with fatty acid metabolism are controlled with a single polypeptide chain called fatty acid synthase. The fatty acid synthase gene in fungi and mammals are most probably mosaic proteins that have assembled from single-domain proteins like the ones found in bacteria (Stower, 2013). The fact that arrangement of domains is different in fungi from that in mammals indicates not only that the two lineages evolved multimodularity independently, but also that different strategies may be employed in the assembly of genes encoding multimodular proteins.

Nested and Overlapping Genes and Their Association With Speciation

In addition to gene duplication and exon shuffling, many other mechanisms for producing new genes or polypeptides are available. Few such entities are overlapping genes, pseudogenes, and nested genes.

Overlapping Genes

A DNA fragment (segment) can code for more than one gene product by using different reading frames or different initiation codons. This phenomenon of overlapping genes is widespread in DNA and RNA viruses, as well as in organelles, and bacteria, also known in nuclear eukaryotic genomes (Makalowska *et al.*, 2005). Overlapping genes can also arise by the use of the complementary strand of a gene; for example, genes specifying $tRNA^{ILE}$ and$tRNA^{GLN}$ in the human mitochondrial genome are located on different strands and there is a three-nucleotide overlap between these that reads 5′-CTA-3′ in the former and 5′-TAG-3′ in the latter (Makalowska *et al.*, 2005). The rate of evolution is expected to be slower in stenches of DNA encoding overlapping genes than in similar DNA sequences that only use one reading frame. The reason is that the proportion of nondegenerate sites is higher in overlapping genes than in nonoverlapping genes, thus vastly reducing the proportion of synonymous mutations out of total number of mutations (Johnson and Chisholm, 2004; Normark *et al.*, 1983). Since gene duplication is a widespread phenomenon for the maintenance of overlapping genes, it would require quite strong selective pressure (against increasing genome size). Studies on aminoacyl tRNA synthetases indicate that overlapping genes may have played a momentous role in the evolution of life (Johnson and Chisholm, 2004; Normark *et al.*, 1983).

Alternate Splicing

Alternative splicing of a primary RNA transcript results in the production of different mRNAs from the same DNA segment, which in turn may be translated into different polypeptides (Baralle and Giudice, 2017). There are two types of exons: Constitutive, that is, exons that are included within all the mRNAs transcribed from a gene, and facultative,that is, exons that are sometimes spliced in and sometimes spliced out (Kornblihtt *et al.*, 2013). There are different types of alternative splicing; the most trivial form is the intron retention (Lee and Rio, 2015). However, more commonly, intron retention results in the premature termination of translation due to frameshifts. Sometimes, alternative splicing involves the use of alternative internal donor or acceptor sites, that is, excisions of introns of different lengths with complementary variation in the size of neighboring exons. Such use of competing splice sites was found in several transcription units of adenoviruses, as well as in eukaryotic cells such as the transformer gene in *Drosophila melanogaster* (Lee and Rio, 2015). Some cases of alternative splicing involved the use of mutually exclusive exons, that is, two exons are never spliced out together, nor are both retained in the same mRNA for example, M1 and M2 from a single gene by mutually exclusive use of exons 9 and 10. A special case of mutual exclusivity is the cassette exon (Roy *et al.*, 2013). A cassette is either spliced in or spliced out in the alternative mRNA molecules. Alternative splicing has often been used as a means of developmental regulation (Wang *et al.*, 2015). A very intriguing situation is seen in several genes involved in the process of sex determination in *D. melanogaster*. At least three genes, doublesex (dsx), Sexlethal (sxl), and transformer (tra), are spliced differently in males and females (Wang *et al.*, 2015). There is rich literature available on alternate splicing and its distribution in almost all available lineages.

Intron-Encoded Proteins and Nested Genes

An intron may sometimes contain an ORF that encodes a protein or part of a protein that is completely different in function from the one encoded by the flanking exons (Kumar, 2009). In many cases, intron-encoded protein genes are located within type-I self-splicing introns. From a mechanistic point of view, an intron-encoded protein gene that is transcribed from the same strand as the neighboring exons may be regarded as special instance of alternative splicing (Lee and Chang, 2013; Yu *et al.*, 2005). When an intron-encoded protein gene is transcribed from the opposite strand of the other gene, it is referred to as a nested gene. A case of nested genes was found in *Drosophila*, where a pupal cuticle protein gene is encoded on the positive strand of an intron within the gene encoding the purine pathway enzyme glycinamide ribotide-transformylase (Kaer *et al.*, 2011).

Functional Convergence

Function of a protein is frequently determined by only a few of its amino acids; a protein performing one function may sometimes arise from a gene encoding a protein performing a markedly different function. If the new function is performed in other species by proteins of unrelated structure and descent, functional convergence may occur. The myoglobin of abalone *Sulculus* consists of 377 amino acids, which are 2.5 times larger than myoglobins belonging to the globin superfamily (Suzuki *et al.*, 1996). Functional convergence provides a robust parameter associated with the existence of a functional protein for a family or superfamily. This convergence is reflected in various levels of organisms at the family and superfamily level based upon rate of selection pressure.

RNA Editing

RNA editing is a molecular process by which protein-coding gene change its message. One of the most common types of RNA editing is C-to-U conversion. This conversion may occur partially or completely in some tissues but not in others, leading to differential gene expression. Occasionally, it can produce a new protein with a different function from the unedited transcript, foe example, apolipoprotein B gene, one of the lipid carriers in the blood (Cooper, 1999). There are two types – Apo B-100 and apo B-48. Despite differences in length, amino acid sequences of the gigantic protein apo B-100 (4536 amino acid) with that of

apo B-48 (2152 amino acid), the result of alignment for the alignable part is 100% identity. It was found that apo B-48 is translated from a very long mRNA that is identical to that of apo B-100 with the execution of an in-frame stop codon resulting from the RNA editing of codon 2153 from CAA (Gln) to UAA (stop). Thus, by using RNA editing, two quite different proteins are produced from the same gene (Cooper, 1999). (**Figs. 2,3,4,5**).

Gene Sharing

Gene sharing means that a gene acquires and maintains a second function without divergent duplication and without loss of the primary function. Gene sharing may, however, require a change in the regulation system of tissue specificity or developmental timing (Cvekl and Zheng, 2009; Patthy, 2007). In literature, the term "multifunctional protein" is frequently used instead of "gene sharing." Gene sharing was first discovered in crystallins, which are the major water-soluble proteins in the

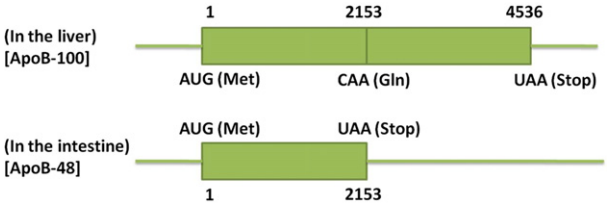

Fig. 2 Mechanism of RNA editing may leads to truncation.

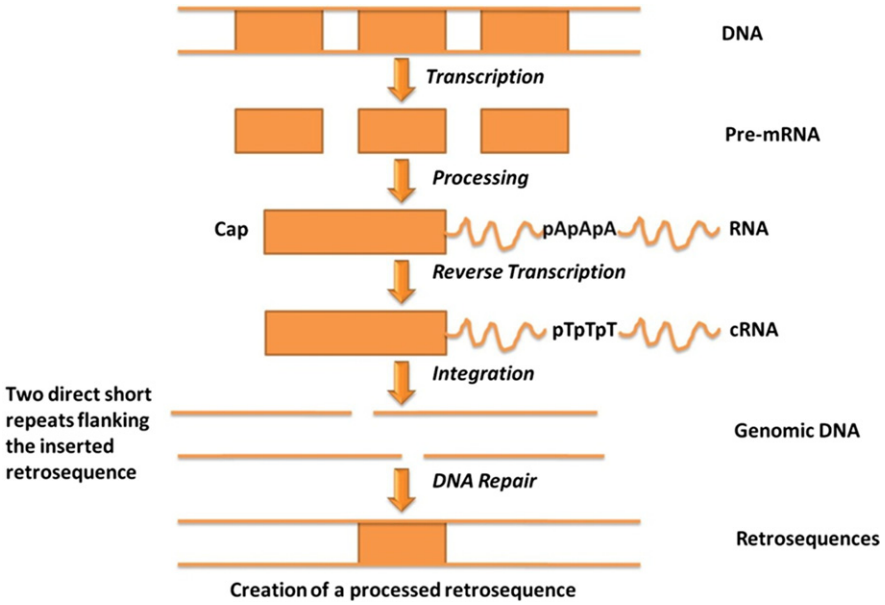

Fig. 3 Molecular mechanism explaining molecular repair.

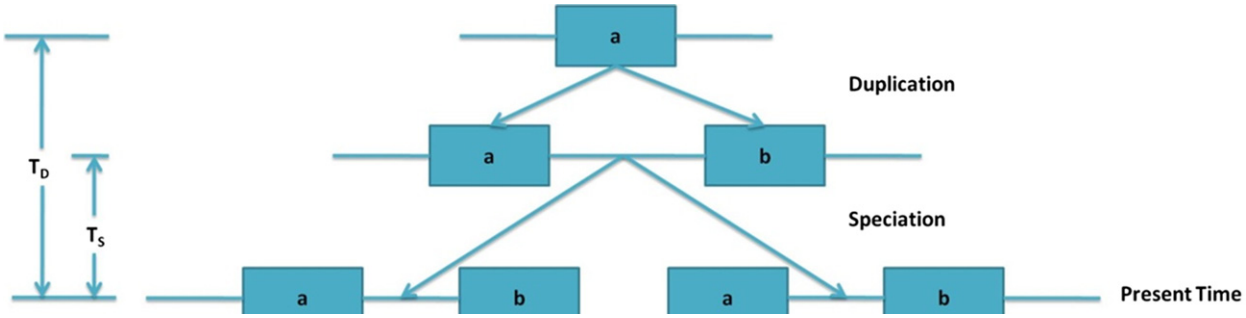

Fig. 4 Duplication and Speciation Events.

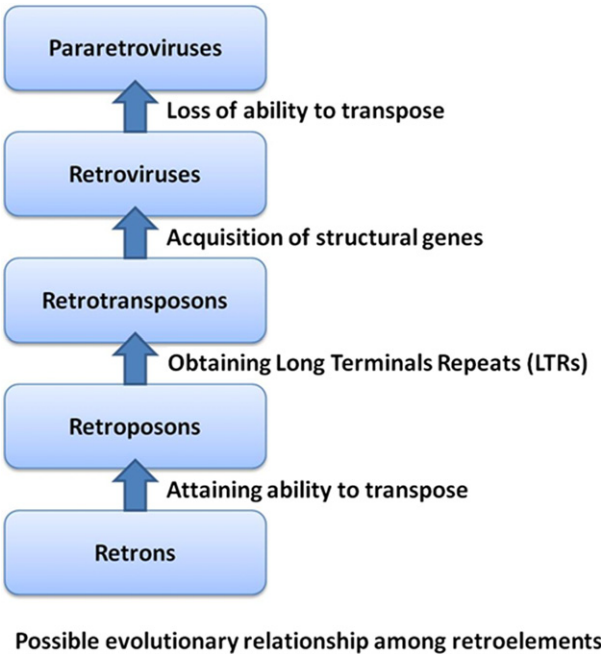

Fig. 5 Evolutionary relationship among retro elements.

eye lens, and whose function is to maintain lens transparency and proper light refraction (Cvekl and Zheng, 2009). Gene sharing might be a fairly common phenomenon, also suspected for several proteins in the cornea and other tissues. Gene sharing clearly adds to the compactness of the genome, even though compactness does not seem to have a high priority in eukaryotes (McKay, 2008).

Molecular Repair

The more we learn about the evolution of genes, the more we recognize that true innovations are only rarely produced during evolution. Many proteins that were originally considered to be relatively recent evolutionary additions turned out to be derived from ancient proteins (McKay, 2008). Besides, all the discussed mechanisms that facilitate tinkering at the molecular level are gene conversion and transposition. We may deduce that molecular tinkering is most probably the paradigm of molecular evolution, and it is reasonable to assume that tinkering also characterizes the evolution of morphological, anatomical, and physiological traits as well.

Gene Gain and Loss and Speciation Events

Gene Loss

More than 7000 diseases and disorders were documented in research papers and literature sources, which state that mutations have a crucial role in destroying and gaining function at the gene level (McKusick, 2007). A number of such mutations either get deleted at a very fast rate from population or sustained at very low frequency due to genetic drift. If there are many copies of genes present and functions normally then deleterious mutations which occur more often collate together compared to significant ones. Repeated duplicate genes usually become nonfunctional instead of being a new gene (Stone *et al.*, 1998).

Lateral Gene Transfer

Lateral gene transfer (LGT) is a process that makes complicated distribution of genes and dissimilar phylogenies with an rRNA tree. Still there is a debate on robust organismal phylogeny over extensive LGT (Kettler *et al.*, 2007). In case there is a presence of a core set of genes that are resistant to LGT, then there should be a reflection of vertical descent and ascent along with cell division. Moreover, various next generation sequencing techniques like metagenomics, genomics, and proteomics pave a path in understanding the core mechanism of LGT. In particular, it will be informative to know the complete genome diversity (Kettler *et al.*, 2007).

Dating Gene Duplication and other Computations

Dating Gene Duplications

Two genes are said to be paralogous if they are derived from a duplication event, but orthologous if they are derived from a speciation event.

Here, genes a and b were derived from the duplication of an ancestral gene and are paralogous, while gene a from species 1 and gene a from species 2 are orthologous, as are genes b from species 1 and gene b from species 2 (Chen *et al.*, 2000). We can estimate the date of duplication, T_D, from sequence data if we know the rate of substitution in genes a and b. The rate of substitution can be estimated from the number of substitutions between the orthologous genes in conjunction with knowledge of the time of divergences T_S, between species 1 and 2. For gene a, let K_a be the number of substitutions per site between the two species. Then the rate of substitution in gene a, γ_a is estimated by:

$$\gamma a = \frac{\mathrm{Ka}}{2\mathrm{TS}} \tag{1}$$

The rate of substitution in gene b, γ_b can also be obtained in a similar way. The average substitution rate for the two genes:

$$\gamma = \frac{\gamma a + \gamma b}{2} \tag{2}$$

To estimate T_D, we need to know the number of substitutions per site between gene a and b (Kab). This number can be estimated from four pairwise comparisons: (1) Gene a from species 1 and gene b from species 2, (2) (Robinson-Rechavi *et al.*, 2004). Gene a from species 2 and gene b from species 1. (3) Gene a and gene b from species 1. (4) Gene a and b from species 2. From these four estimates, we can compute the average value for K ab from which we can estimate T_D as:

$$\mathrm{TD} = \frac{\mathrm{Kab}}{2\gamma} \tag{3}$$

In case of protein coding genes, by using the number of synonymous and nonsynonymous substitutions separately, we can obtain two independently estimates of T_D. The average of these two may be used as the final estimate of T_D. Sometimes problems are due to concerted T_D estimation. Another method for dating gene duplication events is to consider the phylogenetic distribution of genes in conjunction with paleontological data pertinent to the divergence date of the species in question (Zhou *et al.*, 2010).

Unprocessed Pseudogenes

The silencing of a gene due to deletion in a nucleotide and causing deleterious mutation ultimately results in production of pseudogene. Such pseudogenes do not undergo RNA processing. Unprocessed pseudogenes may be the result of derivation from nonfunctionality of a duplicate functional gene. There is much less chance that functional genes come into existence without duplication. Unprocessed pseudogenes may result in various diseases and disorders like frameshift mutation, nonmature stop codon, and misorientation of sliced transcripts or regulatory elements; therefore, it is easy to identify a change in sequence in terms of mutations resulting directly in gene silencing (Tutar, 2012). It is possible in some cases to identify the mutation responsible for nonfunctionalization of a gene through a phylogenetic analysis, for example, human pseudogene $\psi\eta$ in the b-globin family contains numerous defects, each of which could have been sufficient to silence it (Pink *et al.*, 2011). The b-globin clusters in chimpanzee and gorilla were found to contain the same number of genes and pseudogenes as in humans, indicating that the pseudogenes were created and silenced before these three species diverged from one another.

Interestingly, mutations that cause nonfunctionalization are only rarely missense mutations, most probably because such mutations result in the production of defective proteins that may be incorporated into final biological products and thus may have deleterious effects. Because unprocessed pseudogenes are usually created by duplication, they usually found in the neighborhood of the homologous functional genes from which they have been derived.

Unitary Pseudogenes

The pseudogene has no functional correlation with the human genome, called unitary pseudogene. Guinea pigs and humans suffer from scurvy unless they consume L-ascorbic acid in their diet, because they lack a protein called L-gulono-y-lactone oxidase, an enzyme that catalyzes the terminal step in L-ascorbic acid synthesis (Pink *et al.*, 2011). In humans, L-gulono-y-lactone oxidase is a pseudogene that contains molecular defects as the deletion of at least two exons (out of 12), deletions and insertion of nucleotides in the reading frame, and obliterations of intron–exon boundaries (Pink *et al.*, 2011). It has been assumed that the guinea pig and human ancestors managed to survive on a naturally ascorbic acid-rich diet; hence, the loss of this enzyme did not reflect a disadvantage.

Case Studies

There are several case studies where bioinformatics has been implemented successfully to connect molecular evolution events with their functional consequences. Genomics studies paved the path to understand variation at the genomic level through phylogenetic approaches (Pradhan *et al.*, 2017; Wang *et al.*, 2018). Further network reconstruction approaches using co-expression network modules also helps to trace the gene duplication events (Feng *et al.*, 2016; Malviya *et al.*, 2016). For instance, phylogenetic investigation of human FGFR-bearing paralogons favors piecemeal duplication theory of vertebrate genome evolution (Ajmal *et al.*, 2014). All given studies indicate that duplication and speciation events are very much diverse in nature and take many years to evolve and confirm to contribute to significant changes.

Tools and Methods

S.No.	*Tool or method*	*Description*	*References*
1.	Control-FREEC	CNV detection: HTS analysis	A tool for detection of copy-number changes and allelic imbalances (including LOH) using deep-sequencing data. Control-FREEC automatically computes, normalizes, segments copy number and beta allele frequency profiles, then calls copy number alterations and LOH. The control (matched normal) sample is optional. The program can also use mappability data (files created by GEM).	Boeva *et al.* (2012, 2011)
2.	mrCaNaVaR	micro-read Copy number variant regions	A copy number caller that analyzes the whole-genome next-generation sequence mapping read depth to discover large segmental duplications and deletions. mrCaNaVaR also has the capability of predicting absolute copy numbers of genomic intervals.	Alkan *et al.* (2009)
3.	forestSV	Structural variant detection: HTS analysis	Integrates prior knowledge about the characteristics of SVs. forestSV is a statistical learning approach, based on Random Forests, that leads to improved discovery in high throughput sequencing (HTS) data. This application offers high sensitivity and specificity coupled with the flexibility of a data-driven approach. It is particularly well suited to the detection of rare variants because it is not reliant on finding variant support in multiple individuals.	Michaelson and Sebat (2012)
4.	CTDGFinder	Duplication detection: HTS analysis	Formalizes and automates the identification of clusters of tandemly duplicated genes (CTDGs) by examining the physical distribution of individual members of families of duplicated genes across chromosomes. Application of CTDGFinder accurately identified CTDGs for many well-known gene clusters (e.g., Hox and beta-globin gene clusters) in the human, mouse, and 20 other mammalian genomes. Examination of human genes showing tissue-specific enhancement of their expression by CTDGFinder identified members of several well-known gene clusters (e.g., cytochrome P450s and olfactory receptors) and revealed that they were unequally distributed across tissues. By formalizing and automating CTDG identification, CTDGFinder will facilitate understanding of CTDG evolutionary dynamics, their functional implications, and how they are associated with phenotypic diversity.	Ortiz and Rokas (2017)
5.	cn.MOPS	Copy number estimation by a Mixture Of PoissonS	A data processing pipeline for copy number variations and aberrations (CNVs and CNAs) from next generation sequencing (NGS) data. The package supplies functions to convert BAM files into read count matrices or genomic ranges objects, which are the input objects for cn.MOPS. It models the depths of coverage across samples at each genomic position. Therefore, it does not suffer from read count biases along chromosomes. Using a Bayesian approach, cn.MOPS decomposes read variations across samples into integer copy numbers and noise by its mixture components and Poisson distributions, respectively.	Klambauer *et al.* (2012)
6.	RDXplorer	CNV detection: HTS analysis	A computational tool for copy number variants (CNV) detection in whole human genome sequence data using read depth (RD) coverage. CNV detection is based on the event-wise testing (EWT) algorithm. The read depth coverage is estimated in nonoverlapping intervals (100 bp Windows) across an individual genome based on the pileup generated by SAMTools.	Yoon *et al.* (2009)
7.	cnvHiTSeq	CNV detection: HTS analysis	A set of Java-based command-line tools for detecting copy number variants (CNVs) using next-generation sequencing data.	Bellos *et al.* (2012)

Source: *This data is referred from OMICSTOOLS resource. There are various other tools which may be referred at https://omictools.com/duplication-detection-category.

Conclusion

Gene duplication and speciation are two prominent mechanisms for finding clues for evolution. Phylogenetic analysis helps researchers to understand the ancestral association of species or sequence of their interest. Gene duplication events, exon shuffling,

and speciation have a potent role in the process of evolution and to study convergence and divergence from ancestral data. This article provides descriptive information about basic concepts of phylogeny that may help students and researchers to become aware of terminologies used in gene duplication and speciation analysis. It is presented in a way where basic to advanced level information is being compiled on the diverse topics and it is estimated that this information will serve as comprehensive information to students, faculty members, and researchers working in this area. It reflects how bioinformatics can shape a computational pipeline for the analysis of biological data in an evolutionary scenario and will help the evolutionary biologists also to implement bioinformatics at some level for further exploration of basic principles.

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Sensors and Image Processing

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Preface

The last decade has witnessed remarkable changes in IT industry, virtually in all domains. The 50th Annual Convention, CSI-2015, on the theme "Digital Life" was organized as a part of CSI-2015, by CSI at Delhi, the national capital of the country, during December 02–05, 2015. Its concept was formed with an objective to keep ICT community abreast of emerging paradigms in the areas of computing technologies and more importantly looking at its impact on the society.

Information and Communication Technology (ICT) comprises of three main components: infrastructure, services, and product. These components include the Internet, infrastructure-based/infrastructure-less wireless networks, mobile terminals, and other communication mediums. ICT is gaining popularity due to rapid growth in communication capabilities for real-time-based applications. "Nature Inspired Computing" is aimed at highlighting practical aspects of computational intelligence including robotics support for artificial immune systems. CSI-2015 attracted over 1500 papers from researchers and practitioners from academia, industry, and government agencies, from all over the world, thereby making the job of the Programme Committee extremely difficult. After a series of tough review exercises by a team of over 700 experts, 565 papers were accepted for presentation in CSI-2015 during the 3 days of the convention under ten parallel tracks. The Programme Committee, in consultation with Springer, the world's largest publisher of scientific documents, decided to publish the proceedings of the presented papers, after the convention, in ten topical volumes, under ASIC series of the Springer, as detailed hereunder:

1. Volume # 1: ICT Based Innovations
2. Volume # 2: Next Generation Networks
3. Volume # 3: Nature Inspired Computing
4. Volume # 4: Speech and Language Processing for Human-Machine Communications
5. Volume # 5: Sensors and Image Processing
6. Volume # 6: Big Data Analytics

7. Volume # 7: Systems and Architecture
8. Volume # 8: Cyber Security
9. Volume # 9: Software Engineering
10. Volume # 10: Silicon Photonics and High Performance Computing

We are pleased to present before you the proceedings of Volume # 5 on "Sensors and Image Processing." The title "Sensors and Image Processing" highlights the different applications in the field of virtual reality. It also delves into the matter as to how robotics can be applied to strengthen modeling. The title also showcases the various augments of latest mobile technologies, solid modeling, etc.

Sensors are used in everyday objects such as touch-sensitive elevator buttons and lamps which dim or brighten by touching the base, besides innumerable applications of which most people are never aware of. With advances in micro-machinery and easy-to-use microcontroller platforms, the uses of sensors have expanded beyond the more traditional fields of temperature, pressure, or flow measurement, for example MARG sensors. Image processing is processing of images using mathematical operations by using any form of signal processing for which the input is an image, such as a photograph or video frame. The output of image processing may be either an image or a set of characteristics or parameters related to the image. Most image-processing techniques involve treating the image as a two-dimensional signal and applying standard signal-processing techniques to it. The title "Sensors and Image Processing" also amalgamates and showcases the applications of above technologies in different research and real-time domains. The volume includes scientific, original, and high-quality papers presenting novel research, ideas, and explorations of new vistas in speech and language processing such as speech recognition, text recognition, embedded platform for information retrieval, segmentation, filtering and classification of data, emotion recognition. The aim of this volume is to provide a stimulating forum for sharing knowledge and results in the model, methodology, and implementations of speech and language processing tools. Its authors are researchers and experts of these domains. This volume is designed to bring together researchers and practitioners from academia and industry to focus on extending the understanding and establishing new collaborations in these areas. It is the outcome of the hard work of the editorial team, who have relentlessly worked with the authors and steered up the same to compile this volume. It will be a useful source of reference for the future researchers in this domain. Under the CSI-2015 umbrella, we received over 200 papers for this volume, out of which 29 papers are being published, after rigorous review processes, carried out in multiple cycles.

On behalf of organizing team, it is a matter of great pleasure that CSI-2015 has received an overwhelming response from various professionals across the country. The organizers of CSI-2015 are thankful to the members of *Advisory Committee, Programme Committee, and Organizing Committee* for their all-round guidance, encouragement, and continuous support. We express our sincere gratitude to the learned *Keynote Speakers* for support and help extended to make this event a grand success. Our sincere thanks are also due to our *Review Committee Members* and the

Editorial Board for their untiring efforts in reviewing the manuscripts, giving suggestions and valuable inputs for shaping this volume. We hope that all the participated delegates will be benefitted academically and wish them for their future endeavors.

We also take the opportunity to thank the entire team from Springer, who have worked tirelessly and made the publication of the volume a reality. Last but not least, we thank the team from Bharati Vidyapeeth's Institute of Computer Applications and Management (BVICAM), New Delhi, for their untiring support, without which the compilation of this huge volume would not have been possible.

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A Systematic Review on Image Enhancement Techniques

Nishant Bhardwaj, Gagandeep Kaur and Pradeep Kumar Singh

Abstract Image enhancement is a very important process used for enhancing the quality of an image, and for this purpose, numerous techniques have been used and applied. This paper describes how to enhance an image using different techniques. Various techniques have been studied for image enhancement used in different research papers. Understanding and reviewing the techniques used for image enhancement are the main goal of this paper. Our review work leaves a lot of future scopes which can be extended further by researchers.

Keywords Image enhancement · Image quality · Digital image processing

1 Introduction

Image enhancement is a process by which we can improve the quality of the digital image which makes it easier for identifying features. This can be done by removing noise, sharpening, or brightening an image. The techniques identified in the paper to enhance an image are contrast stretching and image sharpening, nonlinear image enhancement technique, genetic algorithm, generalized fuzzy enhancement, wavelet transform technique, multi-scale and single-scale retinex improvement technique, etc. This paper is divided into four sections. Section 1 is an introduction about the image enhancement followed by review procedure in Sect. 2. Section 3 covers the detailed analysis of the selected papers. Finally, in conclusion, answers to the research questions as well as the future scope are discussed in Sect. 4.

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Table 1 Research questions identified

Research questions
RQ1: To identify the various techniques used in the image enhancement?
RQ2: To compare the traditional image enhancement techniques with the new image enhancement techniques?
RQ3: To identify the factors affecting the image quality?

2 Review Procedure

To study the image enhancement techniques, we have read around 150 research papers. We have adopted a similar approach taken by Singh et al. [1, 2, 3] and then identified the most suitable papers using the following steps: (i) we have downloaded the papers using the keywords: image enhancement techniques, (ii) we read the abstract, title, and conclusion, (iii) we have chosen the research papers which are related to our study based on the content of papers, (iv) we have chosen 30 most relevant papers out of 150 papers, (v) the findings have been reported after studying each paper thoroughly, (vi) finally, we made tables which categorize the major contribution of authors, and techniques used in various papers. Following are the research goals to study the image enhancement techniques (Table 1).

3 Related Work

In this section, various papers related to image enhancement have been taken into account for review and analysis.

In [4], Negi et al. discussed contrast stretching and image sharpening techniques. It is an approach that concurrently adjusts contrast and enhances boundaries of an image. On the gray-scale image contrast stretching is applied and then it proceeds to Laplacian mask, and finally, Laplacian image is appended to the original gray-scale image to obtain the desired sharpened image.

In [5], Wu et al. proposed image enhancement using wavelet-based contourlet transform with cycle translation. In this, wavelet transform is used for decreasing the redundancy occurring in the original method of contourlet transform. WBCT and cycle translation are merged. At last, to magnify the images, adaptive enhancement function is selected. The proposed method can efficiently magnify the images and decrease the flecked at the background region, the image edges.

In [6], Wang et al. discussed NIE (Nonlinear Image Enhancement). Simulation and identification processes are used along with the proposed NIE method. This process uses clipping and scaling parameters which are an appropriate combination of various images. This process enhances the quality of blurred image and a better quality is achieved, and PSNR (signal-to-noise ratio) performance is obtained than other nonlinear enhancement techniques.

In [7], Sree et al. implemented the FPGA-based retinal fundus image enhancement algorithms. The design was accomplished using Simulink, and the implementation was accomplished on the Spartan 3E Development Board. It was found out that hardware system performance through different experiments was more as compared to software version for complicated video inputs.

In [8], Yaping et al. discussed the stepwise refinement method. The main objective of this method is how to recognize and enhance the particular portion of a digital image, and maintaining other information of the object by keeping it unchanged. So stepwise refinement method is used to figure out the problem. It comprises of image pre-processing, recognition and enhancement.

In [9], Imtiaz et al. discussed a color image enhancement method. FICE algorithm is used to enhance the RGB endoscopic images. The color reproduction is carried out by transferring chrominance map from the source image to the enhanced gray-scale spectral image in the procedure of corresponding luminance and texture information. It throws light on some of the tissue characterization on the surface part of the base endoscopic image.

In [10], Premkumar et al. discussed the color image contrast enhancement technique. Firstly, RGB image is transformed to HSV (hue, saturation, and value) color space. Hue color channel is selected for DST decomposition. The lower directional sub band is used for reformation. By transforming HSV to RGB color space, the enhanced image is acquired. From proposed DST-based contrast image enhancement approach, the satisfactory result is attained.

In [11], Bhattacharya et al. proposed a fast algorithm for raising the contrast of an image locally by using singular value decomposition (SVD) approach. The contrast of a partially degraded image is magnified by using this approach. Under global and partial degradation, the method is carried out properly and a good perceptual quality after processing is achieved.

In [12], Teng et al. described the Laplacian and Gaussian methods and discovered an upgraded Laplacian pyramid image enhancement method. On the obtained threshold of the Laplacian pyramid improvements, there is a good solution for the color difference between the smaller image detail enhancement and for the large difference in the color image enhancement, the effect is very obvious.

In [13], Wang et al. proposed an improvement to the wavelet transform method, naming it the lifting wavelet transform method for image enhancement purposes. It contrasts the new method with the existing wavelet transform method. The lifting wavelet transform method accredits the image to have wide gray-scale scope and also the detail is clear.

In [14], Munteanu et al. proposed real-coded genetic algorithm method for automatic image enhancement named EVOLEHA. In order to attain better explorative behavior, the method applies a real-coded GA with significant modifications like PCA-mutation. Due to a more exploitative crossover and selection scheme, the search is well-balanced and durable. EVOLEHA attains a combined goal (e.g., efficiency, robustness, wide applicability) that is not achieved by any other known enhancement methods.

In [15], Sun et al. proposed a novel optical transfer function-based micro image enhancement algorithm. An optical transfer function is used by this method for image enhancement. The proposed algorithm was better to save edge information of the micro image and no distortion when it is compared with Butterworth high-pass filter algorithm.

In [16], Ehsani et al. proposed an adaptive and iterative histogram matching (AIHM) algorithm for chromosome contrast enhancement used in medical applications. To meet the different requirements and obtain the different results, some parameters in the presented model could be selected. The detailed simulations were accomplished using different sets of single chromosomes, indicating that the proposed method enhances the details adequately.

In [17], Xiao-guang et al. proposed a generalized fuzzy enhancement method. This method overcomes efficiently the problem of information of middle and low gray levels lost in the method put forward by S.K. Pal. The edge of processed image becomes distinguishable, and by using this method, better object information of low gray levels is kept. It gives highly enhanced image and improves contrast ratio.

In [18], Ke et al. proposed an innovative image enhancement framework consisting of BiTA and SWCE. The traditional gamma adjustment curve is modified using the BiTA algorithm. The adjustment of global luminance is done by BiTA. By analyzing and setting the parameter γ, it limited the contrast lost. The saliency map with a simple contrast enhancement method is integrated by SWCE. SWCE carries out more enhancements in the areas that humans pay larger attention to.

In [19], Tang et al. proposed a new image enhancement technology which is based on a multi-scale contrast measure in the wavelet domain for radiologists to screen the mammograms. It alters the contrast of an image directly, so the proposed image enhancement technology is a direct contrast enhancement technology.

In [20], Dong-liang et al. proposed the generalized fuzzy enhancement method that overcomes the limitations of the traditional fuzzy method of enhancement. The enhancement problem of the low contrast and the narrow gray range images is solved by this method. The improved label algorithm is used for image segmentation and recognition, which is helpful in understanding an image and in object recognition.

In [21], Choi et al. discussed image enhancement technique in which an input RGB color image is transformed into HSV color image. The H component remains unchanged. Firstly, illumination is evaluated using JND-based nonlinear low-pass filter, to enhance the V component. It is done in ratio to the enhanced ratio of V component image, to enhance the S component. Finally, the image is transformed back to RGB color image.

In [22], Hasikin et al. discussed fuzzy gray-scale enhancement technique. The fuzzy measures in the image are maximized by using this technique. By using power law transformation and saturation operator, the membership function is modified. The intensities are increased of the underexposed regions, and intensities are decreased of the overexposed region, which is why the dynamic range is maintained. Other methods use INT operator (the membership value is modified above and below the threshold value) and NINT operator.

In [23], Xianghong et al. discussed the enhancement algorithm for colored medical images. It includes two features: color space transform enhancement and wavelet analysis enhancement. By using wavelet analysis, the image is fragmented and improved. From RGB space, the color image is converted to IHS (intensity, hue, and saturation) space. The new saturation which is enhanced replaces the image saturation. The nonlinear transform adjusts the intensity of the image. The image is then reconverted from IHS space to RGB space, and finally, the image is enhanced.

In [24], Yang et al. discussed morphological reconstruction enhancement. A non-idempotent connected operator is explained in this method. Overall enhancement of simple connected zones of image is done. Finally, the connected zones and the relations of the connected zones of an image are defined which are reconstruction, choice and iteration times. To describe image's peak component, flat area regional maximum, and their relations, a tree structure is used.

In [25], Peng et al. discussed enhancement method of THz images. By using wavelet transform into low and high-frequency part, a THz image is fragmented. Approximation coefficients go through nonlinear enhancement technique. This method magnifies the target and represses the background. Detail coefficients go through histogram equalization but it also enhances noise as well. So firstly, to remove noise in high-frequency band wavelet, denoising is applied. In target identification, the proposed method has good application prospect.

In [26], Gorai et al. proposed an automatic color enhancement technique using particle swarm optimization. Parameters of objective function are made effective by particle swarm optimization. The intensity transformation uses local as well as global information. The objective function makes the use of entropy and edge information for measuring the quality of input image. To obtain the enhanced image, scaling (or sometimes rescaling in case of gamut problem arises) is done.

In [27], Verma et al. used genetic algorithm to enhance an image. GA enhances the image naturally as it measures the fitness of a particular by estimating the intensity of spatial edges comprised in the image. Image is broken into sub images. Transformation function is applied. Fitness function is used. One with higher fitness is selected using tournament selection. Crossover is done using an arithmetic crossover, and finally, PCA-mutation is done.

In [28], Khan et al. proposed fingerprint image enhancement using multi-scale DDFB-based diffusion filters and modified Hong filters. The major goal of a fingerprint image enhancement is to magnify the image in order to remove noise and magnify reliable minutiae points. To calculate orientation field of a fingerprint image, multi-scale DDFB is required. This shows that this technique is more reliable than any derivatives-based techniques.

In [29], Raju et al. proposed a new fuzzy logic and histogram-based algorithm for magnifying low contrast color image. In this method, there are two parameters: K and M, where K is contrast identification parameter and M is image's average intensity parameter. The RGB image is transformed to HSV color space. Under the control of parameter M, V component is strained in order to magnify the image. The visual quality is modified by this method.

Table 2 Analysis of research papers related to various image enhancement techniques

Paper ID	Technique(s) identified
[1], [9]	Laplacian Method (Mask and Pyramid)
[2], [10], [16], [20], [22], [29]	Wavelet transform-based techniques
[3], [8]	Nonlinear image enhancement methods
[13], [26], [30]	Histogram-based techniques
[11], [24]	Genetic algorithm-based enhancement
[14], [17], [19]	Fuzzy-based enhancement
[21], [25], [27]	Multi-scale methods for enhancement
[4], [5], [6], [7], [12], [15], [18], [23], [28]	Other methods (HSV, DoG, PSO, shearlet transform, FPGA, optical method, BiTA and SWCE, FICE, etc.)

In [30], Lin et al. proposed retinex improvement for nighttime image enhancement. In case of low light images, this method can be applied to preserve normal or intensive lighting areas and reduce noise in highly low light areas.

In [31], Samantaray et al. focus on improving fingerprints using a proposed difference of Gaussian method. For that, histogram equalization is used and the proposed method is compared with other approaches also. Separate algorithms for contrast enhancement and detail enhancement are proposed so that fingerprints can be analyzed correctly.

In [32], Chouhan et al. propose a dynamic stochastic resonance-based technique which is used to improve the quality of dark contrast images so that they can be easily identified. For this method to be implemented, image must be in discrete wavelet transform (DWT) domain. For the purpose of contrast enhancement, internal noise of the image is used instead of external noise which improves the performance of enhancement.

In [33], Akila et al. compare various contrast enhancement techniques for images used in breast cancer detection (mammographic image enhancement). Techniques used are HE, CLAHE, BBHE, MMBEBHE, and RMSHE. According to the analysis, HE changes brightness of the image so the details cannot be viewed clearly. BBHE and MMBEBHE provide noise removal from images. Out of CLAHE and RMSHE, which both provide significant contrast enhancement, RMSHE is proved to be better.

4 Conclusion

In this paper, from Sect. 3 and Table 2, research questions proposed earlier in Table 1, i.e., RQ1, RQ2, and RQ3 are identified and answered. The main goal of this systematic review is to identify and analyze various image enhancement techniques which are used to enhance the quality of an image, including noise,

contrast, brightness, etc. These techniques help researchers compare various enhancement algorithms and choose the best of them as per the required purpose.

Answer to RQ1
Various techniques that are identified from our review work are listed as follows:

1. **Laplacian method:** mask and pyramid.
2. **Wavelet-based Enhancement:** wavelet transform, lifting wavelet transform, multi-scale contrast feature in wavelet domain, wavelet and color space transform, wavelet-based enhancement using DSR.
3. **Nonlinear Image Enhancement Methods:** singular value decomposition (SVD).
4. **Histogram-based methods:** HE, CLAHE, BBHE, MMBEBHE, and RMSHE, adaptive and iterative histogram matching (AIHM), fuzzy logic and histogram-based image enhancement.
5. **Genetic Algorithm-based evolutionary enhancement** (EVOLEHA).
6. **Fuzzy-based enhancement:** fuzzy-based iterative image enhancement, generalized fuzzy-based image enhancement.
7. **Multi-scale methods:** multi-scale morphological reconstruction, multi-scale retinex improvement, multi-scale DDFB-based diffusion filters and modified Hong filter.
8. **Other techniques:** field programmable gate array, stepwise refinement method, FICE algorithm, discrete shearlet transform, optical transfer function-based image enhancement, BiTA and SWCE, HSV Transform, particle swarm optimization, difference of Gaussian.

Answer to RQ2:
The most common algorithm traditionally used for image enhancement is histogram equalization. Other algorithms were also used but they were somehow an extension or modification of histogram equalization only.

As the technology advanced, various new methods were developed for the enhancement of images. As expected, new techniques were better than the traditional image enhancement techniques. As studied from various papers, we found out that wavelet transform- and soft computing-based methods (GA and fuzzy) were better than the traditional histogram equalization methods.

Answer to RQ3
As analyzed, there are various factors which can affect image quality. Some of them are noise, sharpness, distortion, contrast, color accuracy, dynamic range, exposure accuracy, lens flare, etc. These factors must be kept in mind while choosing or designing any image enhancement algorithm.

Finally, we can conclude that main techniques identified are histogram equalization, wavelet processing and transform, genetic algorithms, fuzzy enhancement techniques, Laplacian and Gaussian techniques, etc.

In future, this review can be used to compare various image enhancement algorithms and their feasibility can also be determined. Also, a specific area can be

chosen and further review and research work can be carried out. The proposed studies may be used to do comparative analysis, and further improvement may be applied by proposing new image enhancement techniques. Further, proposed image enhancement techniques may increase the quality of images.

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An Analytic Review on Image Enhancement Techniques Based on Soft Computing Approach

Gagandeep Kaur, Nishant Bhardwaj and Pradeep Kumar Singh

Abstract This paper discusses various image enhancement techniques using soft computing approaches. The approaches used are genetic algorithm, fuzzy-based enhancement, neural networks, and optimization techniques (ant colony, bee colony, particle swarm optimization, etc.). The main objective of this paper is to identify the status of currently used soft computing approaches in image enhancement. Our study may help future researchers to overcome the current issues with existing approaches to improve the overall image quality.

Keywords Image enhancement · Image quality · Soft computing approaches · Digital image processing

1 Introduction

Image enhancement is the way of refining the quality of a digital image; thus, making processing of the image easier. After enhancement, the resulting image is better in quality, contrast and can be analyzed correctly by any of the image processing methods. Various techniques can be used for the same, but our study is limited to the techniques based on soft computing approaches. Image enhancement based on soft computing approaches discussed in this paper is genetic algorithm, fuzzy-based enhancement, neural networks, and optimization techniques (ant colony, bee colony, particle swarm optimization, etc.). It has been identified that these techniques provide better enhancement as compared to other traditional image

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enhancement techniques. In addition to this, they are easy to understand and implement.

This paper is divided into four sections. Section 1 is introduction about the image enhancement followed by review procedure in Sect. 2. Section 3 covers the detailed analysis of the selected papers. Finally, conclusions as well as answers to the research questions are discussed in Sect. 4.

2 Review Procedure

To study various image enhancement techniques based on soft computing approaches, we downloaded around 200 papers from IEEE, science direct, ACM, and several other popular digital libraries. We have adopted a similar approach taken by Singh et al. [1, 2] and then identified the most suitable papers using the following steps: (i) we downloaded around 200 papers using standard keywords, (ii) after reading the abstract, title, and conclusion of the downloaded papers, we filtered out 90 relevant papers, (iii) out of the 90 papers selected, we chose 45 most suitable papers related to the suitability of our study, (iv) after that, these papers were thoroughly studied, and the final outcome of each paper was recorded, (v) finally, we have summarized the findings in a tabular format and answered the research questions prepared for conducting systematic review. Following are the research goals to study the image enhancement techniques (Table 1 and 2):

3 Related Work

In this section, various papers related to image enhancement based on soft computing approaches have been taken into account for review and analysis.

In [3], Archana et al. discussed an image enhancement technique using genetic algorithm (GA) which modifies an image with natural contrast. The aim of local contrast enhancement is done by using a, b, c, k parameters with new addition in the range. On the basis of light and dark edges, the gray level of an image is increased. By checking the intensity of spatial edges, the GA measures the individual's fitness. In [4], Deborah et al. proposed a GA technique for magnifying and restoring the old

Table 1 Research questions identified

Research Questions
RQ1: To identify the various techniques used in the image enhancement based on soft computing approach?
RQ2: To compare the traditional image enhancement techniques with the soft computing-based image enhancement techniques?
RQ3: To identify strength and weaknesses of existing image enhancement techniques

Table 2 Search result details

S No.	Soft computing approach used	No. of papers downloaded	No of relevant papers found	Final no of papers chosen for review
1.	Genetic algorithm	42	20	8
2.	Fuzzy enhancement	71	25	18
3.	Neural networks	44	20	11
4.	Optimization technique (PSO, ABC, ACO)	30	10	5
5.	Hybrid	13	10	3
TOTAL		200	85	45

documented image. In this method, the material presents in old documents is retained into digital form. The number of edges having one pixel is the most excellent fitness function. Individuals that have fitness value identical to the fitness value of original image are the optimal solution. In [5], Ueda et al. analyzed an image enhancement system based on GA by acknowledging the liking of the user. GA finds the optimal parameters contained in the selective un-sharp masking of the sharpening system. Based on the liking of the user, the final sharpened image is built. In [6], Radlak et al. considered a method for attaining the optimization visuals by increasing the distance between various colors. The proposed method gives the best visualization result. Using the GA, the final output gives the benefits of pseudo-colorization. In [7], Wu et al. mentioned a method which merges the rough set technique and adaptive genetic algorithm for enhancing an image. Firstly, the image is considered as the knowledge system, and to categorize an image, classification method of rough set theory is used to merge noise attributes and image color attributes. Then, various image enhancement algorithms are applied to modify the image. In [8], Dongzhou et al. analyzed a hybrid genetic algorithm for enhancing an image. It merges the differential evolution with genetic algorithm. For searches and mutation, the fast searching ability of the hybrid genetic algorithm is used. At last, in their work, they have applied transformation function for image enhancement. In [9], Munteanu et al. analyzed an image enhancement method with user behavioral model. In this method, various genetic algorithms are used. This method tries to slightly automate the process of human interpretation which results in rich quality solutions, and hence less human effort is needed. In [10], Daniel et al. proposed a contrast enhancement technique purposely for retinal images. The proposed technique uses masking technique using the green plane and then applying an enhanced GA for the enhancement. The proposed technique is first applied on normal images and then successfully on retinal images. Finally, performance of the proposed technique is evaluated and is found to be better than other traditional techniques.

In [11], Hasikin et al. analyzed a fuzzy set theory method for enhancing the lower contrast image. This method maximizes the fuzzy measurements. The modification of the membership function is done by using the power law transforms and the saturation operator. In [12], Chaira et al. discussed a type II fuzzy

enhancement algorithm for image enhancement. Here, Hamacher T Norm is used for defining the new membership functions. It is then compared with other fuzzy image enhancement methods and is observed that the proposed technique gives better contrast images. In [13], Cepeda-Negrete et al. analyzed a fuzzy rule-based system which automatically chooses color constancy algorithms from white patch, gray world, and gray edge for enhancing the color of dark images. Twelve features, including seven colors, three textures, and two lightning features of each image are extracted for processing. In the end, best of the three algorithms is selected for any test image. In [14], Binaee et al. mentioned a noise reducing fuzzy filter which is applied on ultrasound images. It is used for enhancing the quality of ultrasound images, so that they can be efficiently analyzed without any error. The proposed technique contains two steps: detection and filtering. In detection, details of the image are extracted using two fuzzy rule-based system as well as local gradients. In filtering, de-noising of each region is done by a non-local means scheme in which fuzzy similarity is used for finding similarity in weights. In [15], Bing et al. proposed a new algorithm for image enhancement using information fusion for preserving edge information. It is actually a hybrid filter consisting of fuzzy-based region entropy and triangle module fusion operator for edge detection. In [16], Xiao-guang et al. discussed a generalized fuzzy enhancement method. This method overcomes, efficiently, the problem of information of middle- and low-gray levels lost in the method put forward by a previous study. The edge of processed image becomes distinguishable, and by using this method, better object information of low gray levels is kept. It gives highly enhanced image and improves contrast ratio. In [17], Balti et al. implemented fuzzy C-means algorithm for fingerprint image segmentation. Firstly, statistical features of the fingerprint image are extracted and then are used in the fuzzy C-means algorithm. K means algorithm is also used for comparison with the fuzzy C-means algorithm. Also, enhancement of the fingerprint is done by first calculating mean and variance of an image and then finding difference between the original and mean, as well as original and variance images. Resulting images are enhanced than the original image. In [18], Chaira et al. proposed a new technique for medical image enhancement. The technique consists of a Sugeno fuzzy system which uses an intuition-based method for finding membership values. This method is applied on the medical image to convert it into fuzzy image, and then the parameters are optimized using intuitionistic fuzzy entropy. In [19], Zhang et al. mentioned an improved edge detection and image enhancement algorithm which overcomes the shortcomings of algorithms proposed by a previous study for the same. Instead of choosing random threshold parameter value for enhancement, the proposed new method uses OTSU threshold which appropriately chooses the enhancement parameter and can be adjusted according to the requirement. The proposed method simplifies the complex transformation calculation of fuzzy space values and hence improves the performance of the edge detection and image enhancement process. In [20], Wang et al. proposed a new image enhancement algorithm which is an improvement of the Pal–King algorithm. It implements a new membership function which is used to map the image from space domain to fuzzy domain. Nonlinear transformation is then repeatedly applied

on the image for enhancement. Finally, inverse operation is applied to get enhanced gray scale values in spatial domain. In [21], Xian-Jiu et al. analyzed a new image enhancement technique for algae microscopic images. It is based on subdividing the image into low-pass part and high-pass part using filtering, enhancing each segment and combining the segments using fuzzification technique to get enhanced image. In [22], Wu et al. mentioned an algorithm for contrast enhancement and detection of edges of a blurred image. It is presented to extract as much information as possible from a blurred image. Algorithm used for the same is a multilevel fuzzy edge detection algorithm which is computationally fast from other algorithms and uses fuzzy operators for enhancement and edge detection. In [23], Jia et al. proposed a computationally fast and efficient fuzzy-based image enhancement algorithm. It uses a new linear membership function for converting the image from space domain to fuzzy domain. Then, for enhancement, the generalized fuzzy operator is applied. The new method shows improvement over the traditional image enhancement algorithms. In [24], Jinping et al. discussed a new improved fuzzy enhancement and edge detection algorithm which uses a Gaussian function. Gaussian function provides a notable improvement in the image's quality and edge extraction. In [25], Jaya et al. discussed a fuzzy rule for magnifying the image having lower contrast in the transformation domain. On both medical and general images, the test is carried out. The final output is compared with fuzzy INT operator. To assess the visualization quality and contrast of an image SDME, IEM, and EME metrics are properly used. In [26], Saeed et al. proposed an image's contrast magnification using the fuzzy set theory. In this method, the image is magnified by using the fuzzy set. The proposed algorithm is analyzed with all other algorithms. This algorithm is more preferable in terms of speed with respect to other algorithms. In [27], Raju et al. proposed an algorithm by using the fuzzy logic and histogram for magnifying an image. There are two parameters which are used in this method. The first parameter is K which is contrast identifying parameter, and the other one is M which is average intensity parameter. The RGB image is transformed to hue, saturation, and value (HSV) image. The strain is put on V component under the control of M parameter, so that the image can be magnified. In [28], Hanmandlu et al. implemented an image enhancement method by using the fuzzy intensification. In this method, the hue, saturation, and value (HSV) model's saturation and histogram are converted into the domain of fuzzy. The NINT operator is used in this method. The image's intensity specifications and the fuzzifier are assessed by effectively using the entropy and contrast in the domain of the fuzzy. This method is applicable for the images having the lower contrast and lower intensification.

In [29], Alilou et al. discussed a general regression based neural network technique which is used for image restoration and inpainting. In this technique, the missing regions of the image are defined by applying the GRNN to perform regression over the neighbor pixels. The proposed technique was found to be computationally efficient and easy to implement. It was tested on various gray scale and color images. In [30], Chitwong et al. discussed different image enhancement techniques by applying the competitive Hopfield neural network. The precision of clustering is better in simulated image and is shown by competitive Hopfield neural

network. The enhancement's performance is also finer than he fuzzy C-mean in different clusters for an image. In [31], Nieuwenhuis et al. proposed an adaptive filtering concept. It provides a framework to compose aforementioned high-level knowledge and using it to fix the filtering parameters locally. The performance is improved by using binary rotation of data and multiple class principal component analysis (PCA). In [32], Yin et al. discussed an ultrasound image modifying technique by applying the neural network. Mapping is formed by the artificially neural network. To the artificially neural network, a parameter is computed. The fusion of data is done by the fuzzy logic. To filter the sample data, an algorithm of local histogram is used. The algorithm that is proposed in this paper effectively maps with high-resolution image and low-resolution image. In [33], Zhang et al. considered a technique for high resolution by applying Hopfield neural network. In this method, the Hopfield neural network solves the ill-positioning super resolution problem. This method considers both the blurring and noise in an image and creates a great resolution image with no noise. The image produced by this method has best quality in respect of peak signal-to-noise ratio (PSNR). In [34], Pan et al. proposed a method for diagnosing different types of plants by digital images of leaves. In this method, the clear objects are made in the source image by the image enhancement process. After this, the image blocks are apportioned from the source because of different kinds of size and shape of the block of the image. By applying the image analysis tools, the properties like radius, sizes, solidity, eccentricity, and perimeters are calculated using neural network approach. In [35], Singh et al. analyzed an image enhancement technique for screening the luggage. In the neural network, the input is viewability measures and the output is the image enhancement algorithm. The best choice of the image enhancement algorithm is done by the prediction systems. Then, the prediction system and baseline system approach are compared. In [36], Ma et al. mentioned an algorithm for enhancing the image by using the pulse-coupled neural network and rough set. Firstly, the noise of the image is detected using pulse-coupled neural network time matrix and divides the image in three parts of image based on the noise features and intensity features. After this, denoise the image by applying filter method. At last, enhance the different parts of image by applying the various methods. This proposed algorithm shows better results for the image in the darker regions, and noise is also decreased. In [37], Rao et al. discussed the different types of image enhancement techniques. The good results are shown by the classical spatial filters, and there is very little complexity for computation. A multilayer self-organizing neural network with error back propagation depends on descent gradient is compared. A grand requirement of computations is required because of the adjustment of weights in every layer. In each iteration, the error is negligible. The computation speed of cellular neural network is very high when it's related to neural network. In [38], Weixin et al. implemented a X-ray image enhancement technique by using the Hopfield neural network. In this method, by using a suitable energy function, the image enhancement problem is converted to the optimizing problem. The procedure of normalization is not used in this method because the function for evaluating the quality is used for optimizing the image. In [39], Varghahan et al. discussed a technique for

enhancing the handwritten data by applying the neural network and threshold technic*al*. In this paper, various filtering techniques are discussed. For cleansing the image and reducing the noise, artificial neural network (ANN) showed the best result. Cleansing image result along with threshold technical is used for the training of the multilayer perceptron network.

In [40], Shanmugavadivu et al. discussed a contrast enhancement technique using the basic concept of histogram equalization. In this proposed technique, the image histogram is first divided into two parts using Otsu's threshold. After that, a set of optimized weighing constraints, which are formulated using particle swarm optimization (PSO), are applied over the two parts. The two parts are then equalized independently and then are combined to produce a contrast enhanced and brightness preserved image. In [41], Draa et al. implemented a meta-heuristic search technique named artificial bee colony (ABC) algorithm for image enhancement. In this, old gray levels of the input image are replaced by new enhanced gray levels. These new gray levels are searched for using the ABC algorithm. It is then compared with traditional image enhancement approaches as well as GA and is found to be better almost all of them. In [42], Gorai et al. discussed a particle swarm optimization (PSO)-based image enhancement technique. PSO depends on objective function optimized the parameters. The local information and global information of an input image are used by the intensity transformation function. To measure the quality of an image, the edge information and entropy are acknowledged by the objective function. With the help of scaling, the enhanced image is achieved. In [43], Benala et al. proposed an ABC optimizing algorithm for magnifying the image. This algorithm provides excellent magnitudes for an image. It is better than GA. The chance of dropping into local optimum is less in ABC algorithm. The main goal of this algorithm is to advance the local search ability of GA by maintaining the global search ability. In [44], Hanumantharaju et al. discussed a technique for magnifying an image by applying the particle swarm optimization. The algorithm uses criteria based on the information of edge and entropy of the image. By using this method, the specifications of the multiscale retinex like number of scales, Gaussian surround space constants, etc., are optimized. Their proposed algorithm resulted better image enhancement as compared to existing algorithms like histogram equalization, filtering, etc.

In [45], Zhou et al. explored a fuzzy-based image enhancement algorithm whose parameters are optimized using GA. In the proposed technique, firstly image is transformed from spatial domain to fuzzy domain. Then, membership function is optimized using GA and applied on the fuzzy image. Finally, image is converted back to space domain using de-fuzzification and enhanced image is obtained. Further, enhancement can be done by applying the same process again. In [46], Zhang et al. discussed a satellite cloud enhancing technique. In this method, the nonlinear transform parameters are adjusted to modify satellite cloud images. This method gives a reference for location of center and the prediction of the typhoon's intensity. In [47], Hoseini et al. considered a new hybrid technique for image enhancement. It combines the evolutionary techniques of GA, ant colony optimization (ACO), and simulated annealing (SA). Improvement is done on the fitness

Table 3 Various techniques Identified

Technique identified	Study ID
Genetic algorithm	[3–10]
Fuzzy-based enhancement	[11–28]
Neural network-based enhancement	[29–39]
Optimization algorithms	[40–44]
Hybrid approach	[45–47]

function of GA, whereas the ACO and SA techniques remain same. The combined algorithm is then compared with other traditional image enhancement techniques like linear contrast stretching, histogram equalization, fuzzy, etc. and is found to be better.

After reviewing all these 45 research papers, we have identified mainly five soft computing techniques as mentioned in Table 3 along with paper ID.

4 Conclusions

Research questions RQ1, RQ2, and RQ3 taken in Sect. 1 for systematic review are put forward in Table 1 and resolved after doing the analysis of papers in Sect. 3.

Answer to RQ1: various soft computing approaches used in this paper for image enhancement are GA, fuzzy-based enhancement, neural networks, and various optimization techniques like ABC, ACO, PSO, and hybrid approaches.

Answer to RQ2: the traditional algorithms used for image enhancement like histogram equalization, wavelet transform-based enhancement, contrast adjustment, etc., are compared with the enhancement techniques based on soft computing approaches. It is found after analyzing various papers that the soft computing approach is better than the traditional approaches since performance is better, which is shown in various papers. Better image enhancement results may be achieved using hybrid soft computing approaches, meta-heuristic approaches.

Answer to RQ3: strengths of existing image enhancement techniques

1. They can be used for linear stretching and visual perception when image has close contrast data.
2. They remove noise from the images and provide sharp image by applying local enhancement.
3. Histogram equalization is the most popular enhancement technique which calculates intensity of pixels and uses them for enhancement.

Weaknesses of existing image enhancement techniques

1. Existing image enhancement algorithms are very computation intensive and require a large amount of memory to store the intermediate data.

2. Algorithms are quite complex to understand and implement.
3. Very few techniques are practically used for image enhancement which leaves a large scope for new enhancement techniques.

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A Systematic Review on Scheduling Public Transport Using IoT as Tool



Dharti Patel, Zunnun Narmawala, Sudeep Tanwar and Pradeep Kumar Singh

Abstract Public transport can play an important role in reducing usage of private vehicles by individuals which can, in turn, reduce traffic congestion, pollution, and usage of fossil fuel. But, for that public transport needs to be reliable. People should not have to wait for the bus for a long time without having any idea when the bus will come. Further, people should get a seat in the bus. To ensure this, efficiently and accurately scheduling and provisioning of buses is of paramount importance. In fact, nowadays buses are scheduled as per the need. But these scheduling is being done manually in India. Our survey shows that there are many algorithms proposed in the literature for scheduling and provisioning of buses. There is a need to tailor these algorithms for Indian scenario. We present a brief overview of these algorithms in this paper. We also identify open issues which need to be addressed.

Keywords Scheduling · Provisioning · Public transport · IoT

1 Introduction

With an increase in population, the demand for public transport service also increases. This situation pushes the public transport infrastructure to its limits in peak hours. This has lead to the late arrivals of public transport at their scheduled

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stops, inefficient use of resources, and a decrease in operating cost. And again this situation leads to switching of other modes of transportation by people which is undesirable. The traditional scheduling operation in India is not efficient for large-scale running routes [1]; i.e., public transport still lags behind in India. The intelligent public transportation scheduling becomes the main research area. Hence, by using the emerging technologies, public transportation can be scheduled in an optimized way to meet the public demand. Hence, to provide the better transportation services, the scheduling algorithms have been proposed which focuses on the many factors such as a number of passengers, the capacity of buses, waiting time of passengers, arrival time, and departure time. The best scheduling algorithm is one which leads to the decrease in waiting time of passengers while maintaining the capacity of the passengers in public transport. Hence, IoT is the most emerging technology which has been used by public transport services.

As per the survey of researchers, it has been concluded that all the present systems which are based on transportation system provide the service of either reservation or displays bus status. In transportation system, it is also important to maintain the schedule of buses. But due to traffic and many more parameters, schedules get disturbed. Usually, passengers have to wait for the buses because of bad scheduling, overcrowding, traffic congestion, and breakdowns. Overcrowding occurs because of not determining the correct frequency for demand and improper scheduling. Frequency relates to the number of trips which are needed to cope up with the passenger demand during a peak or fixed period. Hence, it is important to have exact traffic information to notify the exact arrival and departure timings of buses. This information can be available by using GPS [2]. Along with these, it is also important to schedule buses according to the requirements of the public. The solution is to develop efficient scheduling algorithm which can schedule the buses automatically by analyzing the historical data.

There are many scheduling algorithms available such as priority, round robin, first come first serve, last come first serve, and much more. But these algorithms are developed for operating systems. Algorithms like genetic algorithm [3], greedy randomized adaptive search procedure (GRASP) [4], trip frequency scheduling, and vehicle routing problem are such scheduling algorithms which either schedule the vehicles or finds proper routes for buses. These algorithms have the drawback in terms of a number of jobs or vehicles. There is a need of scheduling algorithm which can schedule buses as per the requirement of passengers on proper time and proper routes. Some algorithms use heuristics to calculate the parameters and schedule it accordingly. But these heuristics require same number of jobs with the same number of resources. Hence, if we use these algorithms for scheduling of buses, it will require the same number of buses with the same number of routes. It becomes compulsory to have the same number of parameters. Hence, it is necessary to develop such algorithm which can even schedule one bus. We can use assignment problem to assign buses for required route with heuristics to schedule the buses as per the requirement and reschedule the buses which are not required for that particular route.



Fig. 1 A future scenario of public transport

Figure 1 shows the present scenario of the public transportation system which uses RFID tags to track the public transport to have live data about the stops covered by the buses. It also uses GSM/GPRS to notify the passengers about the current status of buses. Servers are used from which data are fetched to notify the passengers. In more general, this system shows the school bus which is tracked using RFID tags and GSM/GPRS, and its status is notified to the parents so that their waiting time at the stops decreases waiting unnecessarily at stops.

According to the Planning Commission (2013) [5] survey, it has been concluded that there is an increase in traffic of public transport as people refer it much for traveling. According to the survey, people prefer railways and roadways increasingly and it is expected to grow up to 11 percent and 7 percent per year, respectively. By this, it is expected that traffic could increase up to 16 factors by next 20 years. Since it was about 7 to 8 factors in last 10 years, it is growing very fast. Hence, this proves the need for public transport which should be scheduled according to the need. Figure 2 shows an increase in traffic in roadways and railways in billion passenger kilometer (bpkm).

1.1 Contribution of This Paper

The main contribution of this paper is as follows:

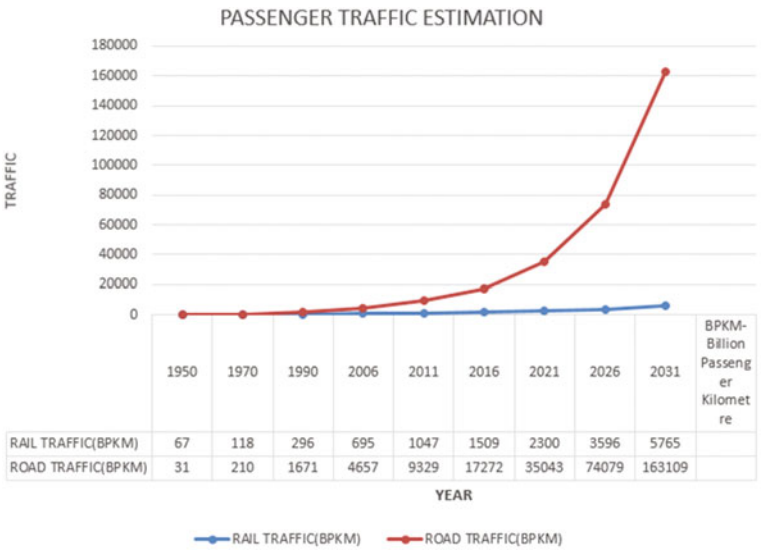

Fig. 2 Passenger traffic estimation

- A complete taxonomy of public transport, which can be further classified into general and selective approach, is provided using IoT as a tool.
- Approaches used for scheduling public transport are analyzed with respect to parameters, such as positioning, time.
- Finally, a systematic comparison of the various public transport system with pros and cons of each is provided in the text.

1.2 Organization

Rest of the paper is organized as follows. Section 2 presents the similar work done by various researchers in this domain with tabular comparison of each approach. Section 3 provides the challenges and open research problems in this domain, and finally, Sect. 4 concludes the article with future scope.

2 Literature Survey

This section provides the detailed description of the work done under this domain by various researchers. We have divided this description into two categories: generalized and selective. Next subsection explains each category in detail with pros and cons of each.

2.1 Generalized Approach

Since last few years, research has been carried out to develop the optimization models which will increase the convenience of passengers, and on the bus management side, bus operations are reduced. Depending on the approach for determining optimal solutions, the bus scheduling models studied so far can be classified into a number of types. These models use heuristics to calculate total traffic cost.

Fu et al. [6] proposed a new operating strategy in which service vehicles is followed by the lead vehicle with all stop service and also by providing the facility to skip some stops as an express service. Chen [7] measures bus service reliability, vehicle load capacity, by considering the headway adherence and average waiting time. Yan proposed a network flow problem using a mathematical model which uses Lagrangian relaxation. Kim et al. [8] constructed a schedule based on the starting point and stops by using travel time response model for critical scheduling areas.

2.2 Selective Approach

Vehicle Routing Problem In vehicle routing problem with time window, a number of vehicles are allocated to route and each with given capacity which is located at a single depot which is serving passengers dispersed geographically. In this problem, each passenger has been given the demand and they must be served in specific time window. The main objective of this problem is to minimize the total cost of traveling while serving the customers with minimum cost. Figure 3 shows the vehicle routing problem (VRP), and how a route is set up from base depot to each stop reducing the traveling cost. It reduces the path cost by setting the optimized route between stops from one station to other from depot. The main objective of VRP is as follows:

1. It minimizes the global transportation cost based on global distance.
2. Minimizes the number of resources needed to serve all customers.
3. Variation in travel time and vehicle load is least.

Online Dial-A-Ride Problem with Time Window (DARPTW) Routing and scheduling of buses can be referred as a On-line-Dial-A-Ride problem [7]. It takes care of the available set of resources and constraints. All the services related to the transportation is Web-based and handled by mobile phones. Here, request is generated one day prior to the beginning of service. Due to a high number of variables involved in it, the solutions available are based on heuristics. In the Online Dial-A-Ride Problem with time windows (ODARPTW) [9] requests are exhibited

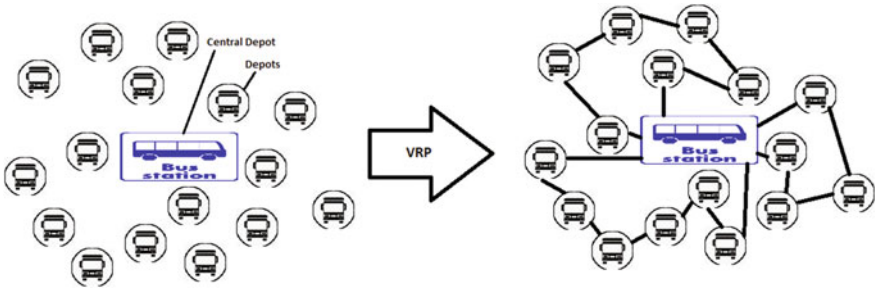

Fig. 3 Vehicle routing problem

after some time, requiring the server to convey the articles from sources to destination, while the server is en-route for serving the different request. On the off chance that a demand is to be served, the server must achieve the time between the demand's landing and its due date. The objective here is to plan techniques for the server to fill in whatever number of approaching requests as could reasonably be expected by their due dates in an on-line way. The system for ODARPTW neither has data about the discharge time of the last demand nor has the aggregate number of request. It must decide the conduct of the server at a specific minute of time as an element of the considerable number of request discharged up to time t (and the present time t). Interestingly, a disconnected technique has data about all requests in the entire succession as of now at time 0.

Assignment algorithm is operation research method to optimize the cost. It deals with the transportation problem and the assignment of jobs to the workers or assignment of resources to the workers. The ultimate objective is how to assign the jobs efficiently to the workers, and which worker should be assigned which type of job. In this problem, at least 3×3 matrix is required and also the same number of parameters. Assignment problem uses heuristics, in which the operating cost of the system can be maximized or minimized. If we are adding any constant in each and every element of columns and rows of the matrix, then it will generate a matrix, which can minimize the total effectiveness. A situation also exists, where we need to add a dummy column or a row when there are no exact number of resources, and jobs. The main disadvantage of this algorithm is a number of jobs must be equal to the number of workers or else allocation of jobs will not be efficient.

The data flow diagram of assignment algorithm is discussed below in Fig. 4. This diagram shows how assignment algorithm works with its two conditions. In assignment problem, basically there are two situations: First, when the number of cutting lines is equal to the number of rows and columns, and second, when the number of cutting lines is not equal to the number of rows and columns.

Fig. 4 Assignment algorithm

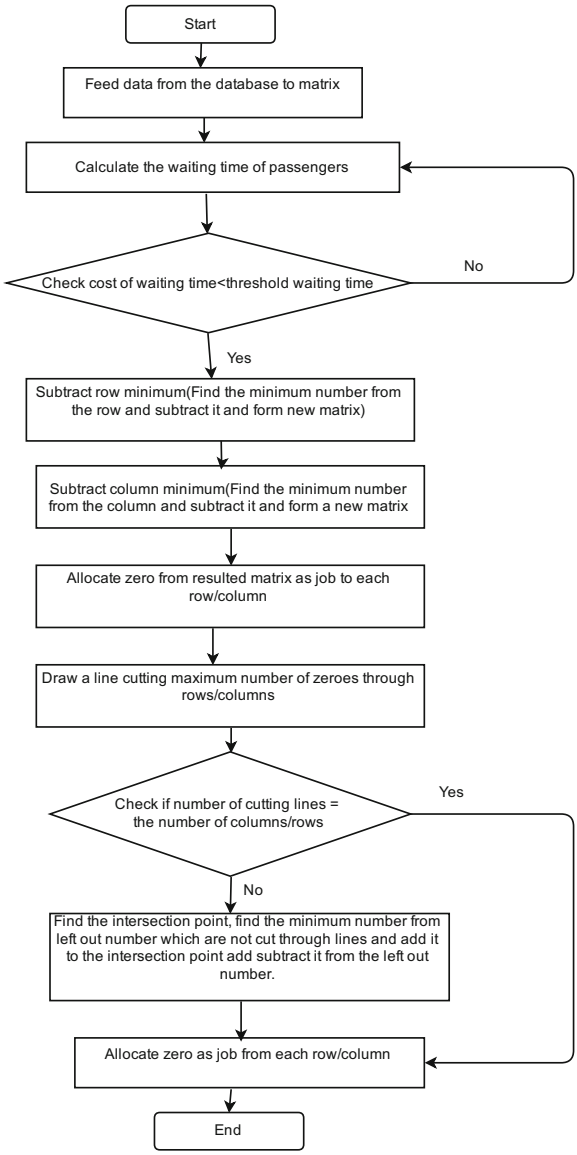

Table 1 represents the summary of the whole survey. In the table, there are four columns. The first column is the name of author, second is the algorithm/method they have used for implementation, third is what are the pros of paper, and the fourth one is what can be added/improved or cons in paper.

Table 1 Comparative summary of all existing approaches

Authors	Methodology	Pros	Cons
Nagadapally et al. [10]	GPS tracking is merged with mobile application to get the exact location of the bus on the map by reducing the waiting time of passengers	Displays the exact bus location	In situation there is lack of data in mobile, this system would not give an accurate result and it works only for selected versions of android and iOS
Asaad Abdul et al.	Developed a Web-based system, which allows passengers to check the availability of tickets with cheap prices.	Allowed passenger to choose their own seats and payment gateway	The passengers must be registered for searching and reservation
Sarma et al. [11]	Developed an algorithm, which predicts the bus arrival time by using existing GPS system	Determines the traffic at routes and also the seat availability	User receive the SMS using USSD technique and such messages cannot be saved so user does not have any other backup
Menon et al. [12]	System used sensors at entry and exit point to calculate the vacant seats of the bus	Used IoT to predict real-time traffic at routes	Cost of system increase installation of costly IoT-enabled components
Lau et al. [13]	System source and destinations timings were fixed to feed them with their order from depot	Source and destination timings are fixed to feed them with their order from depot so it returns an optimized solution which serves as many customers as possible	Restricted number of vehicle is used.
Guy et al. [14]	Heuristics approach used to minimize the cost of the system	Objective function was developed, which minimizes the cost of the system	How to order the nodes is the main problem of this system
Sulaima Le bbe [15]	GPS technology was used with RFID	This system provides data for future forecasting, congestion identification, travel route planning, and modeling	System is handled manually
Singh [16]	Focused on how assignment is done using different methods	Methods are used to optimize the cost of system	Some methods lack in optimization due to improper assignment

(continued)

Table 1 (continued)

Authors	Methodology	Pros	Cons
Olarthichachart et al. [17]	Used to find optimal trip frequency	Reduces cost of operation passenger service quality by efficient scheduling	Applicable to finite set only
Sulaima et al. [18]	Used wireless sensor networks to provide visual information for real-time system	Gives real-time information about the buses using GPS/GSM and Arduino	Only registered passengers can have real-time information

3 Challenges and Open Research Problems in Scheduling Public Transport

In existing public transportation systems, passengers need to register compulsory for traveling. Scheduling of transportation service is limited for the limited resources. Scheduling of public transport is not much efficient as it requires accurate data on traffic. Due to this, the waiting time of passengers increases. Passengers used to travel in public transport mostly in peak hours. Therefore, in peak hours due to nonexistence scheduling mechanism, passengers increase beyond the capacity of public transport. As capacity of public transport increases, the counting of passengers in the existing system is not efficient. Waiting time of passengers increases at stops in peak hours that is in morning and evening which increases traffic in buses. Hence, there is a need to develop an efficient and accurate system for scheduling and provisioning of buses dynamically based on current demand.

Public transport should provide safe traveling, cheap fare, and less travel time. In order to achieve these attributes, govt must focus on road network, optimal routing, and minimum delay. Public transport efficiency depends upon all other related factors, i.e. optimization of route, transfer optimization, and coordination among feeder bus service.

4 Conclusion and Future Scope

In India, traffic congestion problem is increasing day by day in urban centers. It is because of increase in population in urban areas with very high rate, and people prefer private vehicles over public transport, as they need to wait for a long amount of time to get a bus and often buses are crowded too. Hence, it is important to develop an efficient scheduling and provisioning of public transports so that waiting time of travelers reduces and everyone gets seat in the bus. Many algorithms have been proposed by various researchers as discussed in Sect. 2. These proposals do have their drawbacks as highlighted in Table 1. We need to improve these algorithms in terms of scheduling and provisioning of public transport for Indian scenario.

In future, we can develop a system which can allow seat reservation in real time. Sensors can be used to track seat occupancy and allow reservation for unoccupied seats.

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Automated Optical Disc Segmentation and Blood Vessel Extraction for Fundus Images Using Ophthalmic Image Processing

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Abstract. Diabetic Retinopathy that is characterised by the progressive deterioration in retinal blood vessels is considered the root cause of severe vision loss in diabetic patients. This situation can be reduced upto much extent by regular screening and diagnosis. Precise automatic segmentation of optical disc and automated blood vessel extraction results in effective diagnosis of diabetic retinopathy reducing the chances of vision loss. A considerable progress has been made by various researchers towards automating the ophthalmic image processing via computer aided screening but maintaining the image quality as that of the original fundus image is still a challenge. In this paper, authors have evaluated Optical Disc Segmentation methods based on thresholding, region growing algorithm and mathematical morphology for effective removal of optical disc to facilitate blood vessel extraction. A new blood vessel extraction technique using Mathematical Morphology and Fuzzy Algorithm is proposed for precise blood vessel extraction. Two open access standard fundus image databases, DRIVE and STARE were exploited for performance evaluation of the proposed approach. This approach is effective in identifying optical disc to extract the blood vessels near the optical disc area which plays an important role in early diagnosis of diabetic retinopathy.

Keywords: Diabetic retinopathy · Ophthalmic image processing
Computer aided screening · Optical disc segmentation · Blood vessel extraction

1 Introduction

Diabetic Retinopathy (DR) is characterised by long term accumulated damage to the retina occurring due to diabetes mellitus which are marked by the appearance of different lesions like microaneurysms, exudates, haemorrhages, neovascularisation, etc. DR is considered as the major cause of vision loss in most of the diabetic patients and it occurs due to the change in retinal blood vessels which may swell and leak out fluid into the retinal area. These blood vessels may close off completely arresting the oxygen supply to the retina. The other major cause of DR is blood vessel overgrowth leading to bifurcated blood vessel pattern. The newly grown blood vessels are weak and fragile and may leak out blood and fluid into the retinal areas [1]. Broad classification of DR

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falls into two categories Non-Proliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetic Retinopathy (PDR) [2]. The two main structures used for fundus image analysis are optical disc and blood vessels. Optical disc (OD) is the brightest part and it usually appears bright yellowish circular or oval shaped region appearing in the fundus photography. Blood vessels originate from the centre of the optical disc and they are responsible for supplying nutrition to the eye [3]. Segmentation and removal of OD is essential step in image processing for automated detection of DR lesions as inaccurate removal of OD may hamper the detection of bright lesions like EXs leading to misclassification. Since blood vessels appear as dark elongated structures in fundus photography, imprecise detection of blood vessels may impede the detection of dark lesions like MAs and HEMs [4].

Various researchers have contributed to the remarkable improvement in the screening and diagnosis methods by automated optical disc segmentation and blood vessel extraction. In [5], a novel approach based on histogram matching for optical disc segmentation was proposed. In this method, some of the fundus images from the dataset were used to create the template and then the average of histograms for each color component was calculated to localize the centre of the optical disc. Correlation between each of the R, G, B components of the original image and template is also computed and the point which has the maximum correlation value is selected as the centre of optic disc. Authors in [6] proposed an Automated Diabetic Retinopathy Detection System to process the fundus images so that they have similar quality as that of angiogram to obtain better clarity of lesions. Segmentation of optical disc is done employing speed up robust features and blood vessel extraction is done using morphological image processing operations. Authors in [7] employed clustering approach with a novel correction procedure and vessel transform for automatic optical disc detection. To detect the boundaries of the optical disc, the proposed algorithm is integrated with scale space analysis. The work presented in [8] employed High Resolution Fundus image database (HRF database) and for the enhancement of optical disc, histogram equalization function is applied on green channel of fundus image. For OD segmentation speed up robust features function is exploited and the evaluation of results is done using Receiver Operating Characteristics curve (ROC curve). The method proposed in [9] is a modification of vessel transform by using vessel vector-based phase portrait analysis (VVPPA) and a hybrid between VVPPA and a clustering method used in vessel transform. Exceptional performance was achieved in [10] for blood vessels and optic disc segmentation in retinal images by employing the extraction of the retina vascular tree using graph cut technique. Markov random field (MRF) image reconstruction method is utilised for optic disc segmentation by removing vessels from optical disc region. In [11] extraction of retinal vascular tree is done using graph cut method and this blood vessel information is utilized to identify the approximate position of optical disc which is further fed to ANN classifier. Authors in [12] used various image processing techniques like adaptive histogram equalization and image filtering. Optical disc and the blood vessels are detected and removed using morphological operations and employing Otsu thresholding algorithm for better results. Study implemented in [13] utilises adaptive histogram equalization based preprocessing technique and robust distance transform is used for blood vessel segmentation. After reviewing all these articles it was revealed that inadequate illumination of

fundus images and their poor quality leads to inability to analyse them after applying image processing techniques. Therefore, image pre-processing methods plays a major role to improve contrast and illumination for further image analysis steps for OD segmentation, OD removal and extraction of blood vessels. The color and intensity properties of MAs are similar to those of blood vessels due to which most of the methods listed in the literature misses the MAs adjacent to blood vessels and some MAs that are too small or blurred to be seen with the naked eyes. Thus the authors in this research work came up with a solution for optical disc segmentation and blood vessel extraction to facilitate the ophthalmologists for effective diagnosis of eye related diseases using fundus image analysis. In this paper, authors have implemented and critically analysed different OD segmentation methods and proposed a Mathematical Morphology based Fuzzy Algorithm for efficient extraction of blood vessels. Fundus images are obtained from standard publically available DRIVE and STARE databases. The RGB images are converted to green channel as only this channel has maximum intensity out of all the R, G and B channels. Further, histogram equalization is performed to enhance image quality followed by optical disc segmentation of equalized image and blood vessel extraction is done using the proposed approach. Various performance metrics were evaluated to validate the proposed method. Rest of this article is organized as: Sect. 2 comprises of Materials and methods presenting the proposed algorithms for optical disc segmentation. Experimental results comparing different OD detection methods are discussed in Sect. 3 followed by conclusion and future work in Sect. 4.

2 Materials and Methods

2.1 Fundus Image Databases

This research work utilizes two of the publically available standard databases for fundus image analysis. Some of the fundus image databases referred in the literature are as follows; DRIVE [14], STARE [15], DIARETDB0 [16], DIARETDB1 [17], MESSIDOR [18]. The detailed explanation of different databases is given Table 1. These databases are beneficial for image testing, blood vessels extraction, segmentation [19], feature extraction [20] and classification [21] for DR screening and detection.

Out of all the databases discussed in the table above, DRIVE and STARE databases are commonly used databases for fundus image analysis. To generalize our research work, the proposed algorithm was implemented on images obtained from DRIVE and STARE databases and experiments are performed on these databases.

2.2 Different OD Segmentation Techniques

Thresholding: Thresholding is the most common segmentation method and it is used in many of the applications due to its simplicity of implementation and computation speed. Thresholding is used in such applications where the image can be divided into two groups; the main object and the background depending upon the pixel intensity values. Let us consider an image $f(x, y)$, which is composed of a light object on a dark

Table 1. Description of publically available databases for fundus images

Sr. no.	Fundus image database	Field of view (FOV)	Image resolution	Database description
1.	DRIVE [14]	45°	768 × 584	20 color testing images and 20 color training images with extracted blood vessels.
2.	STARE [15]	35°	605 × 700	400 images with masked and extracted blood vessels.
3.	DIARETDB0 [16]	50° FOV with varying imaging settings	1500 × 1152, 1936 × 1296	130 color fundus images of which 20 are normal and 110 contain signs of the diabetic retinopathy.
4.	DIARETDB1 [17]	50° FOV with varying imaging settings	1500 × 1152, 1936 × 1296	89 color images out of which 84 images contains the sign of non-proliferative DR and remaining 5 are normal fundus images containing no sign of DR.
5.	MESSIDOR [18]	45° FOV	1440 × 960, 2240 × 1488, 2304 × 1536	1200 colored fundus images, out of which 800 images are acquired with pupil dilation and 400 without dilation.

background such that all of the image pixels are distributed into two dominant modes of the dynamic range of pixels. Then select a threshold value based on the intensity variation of foreground and background objects to exactly separate these two modes and extract the object from the background [22, 23]. The algorithm used for thresholding is explained in the following section.

Algorithm 1

Input: Image f (x,y)
Output: Segmented image after extracting the optical disc

BEGIN
Step 1: Take the input image and convert the RGB image into gray scale image.
Step 2: As OD is the brightest part in the fundus image, select a threshold value to extract the brightest object from the image and rest is considered as the background.
Step 3: At any point *(x,y)* in the image at which $f(x,y) > T$ is considered an object point and otherwise the point is considered as background.
Step 4: The optical disc segmented part *g (x,y)* is given by

$$g(x,y) = \begin{cases} 255\ (White) & if\ f(x,y) > T \\ 0\ (Black) & if\ f(x,y) \leq T \end{cases}$$

Step 5: Fundus image after extracting the optical disc is obtained by subtracting the segmented part from the original gray scale image.
END

Region Growing: This procedure groups pixels or small sub-regions into larger regions based on some predefined criteria for growth. It involves the selection of initial seed point and then growing the regions by appending those neighbouring pixels to the seed point having similar properties to those of the seed point. The properties upon which the similarity is calculated may be a specific range of intensity or color. The region growing in this technique depends upon the homogeneous neighbouring pixels around the seed. The selection of similarity criteria depends upon the image type of the data available and also on the problem under consideration.

Algorithm 2

Input: Original Image f (x,y)

Output: Segmented image after extracting the optical disc

BEGIN

Step 1: input image and convert the RGB image into grayscale image.
Step 2: Calculate the centre of the optical disc and take that point as the initial seed point *S (x,y)* array containing 1's at the location of the seed point and 0's elsewhere.
Step 3: All the connecting pixels in the neighbourhood of *S (x,y)* fulfilling the similarity criteria are eroded to one pixel and labelled as 1 and all other pixels in S are labelled as 0.
Step 4: Set a threshold value as the absolute difference between the seed and the pixels at *(x,y).* This threshold is considered as the stopping criteria that give the difference in the intensity values differentiating a darker and a brighter region.
END

Mathematical Morphology (MM): Morphology is an image processing tool that is particularly suitable for extracting and analyzing region shapes like boundaries, skeletons, etc. in images. For morphological operations, a structuring element is used that is a small subset or a sub image used to investigate the image under study to determine the properties of interest. Green channel image is complemented followed by adaptive histogram equalization to apply morphological operations. Morphological opening function is used and the morphologically opened image is subtracted from the histogram equalized image to obtain optical disc segmented image.

2.3 Proposed Methodology

This research work anticipates the importance of OD segmentation and blood vessel extraction in the diagnosis and computer aided screening of fundus images. The fundus images obtained from the databases lack clarity due to poor contrast as they are under illuminated and these images also have larger dimensions which increase the system complexity. These artefacts are removed from the image by using image pre-processing techniques.

Figure 1. gives the block diagram of proposed approach for this research work. Fundus images are collected from fundus image databases [14, 15] and are pre-processed utilizing steps like intensity conversion, image denoising and image contrast

enhancement. The various Optical disc segmentation algorithms were implemented on fundus images taken from DRIVE and STARE databases. The centroid of the image is determined followed by detection of optical disc boundaries using morphological operations for optical disc segmentation and removal. After critical analysis of all these OD segmentation techniques, authors proposed a Mathematical Morphology based Fuzzy Algorithm approach for optical disc removal. Various performance metrics are evaluated to validate the proposed method. The algorithm for the proposed approach is depicted in the flowchart shown in Fig. 2.

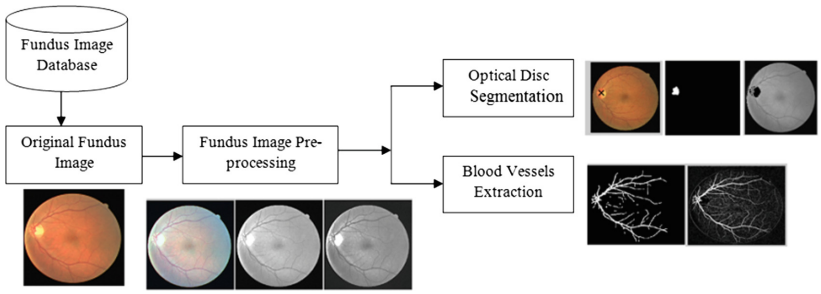

Fig. 1. Block diagram for the proposed approach

2.4 Performance Evaluation Metrics

For this research work various performance metrics are also incorporates to validate the result of the proposed approach and it was found that fuzzy approach when combined with MM approach gives better results in terms of Structural Similarity Index (SSIM), Root Mean Square Error (RMSE), Peak Signal to Noise Ratio (PSNR) and run time elapsed when the extracted blood vessels are compared with the ground truth images.

3 Results and Discussion

3.1 Experiment 1

DRIVE database [14] is considered for this experiment to investigate and analyze the effectiveness of all the algorithms explained in the Sect. 2.2. All the experiments are performed using MATLAB2013 software and a tabular comparison is also presented to investigate parameters of ground truth blood vessel images and extracted blood vessels for better quality assessment. In this experiment the OD segmentation using thresholding function is investigated and is shown in Fig. 3. The figure depicts the original image, grayscale converted image, segmented part of optical disc along with the output fundus image after removing the OD. The drawback of this approach lies in setting a new threshold value every time for a new fundus image to be processed. A constant threshold value does not work for this segmentation approach as the intensity of OD is not same for all the fundus images.

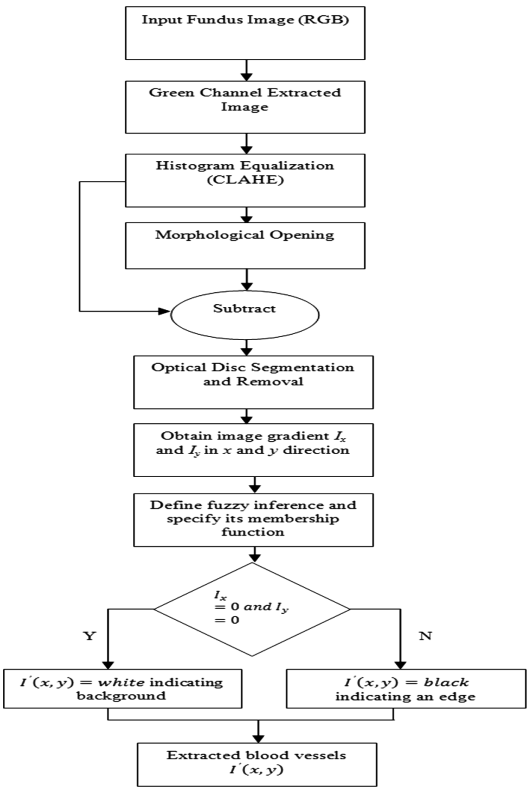

Fig. 2. Flowchart of proposed approach for OD segmentation and blood vessel extraction

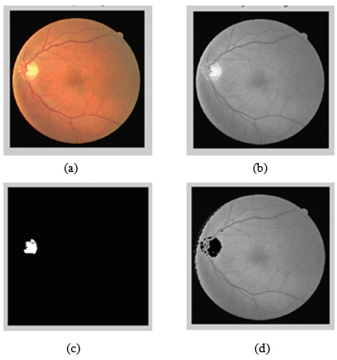

Fig. 3. Optical disc segmentation using thresholding function (a) Input fundus image from DRIVE database, (b) grayscale converted image, (c) segmented part using thresholding and (d) output fundus image after OD segmentation

Region growing process is initiated through a seed point. Selection of seed point is the important criteria for region growing process and is an open challenge. Centre of optical disc is obtained and this point is considered as the seed point for region growing process. After selecting an initial seed point, regions are grown by appending to each seed those neighboring pixels those having the properties similar to the seed point. The absolute intensity difference between the seed point and pixel at point *(x, y)* to stop growing the region is set as stopping criterion. Figure 4. depicts the results obtained by OD Removal using Region Growing algorithm. Segmentation is done using Region growing process and the segmented part is shown along with the output fundus image.

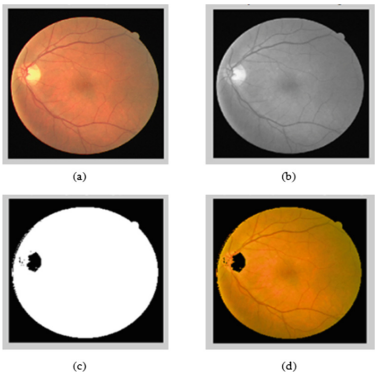

Fig. 4. optical disc removal using region growing approach (a) Input fundus image from DRIVE database, (b) grayscale converted image, (c) segmentation using region growing process and (d) output fundus image after OD segmentation using region growing

The results of Optical Disc elimination done using the MM approach are given in Fig. 5. Figure consists of the original fundus image depicted in Fig. 5(a), green channel is extracted as it is the maximum intensity channel and shown in Fig. 5(b). Segmented part of OD is shown in Fig. 5(c) and the output fundus image after OD segmentation is shown in Fig. 5(d).

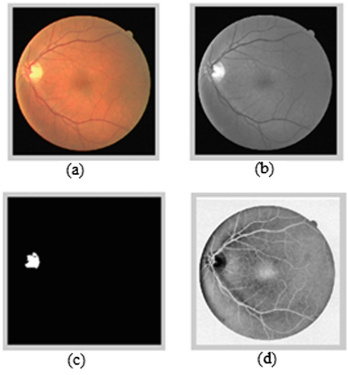

Fig. 5. Optical disc elimination using mathematical morphology approach

3.2 Experiment 2

Structured Analysis of Retina (STARE) consists of 20 fundus images captured by TopCon TRV-50 fundus camera with 35 degrees of FOV. Each image is digitized to 605 × 700 pixels with 24 bits per pixel resolution. Ground truth vessel segmentation was created for all the twenty images which are labelled manually by the professional expert [15]. Thresholding method for OD segmentation was investigated and it is shown in Fig. 6. Figure 6 depicts the original image, grayscale image, segmented part along with the output fundus image after removing the optical disc. It can be seen that for STARE database thresholding function segments all other parts also in the fundus image having similar intensity as optical disc. Thus this technique does not perform better for STARE database.

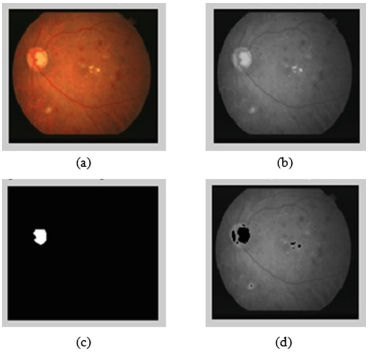

Fig. 6. Optical disc segmentation using thresholding function (a) Input fundus image from STARE database, (b) grayscale converted image, (c) segmented part using thresholding and (d) output fundus image after OD segmentation

Figure 7. gives the output of Region based Growing Segmentation method. It is the visualization of original image along with the output image of optical disc after applying Region Growing Algorithm.

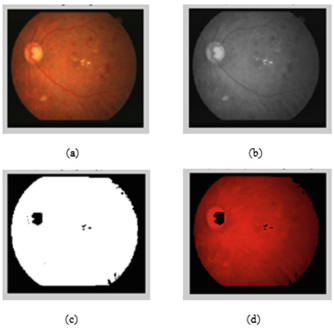

Fig. 7. Optical disc removal using region growing approach (a) Input fundus image from STARE database, (b) grayscale converted image, (c) segmentation using region growing process and (d) output fundus image after OD segmentation using region growing

Optical disc elimination done using MM approach is shown in Fig. 8. It consists of the original fundus image and green channel extracted image in Fig. 8(*a*) and (*b*). Segmented part is shown in Fig. 8(*c*) and the output fundus image after OD segmentation is shown in Fig. 8(*d*). It is clear from the visualization of results obtained from evaluating both DRIVE and STARE databases that MM yields better quality blood vessels after OD removal as compared to the other mentioned two techniques; Thresholding and Region Growing.

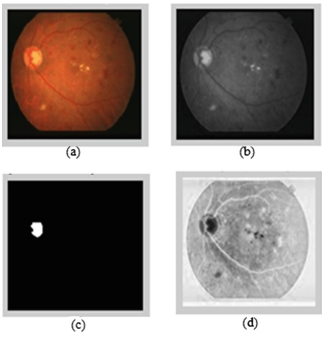

Fig. 8. Optical disc elimination and blood vessel extraction using MM approach

3.3 Extraction of Blood Vessels

After evaluating the optical disc segmentation results using all the approaches, it was revealed that MM approach gives the best results. Fuzzy algorithm is applied on output blood vessels obtained using MM algorithm. The results after applying fuzzy approach are shown in Fig. 9.

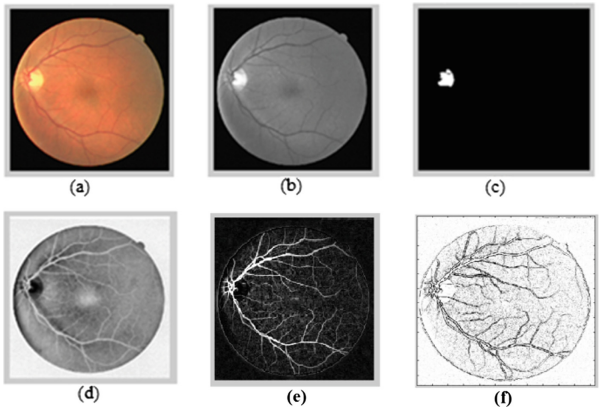

Fig. 9. Blood vessel extraction using proposed approach for DRIVE database image (a) Input fundus image from DRIVE database, (b) green channel converted image, (c) segmented region, (d) CLAHE converted image, (e) blood vessels after OD segmentation and (f) output of blood vessel extraction after applying fuzzy approach

It is seen that proposed approach yields better results for optical disc elimination and also blood vessels are better extracted using this method. Performance assessment of the proposed approach for optical disc elimination and blood vessel extraction is done in Table 2. Area in pixels for the extracted optical disc was calculated. The ground truth of blood vessels were available in the DRIVE database, thus on comparing the extracted blood vessels with the ground truth blood vessels labeled by hand, metrics like RMSE, PSNR, SSIM and run time elapsed are calculated. The range of SSIM is in between 0 to 1 and it is a similarity based parameter providing the statistical similarity information about extracted blood vessels and ground truth blood vessels. RMSE and PSNR are pixel intensity based parameters and they are also exploited in this research work to analyze the image quality of extracted blood vessels. Performance assessment of all the images taken from DRIVE database is done but the results for 10 images are reported in this paper. The ground truth images for original hand labeled images are missing for STARE database therefore the performance evaluation is done only for DRIVE database.

Table 2. Performance assessment parameters of proposed technique for blood vessel extraction using DRIVE database

Sample image	OD Area (pixels)	RMSE	PSNR	SSIM	Runtime elapsed (seconds)
Image_1	2213	0.9619	48.4681	0.8809	2.8248
Image_2	2024	0.9538	48.5420	0.8840	3.0535
Image_3	2036	0.9665	48.4266	0.8790	3.2653
Image_4	2044	0.9403	48.6656	0.8882	2.8248
Image_5	3116	0.9508	48.5690	0.8845	3.1663
Image_6	3694	0.9573	48.5098	0.8822	3.2183
Image_7	4426	0.9549	48.5314	0.8837	2.9538
Image_8	2516	0.9499	48.5772	0.8851	3.1135
Image_9	1935	0.9570	48.5123	0.8826	3.1138
Image_10	2009	0.9600	48.4856	0.8817	3.2743

Blood vessel extraction algorithms discussed in this paper are also compared with the existing approaches in Table 3 and it is revealed that the proposed approach gives the better results in terms of PSNR and MSE as compared to the proposed techniques discussed in [24] and [25]. PSNR should be high for better image quality, and PSNR computed in [24] gives the highest value approximately equal to 8 dB for method employing adaptive median filter. The proposed technique employed in this work has PSNR value of 48 dB which is much higher than reported in [24]. Another comparison is made with the work done in [25] comparing different histogram equalization approaches for comparative analysis of fundus image enhancement techniques. This comparison also reveals that our approach gives the better contrast enhancement as it employs CLAHE approach for histogram equalization which gives highest PSNR value out of all other HE approaches.

Table 3. Tabular comparison of existing techniques with proposed techniques

Sr. No.	Employed techniques	MSE	PSNR
1.	Adaptive median filter (30)	10305.77	8.00
2.	CLAHE (31)	129.49	27.01
3.	Proposed approach	0.96	48.53

4 Conclusion

In this research work, segmentation techniques are exploited for optical disc segmentation. A novel approach is proposed using mathematical morphology for optical disc removal and improving the blood vessel extraction by applying fuzzy algorithm. The experimentation was performed on all the images obtained from both the datasets but due to space constraints results form single image from each of the database are visualised. The proposed approach was concluded the most effective approach for identifying the optical disc to extract the blood vessels near the optical disc area for early diagnosis of diabetic retinopathy. For critical analysis, RMSE, PSNR, SSIM and run time elapsed were calculated, comparing the ground truth blood vessel images obtained from DRIVE database and extracted blood vessels using proposed technique. The future work in this field comprises further image analysis for feature extraction and classification to detect the lesions like MAs, HEMs, EXs, etc. to facilitate ophthalmic services for early detection of DR.

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Morphology Analysis and Time Interval Measurements Using Mallat Tree Decomposition for CVD Detection

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Abstract. Electrocardiogram signal is used to identify the heart related abnormalities as cardiovascular disease. Automatic detection and analysis of abnormalities of long duration of ECG signals is tedious and quite subjective as it is difficult to decipher the minute morphological variations. In this paper, Morphology Analysis and Time Interval Measurements using Mallat Tree Decomposition (MTD) are done to obtain the signal in the desired form for calculation of heart rate. ECG signals are analyzed with various mother wavelets using MTD, and analyzed on the basis of performance matrices. It was found for this research work bior 3.9 wavelet is well suited for the processing of ECG signal. Heart rate using Peak Detection Algorithm (PDA) is calculated after pre-processing technique and bior 3.9 wavelet. The experiments were carried out on MATLAB R2016a environment.

Keywords: Cardiovascular disease · Mallat Tree Decomposition
Heart rate · Time interval measurement · Morphology analysis

1 Introduction

Cardiovascular disease (CVD) is a major disorder that results in to hypertension and myocardial infarction. Approximately 30% of worldwide deaths are due to CVD disease [1, 2]. Early detection of CVD disease is an important step to prevent these deaths. Therefore, a regular analysis of ECG signal is required for early detection [3, 4]. An ECG signal consists of five waves namely *P*, *Q*, *R*, *S*, and *T* which performs four main events: the *R*-*R* interval, the *P*-*Q* interval, the *QRS* complex, and the *S*-*T* interval [5]. These events contain their own peaks to analyze the morphology, amplitude and time duration for CVD detection [6–8]. All the important features such as duration and amplitude on this recording must lies within normal range. P wave is the upright positive deflection with respect to baseline in the waveform. The duration and amplitude of this wave should be less than or equal to 0.11 s and 0.25 mV respectively. *P*-*Q* is measured from the beginning of *P* wave to the start of the *QRS* complex. *QRS*

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complex being the most prominent feature of entire waveform have the duration and amplitude range lies in between 60–100 ms and 2.5–3.0 mV respectively. Resting state of ventricles signified by *T* wave in which repolarization process takes place. The *S-T* segment requires approximately 320 to 350 ms. Repolarization period of ventricles is from 100–250 ms having amplitude in between 0.1–0.5 mV [9]. Machine Learning based ECG analysis is required for an accurate detection of peaks which is a very tedious task as this signal is affected by Baseline Wander noise, Power line interference noise, Burst noise and Electromyography noise [10–12]. False detection of *R*-wave leads to undesired results which further resulted in to poor signal-to-noise ratio (SNR) [13]. Many researchers have done research on heart rate calculation, feature extraction [14–20], ECG compression, *R-R* interval analysis, and *P*, *S*, & *T* wave detection which are mainly categorized in to three categories: Time Detection Technique, Transform Domain Detection Techniques, & Morphologic Filtering Techniques and Template Matching Methods [21].

Wavelet transform has become an important computational tool for performing Signal Processing. It overcomes the shortcomings of time window size which does not vary with frequency. Authors in [22] uses wavelet transform which is applied to extract the coefficients and they uses autoregressive modelling for calculating temporal structure of an ECG signal [22]. A new technique is presented by authors in [23] in which feature sets has been obtained using mathematical morphology. A novel ECG obfuscation method has been formulated which uses cross correlation based template matching approach to distinguish all ECG features [24]. Another method of feature extraction based on Discrete Wavelet Transform (DWT) has been designed to solve the problem of non-stationary ECG signals by providing stable features [25]. A modified technique based on the combined wavelet transform is presented in which two wavelets a Quadratic Spline Wavelet (QSWT) for *QRS* detection and the Daubechies six coefficient (db6) wavelet for *P* and *T* detection have been used [26]. Authors in [27] uses technique based on cepstrum coefficient method for feature extraction and artificial neural network (ANN) models for the classification and has developed a model which gives the accuracy of 97.5% to diagnose cardiac disease [27]. An integrated feature extraction approach has been proposed using Principal Component Analysis and DWT that shows the wavelet features are more significant than time domain feature for better discrimination [28]. An author in [29] proposes an automatic ECG feature extraction system based on DWT for various feature extraction.

In this research paper, distinct families of discrete wavelets have been applied for multilevel decomposition of MIT-BIH Arrhythmia v5 ECG input signal to extract the *R-R* interval, *P-Q* interval, *QRS* complex, and *S-T* interval along with Heart Rate calculation. This paper is further organized as follows: Sect. 2 introduces signal decomposition using Mallat Tree Decomposition (MTD). Section 3 describes the methodology which is followed by results and discussions and concluded in the last.

2 Signal Decomposition Using Mallat Tree Decomposition Algorithm

DWT derived from sub-band coding result in less computation time and reduced number of required resources. In DWT time scale representation of signal is obtained using digital filtering technique. The signal is passed through filters having different cut-off frequency at different scales. The DWT function is given by

$$W_{\psi}(j,\, k) \;=\; \frac{1}{\sqrt{m}} \sum x(n)\; \psi_{j,k}(n) \tag{1}$$

where $x(n)$ = input signal, $1/\sqrt{m}$ is a normalizing term, m is the number of samples in the sequence and n is integer = 0, 1, 2 … m–1.

The DWT is defined by MTD algorithm in which output is computed by successive low pass and high pass filtering of discrete signal as shown in Fig. 1.

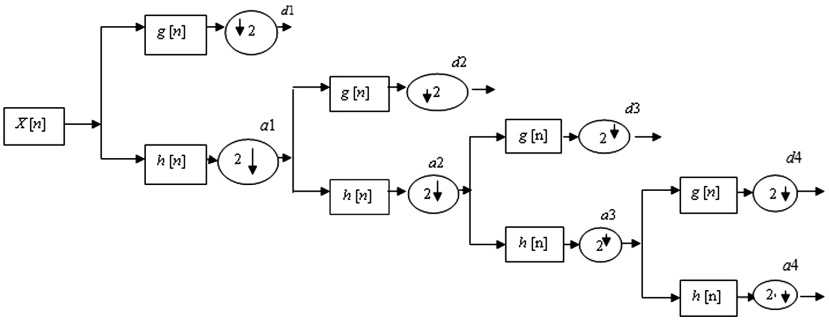

Fig. 1. Multilevel decomposition at level4

In Fig. 1, $x[n]$ is the input signal which is decomposed into two: high pass filter $g[n]$ and low pass filter $h[n]$. Each stage comprises of two digital filters and two down samplers (by 2) to produce further varying frequency digital signals. The down sampled output of first high pass filter $g[n]$ and low pass filter $h[n]$ give detail coefficient $d1$ and approximation coefficient $a1$ respectively. The approximation coefficient $a1$ is further decomposed and this process continues till the set level of decomposition. In this research paper, 4 level of decomposition is used which provide $d1$, $d2$, $d3$, $d4$ as detailed coefficients and $a4$ as an approximation coefficient. Different families of DWT such as Daubechies, Biorthogonal, Reverse Orthogonal, Symlets and Coiflets have been used for signal decomposition.

3 Methodology

Input signal of ECG with 100 record databases from MIT-BIH Arrhythmia v5 is taken from Physio Bank ATM. This input ECG signal has length of 1460 samples which is sampled at rate of 360 Hz. The following steps are followed for Peak Detection (morphology analysis) and computation of different intervals (time interval measurement).

Step 1: MIT-BIH Arrhythmia database ECG signal 100 m.mat is loaded.
Step 2: Pre-processing: Input ECG signal is fed to digital FIR High pass filter using Blackman windowing technique to remove Base Line Wander noise with cut-off frequency 0.5 Hz. The order of filter is taken $N = 10$ by defining the window length i.e. $N + 1 = 11$ [11].
Step 3: Compute Heart Beat rate of pre-processed signal: Output of FIR High pass filter is used to compute the Heart rate of an ECG signal is defined by Eq. 2.

$$Heart\,Rate = \frac{Sample\,Rate \times 60}{R_2 - R_1} \tag{2}$$

where R_2 and R_1 represents the location of two subsequent R peaks on time scale.

Step 4: Different ECG peaks (*P*, *Q*, *R*, *S*, and *T*) and their location (amplitude and time) has been detected using Peak Detection Algorithm (PDA). Out of 5 different waves/peaks, *R* peak has the maximum amplitude of an ECG signal in every cycle.

Peak Detection Algorithm

Input – Pre-processed signal (Y)
Output – Peak Detection

1. Define Sample Rate
2. Detection of *R* peak: The point with maximum amplitude gives the *R* peak location.

If *R* peak is located for each cycle (R_{peak}) , then different other peaks are detected by the following methods :

3. Detection of *P* peak :*P* peak location detection is given as

$$a = \left[R_{peak} - \left(\frac{Sample\,Rate \times 25}{Beat} \right) \right] : \left[R_{peak} - \left(\frac{Sample\,Rate \times 5}{Beat} \right) \right]$$

P peak amplitude= max($Y(a)$);

4. Detection of Q peak:Q peak location detection is given as

$$b = \left[R_{peak} - \left(\frac{Sample\,Rate \times 10}{Beat} \right) \right] : \left[R_{peak} - \left(\frac{Sample\,Rate \times 1}{Beat} \right) \right]$$

Q peak amplitude = min($Y(b)$);

5. Detection of Speak :S peak location detection is expressed as

$$c = \left[R_{peak} + \left(\frac{Sample\,Rate \times 1}{Beat} \right) \right] : \left[R_{peak} + \left(\frac{Sample\,Rate \times 5}{Beat} \right) \right]$$

Speak amplitude = min($Y(c)$);

6. Detection of T peak :T peak location detection is represented as

$$d = \left[R_{peak} + \left(\frac{Sample\,Rate \times 10}{Beat} \right) \right] : \left[R_{peak} + \left(\frac{Sample\,Rate \times 30}{Beat} \right) \right]$$

T peak amplitude = max($Y(d)$);

End

Step 5: Detection of Time Interval Measurements: After detecting different ECG peaks, different intervals are calculated. R-R interval is calculated by Eq. 3

$$R\text{ - }R \text{ interval} = (R_2 - R_1)/\text{sample rate} \tag{3}$$

where R_2 and R_1 are the locations of two subsequent R peaks.

P-Q interval is given by Eq. 4

$$P\text{ - }Q \text{ interval} = \left(Q_{\text{peak}} - P_{\text{peak}}\right)/\text{sample rate} \tag{4}$$

where Q_{peak} and P_{peak} are the location of Q and P peak in that particular cycle.

QRS complex is calculated by Eq. 5

$$QRS \text{ complex} = (S_{\text{peak}} - Q_{\text{peak}})/\text{sample rate} \tag{5}$$

where S_{peak} and Q_{peak} are the location of S and Q peak in that particular cycle.

S-T interval is given by Eq. 6

$$S\text{ - }T\text{ interval} = \left(T_{\text{peak}} - S_{\text{peak}}\right)/\text{sample rate} \tag{6}$$

where T_{peak} and S_{peak} are the location of T and S peak in that particular cycle.

Step 6: Decomposition level is set at level 4 to maintain the balance to remove noise without removing important features. Different wavelet families are used: Daubechies, Biorthogonal, Reverse Orthogonal, Coiflets and Symlets.
Step 7: In this step, performance metrics of different wavelet families has been examined using different parameters to find out which wavelet transform is better for ECG signal computation.

1. Signal-to-noise ratio (SNR) is calculated as root mean square amplitude of signal and noise.

$$\text{SNR} = 10\log_{10}\left(E_{\text{signal}}/E_{\text{noise}}\right)^2 \tag{7}$$

2. Mean Square Error (MSE) signifies the difference between Original signal and cleaned signal without noise.

$$MSE = 1/N\sum\nolimits_{n=1}^{N}\left[x(n) - y(n)\right]^2 \tag{8}$$

3. Percent root mean square difference (PRD) is used to measure the distortion and is defined by Eq. (9)

$$PRD = \sqrt{\frac{\sum_{n=1}^{N}\left[x(n) - y(n)\right]^2}{\sum_{n=1}^{N}\left[x^2(n)\right]}} \tag{9}$$

In Eqs. 8 and 9, $x(n)$ is noisy input signal and $y(n)$ represents filtered signal.

Step 8: On the basis of performance parameters best wavelet method is analysed which is used for the further experiments. Wavelet coefficients using MTD are extracted and smoothing of coefficients has been done using Global Thresholding followed by denoising.
Step 9: After getting the wavelet coefficients using MTD, different peaks of an output signal has been detected using Peak Detection Algorithm as explained in step 4 which are compared with the peaks obtained after pre-processing techniques.

Step 10: Different time intervals of wavelet coefficients obtained using MTD has been calculated by equations used in Step 5 and compared the results obtained after pre-processed signals.

4 Results and Discussions

In this section, output of an ECG signal has been observed at different stages. In first stage, output has been obtained after removing baseline wander noise. In second stage, output of an ECG signal has been obtained after performing multilevel decomposition using MTD. The best wavelet on the basis of performance parameters such as SNR, MSE and PRD has been selected which is followed by extracting coefficients. Lastly peaks of ECG signal are detected and different time measurement intervals are calculated which are compared with the values obtained after pre-processing.

4.1 Removal of Baseline Wander Noise by Pre-processing Technique and Detection of Various Peaks

To remove low frequency Baseline wander noise, FIR filter has been designed using Blackman window technique explained by Prashar *et al*. [11]. Order of filter is $N = 10$ and window length is $N + 1$. Peaks of the filtered output ECG signal have been detected using Peak Detection Algorithm shown in Fig. 2.

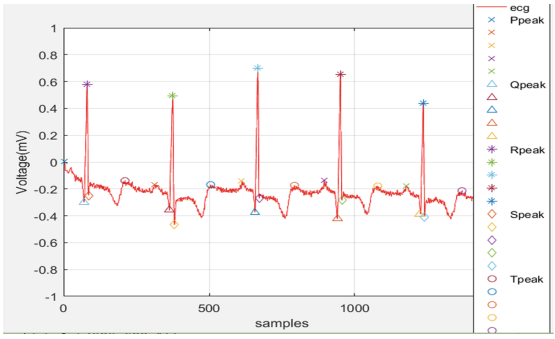

Fig. 2. Time domain analysis of Output ECG signal after filtered by Blackman window with Peak Detection.

4.2 Performing Multilevel Decomposition Using Mallat Tree

The output of High pass FIR filter is fed to the different wavelet families. Different families of wavelet used in this paper are Daubechies- db4, db5, db6, db7, db8, Biorthogonal-bior3.5, bior3.7, bior3.9, Reverse Orthogonal – rbio4.4, rbio5.5, rbio6, Coiflets-coif4, coif5 and Symlets –sym4, sym5, sym6, sym9. Table 1 shows the performance metrics of different wavelets families in terms of SNR, MSE and PRD. Result

shows that bior3.9 wavelet is well suited for ECG signal processing as it has high SNR and low value of MSE and PRD among all the wavelet families.

Table 1. SNR comparison of window based FIR filters

Wavelet families	Type	SNR	MSE	PRD
Daubechies	**db4**	25.0144	2.0134e−04	0.0561
	db5	24.6097	2.2101e−04	0.0588
	db6	24.3737	2.3335e−04	0.0604
	db7	24.5116	2.2606e−04	0.0595
	db8	24.0698	2.5027e−04	0.0626
Biorthogonal	**bior3.5**	26.3158	1.4921e−04	0.0483
	bior3.7	26.4652	1.4416e−04	0.0475
	bior3.9	26.5396	1.4172e−04	0.0471
Reverse orthogonal	**rbio4.4**	24.4049	2.3168e−04	0.0602
	rbio5.5	24.9515	2.0428e−04	0.0565
	rbio6.8	25.1085	1.9703e−04	0.0555
Coiflets	**coif 4**	25.1166	1.9666e−04	0.0555
	coif5	24.8627	2.0850e−04	0.0571
Symlets	**sym4**	24.8996	2.0674e−04	0.0569
	sym5	24.6218	2.2039e−04	0.0587
	sym6	25.2806	1.8937e−04	0.0552
	sym9	24.8941	2.0700e−04	0.0569

Detailed coefficients and approximation coefficients are extracted from the ECG signal. Global Thresholding has been applied to smooth the wavelet coefficient. Lastly, different peaks of denoised signal are detected using PDA along with computation of different time interval measurements. Detection of various peaks of denoised ECG signal is shown in Fig. 3.

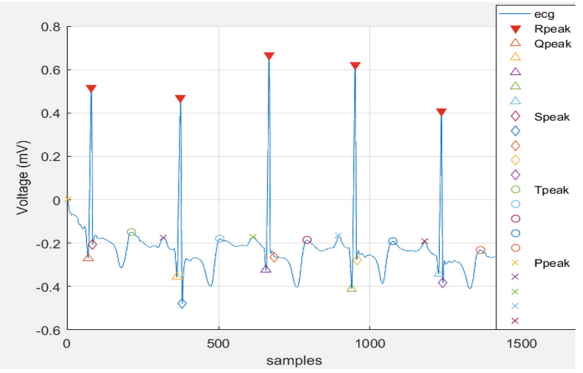

Fig. 3. Detection of peaks of denoised signal using PDA

Table 2 shows the computation of Heart Rate after pre- processing of an ECG signal and after processing by bior3.9 wavelet.

Table 2. Heart Rate computation

Heart Rate per minute	Heart Rate computation after High pass FIR filter	Heart Rate computation after processing by bior3.9 wavelet
	74.8882	74.8256

Table 3 shows the various peak errors such as *P* peak error, *Q* peak error, *R* peak error, *S* peak error and *T* peak error. Peak error is computed by equation

Table 3. Different peak error computation

Peak type	Peak error (%)
R peak error	0.2000
P peak error	2.000
Q peak error	0.4000
S peak error	2.4000
T peak error	2.4000

Table 4. Calculation of different peak intervals

S. No.	Types of intervals	Indications	Normal values of intervals (sec)	Output after high pass FIR filter (sec)	Output after processing by bior3.9 wavelet (sec)
1	*R*-*R* interval	Useful to calculate Heart Rate	0.6–1.2	0.8014	0.8021
2	*P*-*Q* interval	*P*-*Q* interval specifies the certain medical conditions. *P*-*Q* interval over 0.2 s indicates first degree of Heart blockage. Prolongation also indicates Hypokalemia, acute rheumatic fever	0.12–0.2	0.1378	0.1333
3	*QRS* complex	It indicates the depolarization of the right and left ventricle of human heart. Useful in diagnosing Cardiac arrhythmia, myocardial infraction	0.06–0.1	0.0461	0.0517
4	*S*-*T* interval	Variations in ST interval indicate the disease like transmural myocardial infarction	0.32–0.35	0.3451	0.3479

$$Peak\,Error = abs\left(x_p - x_p'\right) \tag{10}$$

where x_p is output from high pass filter and x_p' is identified after MTD.

Table 4 shows the time level measurement of different peak intervals i.e. *R-R* interval, *P-Q* interval, *QRS* complex and *S-T* interval in every cycle of an ECG signal at two levels: (a) Output of ECG signal after High pass FIR filter using Blackman window and (b) Output of ECG signal after processing through bior3.9 wavelet.

5 Conclusion

The manual detection method is not suitable for a long-term monitoring system, and whenever an ECG is acquired from a patient body, a lot of noises accumulate with it, so proper detection is not feasible. Machine Learning based ECG analysis is required for an accurate detection of peaks which is a very tedious task as this signal is affected by various noise. In this paper, Morphology Analysis and Time Interval Measurements using Mallat Tree Decomposition (MTD) are done to obtain the signal in the desired form for calculation of heart rate. ECG signals are analyzed with various mother wavelets using MTD, and analyzed on the basis of performance matrices.

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Part 1





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Implementation and Performance Assessment of Gradient Edge Detection Predictor for Reversible Compression of Biomedical Images

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Abstract. Technological advancement of medical imaging techniques are progressing constantly, dealing with images of increasing resolutions. In hospitals, medical imaging techniques like X-rays, magnetic resonance imaging and computed tomography etc. are of high resolution consuming large storage space. Such high resolution of medical images transmitted over the network utilizes large bandwidth that often results in degradation of image quality. So, compression of images is only a solution for efficient archival and communication of medical images. Predictive based coding technique is explored in this paper for medical image compression as it performs well for lossless compression. This paper presents a comparative investigation on 2D predictor's coding efficiency and complexity on CT images. It was observed that among 2D predictors Gradient Edge Detection (GED) predictor gave better results than Median Edge Detector (MED) and DPCM. GED predictor at proper threshold value achieved approximately same results in terms of various performance metrics as Gradient Adaptive Predictor (GAP) though it is less complex.

Keywords: Compression · Predictors · Coding efficiency · Complexity

1 Introduction

Digital image processing has a great demand for transmission and storage of data efficiently with the rapid advancement in information and communication technology. In biomedical area, technology of medical images are progressing dramatically and dealing with images of increasing resolutions. Healthcare departments deal with abundant amount of medical images and terabytes of digital data is generated by hospital per year [1, 2]. Currently various medical imaging techniques are in use like magnetic resonance (MR), X-rays and computerized tomography (CT) that produce enormous amount of data as these techniques normally contains set of 2D frames that represent cross sectional part of human body. This growing amount of medical data makes a demand for effectual techniques of compression that are used for proper storage and communication [3]. Efficient compression techniques are required to deal

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with the rapid expansion of medical data, to save time and to shrink storage space. Additionally, telemedicine is an application that requires progressive lossy to lossless compression. Since compressed image file sizes require less time for transmission so it is valuable for telemedicine application [4]. Medical image compression has been proved as a very important aspect to get a successful real time application of telemedicine along with an efficient storage and transmission. Compression technique removes the irrelevant and redundant bits from the image and accelerates the transmission speed. Compression results in lesser number of bits to represent the information. An efficient compression technique can reduce file size and transmission time, i.e. improving effectiveness of the image transmission system. Generally used image compression techniques are discussed.

Lossy compression technique does not provide exact replica of original image but it results in higher compression ratio. Lossy technique system is not acceptable in medical field because any loss of information result in false and it may create issue. So it is not preferred technique for compression of medical images [5, 6]. Lossless compression of image is an appropriate technique in medical field as it results exact replica of original image [7]. Diagnosis of image cannot afford any deficiency in diagnostically important regions of interest (ROIs). Thus it is necessary to have an approach that brings a high compression rate maintaining good quality of medical images. There are many compression techniques available in literature like transformation coding, entropy encoding and dictionary encoding.

As it is essential that compression and reconstruction of signal should be efficient without any loss of medical information as little loss of data especially in medical field is unbearable because it may lead to diagnose mistakenly [8].

Related Work

It is seen in literature that predictive coding performs well for lossless compression technique and efficiency of compression system depends upon the choice of predictors. Choice of is necessary for predictor for efficient prediction results in reduction of redundancy from the image that further contributes for better compression ratio. Many researchers have reported applying predictive coding technique on medical images for lossless compression.

In [9], author reviewed various image compression techniques based on medical image compression. In the rising field of telemedicine and teleradiology, comparative analysis of compression techniques and their applications has been carried out. In [10] predictive coding with a simple context-based entropy coder is offered and different predictor efficiency were analyzed with higher bit depth, achieving approximately same bit rate as standard predictor algorithm. [11] In this paper, author examined various compression techniques and it was explored that although medical image compression is an emerging need, but it encounters higher dimensionality of challenges and complicatedness for catering the increasing demands of the medical science. Authors in [12] proposed threshold controlled gradient edge detection which combines MED predictor and GAP. It is seen that GED predictor can achieve comparable bit rates as more complicated GAP predictors. In [13], author has used differential pulse code modulation for image compression lossless and near-lossless compression method and due to its high compression ratio and simplicity; it is an efficient technique for lossless

compression. Enhanced DPCM transformation is used in this method which has a good energy compaction and Huffman encoding was used for image coding. In [14], proposed prediction based algorithms on the detection of edges and assessment of local gradients. MED and GAP were analyzed and comparative analysis of these predictors were also done in terms of entropy. Authors in [15] adopted a compression method that is based on a combination between predictive coding and bit plane slicing for compression of medical and natural image samples. High system performance is achieved by this lossless compression technique with high compression ratio. The main objectives through this research paper are to find the more efficient prediction algorithm by comparing different 2D predictors for image prediction. Another objective of this paper is to analyze the effectiveness of varying resolution values on entropy of prediction error image. The rest of this paper is organized as follows. In Sect. 2, details of prediction based compression is presented. In Sect. 3 results and discussion are shown. Conclusion of paper is drawn in Sect. 4.

2 Materials and Methods

2.1 Data Set

Different medical images of CT-scan are collected from CIPR [16] and OSRX [17] for validation, testing and examine coding efficiency of different predictors on patient's medical images. Details of CT medical test samples are shown in Table 1. These datasets are commonly used datasets having CT images of varying resolutions. In this research work, CT images are taken to test the algorithms and there is no effect in the performance of algorithms with varying image modality, resolution and number of images.

Table 1. Dataset details of CT medical test images

TAG	Sequence name	Modality	Image size
CIPR-CT-01	CT_Aperts	CT	256 × 256
CIPR-CT-02	CT_carotid	CT	256 × 256
CIPR-CT-03	CT_skull	CT	256 × 256
CIPR-CT-04	CT_wrist	CT	256 × 256
OSRX_CT_01	BREBIX	CT	512 × 512
OSRX_CT_01	MAGIX	CT	512 × 512
OSRX_CT_02	CEREBRIX	CT	336 × 336

2.2 Predictive Based Lossless Image Compression

Additional amount of bits and information that do not provide any relevant information is called redundancy [18]. Neighboring pixels in an image are related to each other and correlation between these pixels results in interpixel redundancy. Neighboring pixels

are used to calculate the value of current pixel and difference between adjacent pixels can be used to represent an image to reduce the interpixel redundancy. Basic Scheme of predictive coding technique is shown in Fig. 1.

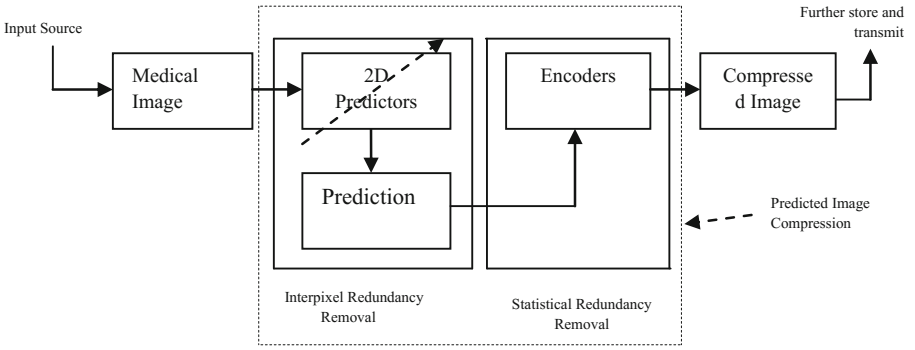

Fig. 1. Scheme of predictive coding technique

In predictive coding technique, interpixel redundancy is removed by 2D predictors and statistical redundancy is removed by encoders like Huffman and Arithmetic coding.

2.3 2D Predictors Used in Predictive Based Coding Techniques

Most important part of lossless predictive coding technique is prediction as it exploits interpixel redundancy from the image. 2D predictors can also be used for removing redundancy from volumetric images when operated slice by slice. 3D volumetric medical data is splitting into 2D image slices and separately enhance and predicted by the 2D predictor algorithms. Basic arrangement of pixels in causal template is denoted as follows:

$$\left.\begin{aligned} &X_{i,j} = X[i, j],\ X_N = X[i, j-1],\ X_W = X[i-1, j], \\ &X_{NW} = X[i-1, j-1],\ X_{NE} = X[i+1, j-1], \\ &X_{NN} = X[i, j-2],\ X_{WW} = X[i-2, j],\ X_{NNE} = X[i+1, j-2]. \end{aligned}\right\} \quad (1)$$

Where $X_{i,j}$ is current pixel and X_N (North pixel), X_W (West pixel), X_{NW} (North–West pixel), X_{NE} (North-East pixel), X_{NN} (North-North pixel), X_{WW} (West–West pixel) X_{NNE} (North-North-East pixel) are neighbour pixels in causal template. The various 2D predictors taken into consideration in the work are Median Edge Predictor (MED), Gradient Adjusted Predictor (GAP), Differential Pulse Code Modulation (DPCM) and Gradient Edge Predictor (GED).

Median Edge Detection Predictors (MED): The value of current pixel $X_{i,j}$ is predicted by Median edge detector that selects the median value among neighboring pixels X_N, X_W and $X_W + X_N - X_{NW}$ (pixels are shown in Eq. 1). It is uses three causal pixels

which are used to select one of the three sub-predictors depending upon whether it is horizontal edge or vertical edge [19].

Gradient Adjusted Predictors: GAP is based on the gradient estimation which is done around the current pixel. It can adapt itself to the intensity gradients of immediate neighbors of predicted pixel. For gradient estimation six causal pixels are used and predicted value is determined on some threshold. Threshold use in this predictor is fixed and typical values of threshold are 8, 32 and 80 [12].

Differential Pulse Code Modulation (DPCM): Differential encoding compression method predicts the current signal value based on the past encoded signal values. Error signal is obtained by taking difference of original value and predicted value and then encoded. It gives good compression ratio for images with high correlation between neighbouring pixels [20]. Error signal having peaked histogram is containing small error value.

Gradient Edge Detection: MED and GAP predictors have their own merits and demerits and GED predictor takes the advantage of both predictors. It is finest combination of simplicity and efficiency. It uses local gradient estimation on proper threshold value (T) as that of GAP and chooses between three sub predictors, defined as in MED predictor [4]. Threshold values used in standard GAP predictor are fixed but in GED predictor value of threshold is user defined. On proper threshold value GED provides efficient results as that of GAP. Like MED, it is also simple to implement. Algorithm of GED is as follows:

$$\left.\begin{array}{l} \mathrm{Av} = |\mathrm{NW} - \mathrm{W}| + |\mathrm{NN} - \mathrm{N}| \\ \mathrm{Ah} = |\mathrm{WW} - \mathrm{W}| + |\mathrm{NW} - \mathrm{N}| \\ \text{if } \mathrm{Av} - \mathrm{Ah} > \mathrm{T}, \mathrm{Px} = \mathrm{W} \\ \text{else if } \mathrm{Av} - \mathrm{Ah} < -\mathrm{T}, \ \mathrm{Px} = \mathrm{N} \\ \text{else } \mathrm{Px} = \mathrm{N} + \mathrm{W} - \mathrm{NW} \\ \\ \text{where, T = Threshold} \\ \text{Av, Ah = vertical and horizontal gradients} \\ \text{Px = Predicted pixel} \end{array}\right\} \quad (2)$$

2.4 Performance Metrics

Different predictors for medical images are examined with various evaluation metrics as entropy, Peak Signal-to-Noise Ratio, Structural Similarity Index (SSIM). Entropy is final step in predictive coding technique that removes the statistical redundancy from the image [21, 22]. Entropy of an image is calculated as:

$$H(X) = -\sum_{\mathrm{x}} \mathrm{p(x)log\ p(x)} \quad (3)$$

Where, p(x) is probability of a symbol x.

Quality of an image is express in terms of PSNR and its typical value is 30 db for 8 bit depth. It depends upon Mean Square Error (MSE), lower the value of square error higher will be PSNR and better quality of an image is obtained [23]. PSNR is calculated by

$$\begin{aligned} \text{PSNR} &= \frac{10\log_{10}(255)^2}{\text{MSE}} \\ \text{MSE} &= \frac{1}{\text{MN}}\sum\sum\frac{\text{error}^2}{\text{rows} \times \text{columns}} \\ \text{RMSE} &= \sqrt{\text{MSE}} \end{aligned} \tag{4}$$

SSIM is the combination of luminance, contrast and structure and based on mean and variance. Value of SSIM is lies between 0 and 1 and predicted image is more similar to original image if SSIM approaches to 1 [8].

$$\text{SSIM}(x, y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{\left(\mu_x^2 + \mu_y^2 + c_1\right)\left(\sigma_x^2 + \sigma_y^2 + c_2\right)} \tag{5}$$

3 Results and Discussion

Results of several 2D predictors of predictive coding technique for the various CT-scan databases are presented, implemented in MATLAB 2013.

Medical images of Computed Tomography (CT) are compressed using 2D predictors MED, DPCM, GAP and GED are obtained and shown in Figs. 2, 3. It is found that interpixel redundancy is better removed by GAP than the MED and DPCM predictor as GAP provides less entropy and RMSE of prediction error image. Results of GED predictor are approximately same as that of GAP predictor. Original image and residual image obtained from MED, GAP, DPCM and GED predictors are shown in Figs. 2, 3 with their corresponding histograms.

3.1 Comparative Analysis of 2D Predictors for Computed Tomography (CT) Images

Analysis in Terms of Entropy: Comparative analysis is carried out for different samples of CT medical images taken from different database. These images are tested by all four predictors MED, GAP, DPCM and GED, which provides better assessment in contrast to entropy, PSNR, RMSE and SSIM. As GED predictor is based on threshold value and we got 44 as a optimal threshold when it is tested for different values of threshold from 8 to 256 at the difference of 16. Resolution Independent Gradient Edge Predictor (RIGED) is a GED predictor with threshold value 44 for efficient prediction. So for 8 bit depth images RIGED is efficient. It is estimated that performance of RIGED is better obtained than MED, DPCM and GAP as it takes the advantage of simplicity and efficiency from standard MED and GAP predictors.

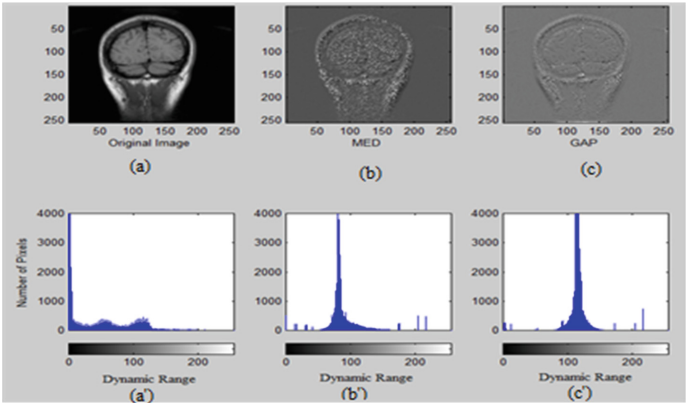

Fig. 2. (a) Original CT-scan image of brain, residual image obtained from (b) MED and (c) GAP predictors (a'), (b'), (c') corresponding histograms.

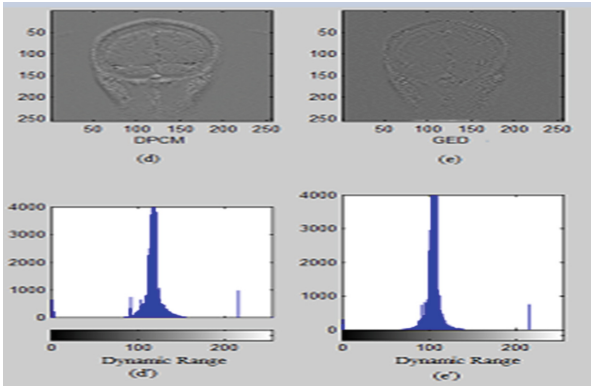

Fig. 3. Residual image of CT obtained from (d) DPCM and (e) RIGED predictors (d'), (e') respective histograms.

RIGED gave better results than MED and DPCM predictor and approximately same results as that of GAP even it is less complex than GAP. Entropy values of prediction error image obtained from MED, DPCM, GAP and RIGED for different CT images are represented in Fig. 4.

It is clear from above figure that for different CT image samples, entropy after prediction by 2D predictor is less as compare to entropy of original image. So it is depicted that lower number of bits are required to encode the image if prediction is done before encoding. Efficiency of predictor depends upon the entropy value, lower the entropy value, more efficient is the predictor. From the above figure, it is clear that RIGED achieved minimum value of entropy so it is efficient than other predictors.

Analysis of 2D Predictors for CT Images in Terms of Entropy Value for Varying Image Resolutions: Analysis of 2D predictors for CT images of varying resolutions is

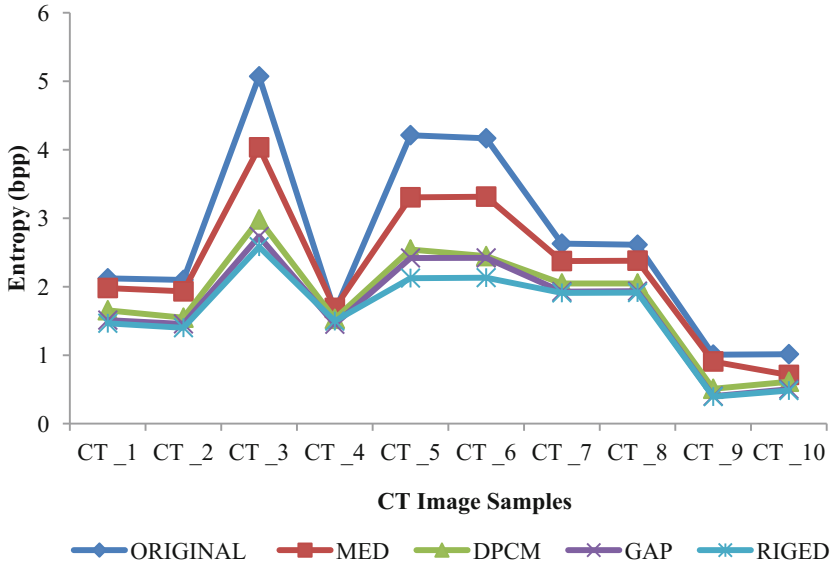

Fig. 4. Entropy values of original image residual image predicted from MED, DPCM, GAP and RIGED predictor for CT image samples.

also carried out in terms of entropy values. Average entropy values for different resolution obtained from 2D predictors are represented graphically in Fig. 5. It is depicted from the figure that entropy value obtained from lower resolution image is larger than higher resolution image. When resolution increases, entropy value of images decreases as shown in figure below. Entropy values obtained from different 2D predictors for 256×256 resolution is large as compare to 512×512. For resolution in between 256×256 and 512×512, entropy values are lie between the entropies of 256×256 and 512×512.

3.2 Analysis in Terms of Other Performance Metrics

In Terms of Root Mean Square Error: Analysis of 2D predictors is also done with reference to other performance metrics. Root mean error square of prediction error image or residual image is obtained that is shown in Table 2. Lower the value of RMS, better will the prediction and interpixel redundancy is also better removed. It is clear from the table below that RMSE of residual image calculated from GAP is lowest as compare to MED and DPCM. RIGED gave better results than MED, DPCM and approximately same values of error as that of GAP. GED is optimum combination of simplicity and efficiency. It is pointed that RMSE of prediction image is better obtained by RIGED as compare to other predictors.

In Terms of Peak Signal to Noise Ratio: Peak signal-to-noise ratio is also calculated for different image samples of CT-Scan as shown in Table 3 similar to the previous discussion. Optimal result of PSNR is achieved by RIGED. MED predictor gave lowest

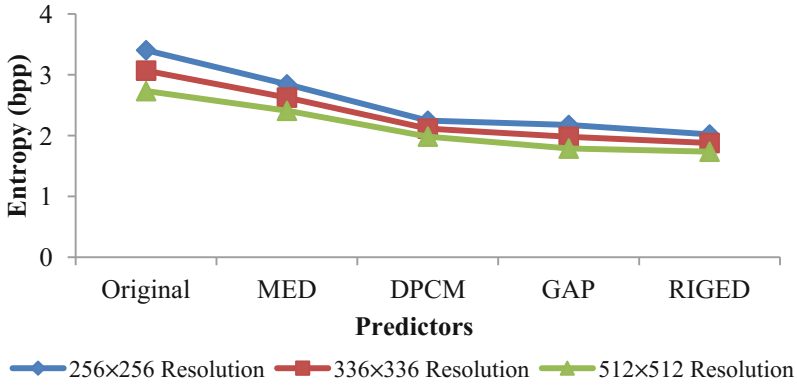

Fig. 5. Average entropy values of original image residual image predicted from MED, DPCM, GAP and RIGED predictor for CT image samples having different resolution.

Table 2. RMSE values for CT images having different resolutions

Medical images test samples	Image size	RMSE			
		MED	DPCM	GAP	RIGED
CT_1	256 × 256	18.707	4.231	3.888	3.695
CT_2	256 × 256	18.328	4.112	3.792	3.574
CT_3	256 × 256	33.618	5.1679	3.736	3.269
CT_4	256 × 256	11.245	5.405	4.377	4.836
CT_5	512 × 512	34.148	10.124	14.741	14.671
CT_6	512 × 512	33.724	9.998	14.497	14.434
CT_7	512 × 512	29.449	8.916	7.796	8.313
CT_8	512 × 512	30.219	9.075	8.190	8.680
CT_9	336 × 336	3.463	1.387	1.336	1.298
CT_10	336 × 336	5.221	1.235	1.145	0.996

value of PSNR as compare to other predictors but it has advantage of simplicity. GAP achieved good results in terms of PSNR but it is computationally complex predictor. RIGED achieved comparable values of PSNR and it is also simple to implement.

In Terms of Similarity Index: Another quality parameter Structural Similarity Index (SSIM) is also calculated for predicted image. It shows the similarity between predicted image and original image. Its value is in the range from 0 to 1 and if the SSIM of predicted image approaches value 1 then it is more similar to original image whereas approaching to 0 shows the dissimilarity between the images. Values of SSIM for various CT images from 2D predictors are given in Table 4.

It is seen from the above Table that RIGED achieved maximum values of SSIM for different CT test image. RIGED is highly efficient than other 2D predictors and it is also simple to implement.

Table 3. PSNR values for CT images having different resolutions

Medical images test samples	Image size	PSNR			
		MED	DPCM	GAP	RIGED
CT_1	256 × 256	22.690	35.600	36.337	36.778
CT_2	256 × 256	22.868	35.849	36.557	37.067
CT_3	256 × 256	17.599	33.864	36.702	37.840
CT_4	256 × 256	27.111	33.473	35.310	34.441
CT_5	512 × 512	17.463	28.023	24.760	24.801
CT_6	512 × 512	17.571	28.132	24.905	24.943
CT_7	512 × 512	18.749	29.126	30.293	29.735
CT_8	512 × 512	18.525	28.973	29.866	29.360
CT_9	336 × 336	37.341	45.286	45.619	45.863
CT_10	336 × 336	33.774	46.296	46.970	48.158

Table 4. SSIM values for CT images having different resolutions

Medical images test samples	Image size	SSIM			
		MED	DPCM	GAP	RIGED
CT_1	256 × 256	0.980	0.832	0.988	0.989
CT_2	256 × 256	0.981	0.836	0.989	0.990
CT_3	256 × 256	0.972	0.414	0.983	0.983
CT_4	256 × 256	0.944	0.859	0.960	0.957
CT_5	512 × 512	0.989	0.714	0.990	0.993
CT_6	512 × 512	0.989	0.724	0.990	0.993
CT_7	512 × 512	0.978	0.847	0.985	0.987
CT_8	512 × 512	0.979	0.846	0.986	0.987
CT_9	336 × 336	0.992	0.975	0.993	0.992
CT_10	336 × 336	0.995	0.965	0.996	0.997

4 Conclusion

For the lossless compression of medical images, predictive coding performs better as it is simple to implement and most essential it provides lossless compression with less storage space, low bandwidth and less transmission time. Different 2D predictors MED, DPCM, GAP and RIGED are used in this research work to removes interpixel redundancy of the image. Performance parameters such as entropy, RMSE, PSNR and SSIM are calculated after prediction for all these predictors. It is calculated from various experiments conducted that GED predictor at good threshold value (RIGED) can achieve comparable results as that of most efficient GAP predictor. RIGED is also simple to implement as that of MED and also provides efficient results.

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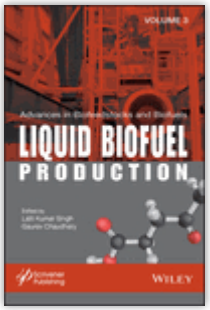

Liquid Biofuel Production

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About this book

Biofuels production is one of the most extensively studied fields in the energy sector that can provide an alternative energy source and bring the energy industry closer to sustainability. Biomass-based fuel production, or renewable fuels, are becoming increasingly important as a potential solution for man-made climate change, depleted oil reserves, and the dangers involved with hydraulic fracturing (or "fracking"). The price of oil will always be volatile and changeable, and, so long as ... Show all

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7

Technological Barriers in Biobutanol Production

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Abstract

The depletion of fossil fuels coupled with ever-increasing pollution has driven people's attention towards renewable energy sources such as biodiesel and bioalcohols. Among biofuels, biobutanol has emerged as a potential biofuel as a substitute for gasoline. The production of biobutanol comprises different tedious tasks and is hindered by a number of obstacles. Traditionally, biobutanol production by traditional ABE fermentation utilizing *Clostridium acetobutylicum* species suffers from limitations such as low butanol yields, solvent toxicity issues in the solventogenic phase to bacterial cell wall and cost of pretreatment of lignocellulosic biomass. Hence, the present review puts forth the discussion on existing limitations along with feasible solutions such as metabolic engineering approaches and utilization of solvent-tolerant microbial strains for an enhanced biobutanol production.

Keywords: Biobutanol, ABE (acetone-butanol-ethanol) fermentation, oxo-synthesis, aldol condensation strain modification

7.1 Introduction

Biofuel is the energy derived from animal material (animal manure, animal fats) and renewable plants (algae, lignin) with the potential of mitigating the upcoming issues of fossil fuel depletion and existing greenhouse gas emissions. Owing to the positive attributes of renewable biofuels,

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overwhelming research is going on towards production technologies of biodiesel, bioethanol and biobutanol. The economics of biofuels production is mostly dependent on the cost of the fermentation substrate. The biomass feedstock cost and biomass availability are the two main decisive factors in establishing a production technology for alternative fuels [1].

Currently, bioethanol and biodiesel are used in the transportation sector. Biobutanol is one of the option, investigated recently and emerging as a potential source of biodiesel and bioethanol. The sources for biobutanol production mainly comprise lignocellulosic waste biomass and non-food agricultural products, which is considered a second-generation biofuel system. Although the biotechnological production of biobutanol is a more complex process than bioethanol, the high energy content associated with the lesser water miscibility, vapour pressure and corrosiveness are the favorable factors towards the ongoing biobutanol production. Moreover, the potential of *Clostridium* bacteria to ferment various substrates such as municipal wastes is also an added advantage to the biobutanol production. Different engineered strains also came into the race of efficient biobutanol production [2].

Different industries are putting maximum effort into biobutanol production on an industrial scale by focusing mainly on novel alternative methods for existing traditional ABE (Acetone, Butanol and Ethanol) fermentation. *Gevo* and *Butamax* are the two leading technology developers of butanol. *Gevo* commenced with the world's first commercial-scale biobutanol production with a capacity of 18 MGPY and targeted to produce 50,000 to 100,000 gallons per month of isobutanol in upcoming years. *Butamax* in conjunction with *Fagen* Inc. set up a large-scale commercial production of biobutanol via retrofit of ethanol plants through the patented *Butamax* technology. India-based Laxmi Organic, Industries, in collaboration with Green Biologics, England, built a commercial-scale plant of 1,000 metric tons of butanol per year and began production from 2010 onwards. The facility would use sugarcane as a feedstock, and a combination of thermophilic organisms and thermostable enzymes to break the biomass down into butanol. Cobalt Biofuels in Mountain View, California, USA, had raised $25 million in equity to continue pursuing its goal of commercializing biobutanol production (http://www.biofuelstp.eu/butanol.html).

7.2 Production Technologies of Biobutanol

Butanol could be produced biologically as well as chemically. In chemical processes it is produced through oxo synthesis (through syngas reacts

with propylene) and aldol condensation. In biological process, anaerobic bacteria-based fermentation approach is used to produce acetone and ethanol. The advantages and disadvantages of biological and physicochemical methods for biobutanol production are tabulated in Table 7.1.

Cellulose and hemicelluloses also serve as substrates for biobutanol production with the aid of *Clostridium* sp. and other cellulolytic enzymes. Various pretreatment techniques such as utilization of alkaline peroxidases, steam explosion, hydrothermal techniques, and organic acids could be used to utilize the lignocellulosic substrate effectively. After pretreatment, detoxification is the subsequent step which is done through the utilization of activated charcoal, overliming, electrodialysis, and membrane extraction based detoxification methods. The pretreated and detoxified

Table 7.1 Advantages and disadvantages of biological and physico-chemical method for the production of biobutanol.

Method	Advantages	Disadvantages
Biological method	• Renewable source of fuel (feedstock)	• High feedstock cost significantly increases operating cost • Low butanol titre increase recovery cost. Low titres also increases sugar loading and water usage • Solvent recovery using distillation is energy intensive and expensive • Low butanol yield increases feedstock cost.
Physico-chemical	• Requires only one step for producing n-butanol from ethanol. • Relatively high yield	• Catalysts used in the process are costly

The sequence steps for formation of acetyl-CoA and its utilization for further fermentation intermediates are depicted in Figure 7.1

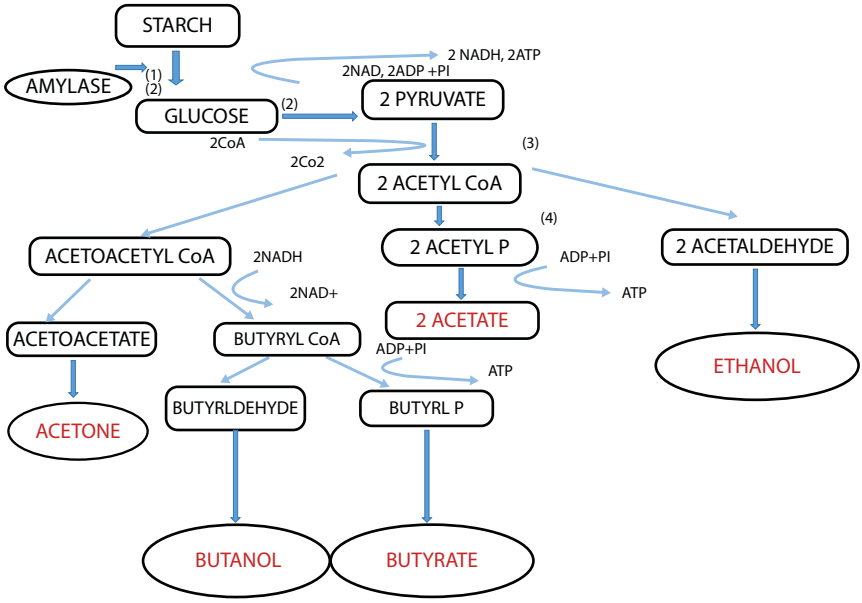

Figure 7.1 Biobutanol production from starch.

substrate is fermented finally through the utilization of microbial strains which convert polysaccharides to different sugars which are subsequently converted to pyruvate by glycolysis.

The formed pyruvate is converted to acetyl-CoA by pyruvate dehydrogenase complex (PDC), which in turn act as a common originator of all fermentation intermediate [1].

The fermentation process is divided into two phases, namely acidogenesis and solventogenesis. In acidogenesis, glucose in substrate feed stream is converted to butyric acid and acetic acid by the action of *Clostridium tyrobutyricum*. The product streams are then circulated and passed through a series of heat exchangers, where they are sterilized at 250°F and then cooled back to 98.6°F before entering into the next phase of fermentation, solventogenesis [3]. During solventogenesis, the cells enter into the stationary phase where acids are converting to solvents by *Clostridia acetobutylicum*. The product stream obtained is then pumped to a centrifuge where separated solids are sent for Dried Distillers Grain (DDGS) for drying and liquids are sent to the separations process [4]. Butanol must be recovered from the fermentation broth by processes such as adsorption, using immobilization techniques with the help of membrane reactors and gas stripping.

An overview of the biobutanol production from lignocellulosics is shown in Figure 7.2.

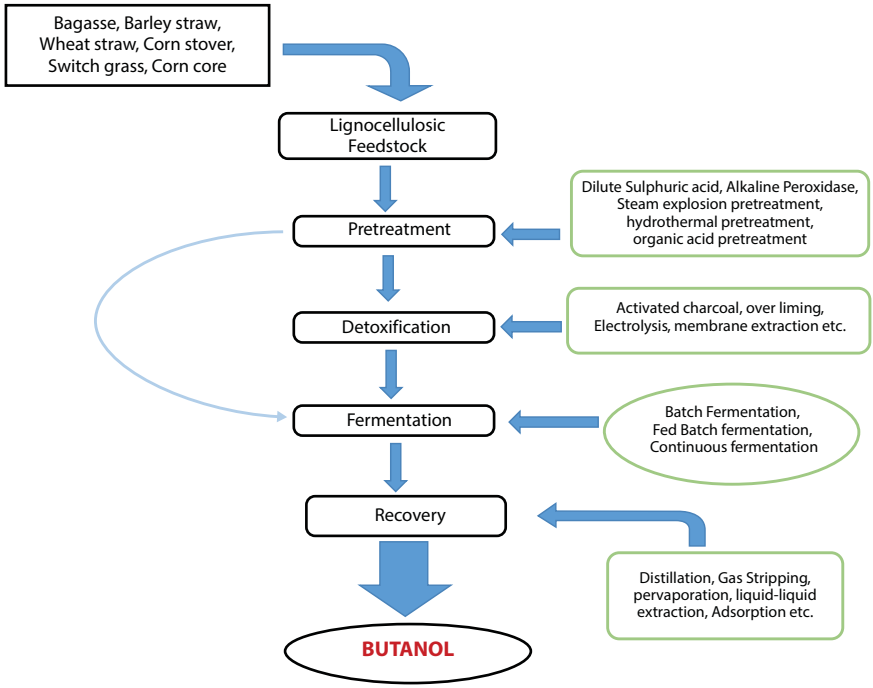

Figure 7.2 Butanol production from lignocellulosic feedstocks.

7.3 Lignocellulosic Materials for Bio-Butanol Production

Lignocellulosic materials used for biobutanol production face many challenges such as cost of the raw material, pretreatment and hydrolysis strategies, low butanol tolerance of fermenting strain which will affect the yield and productivity as well as downstream processing of biobutanol. There exists another barrier also which hinders its production, the inconsistency in biomass availability throughout the year. Lignin, ash, protein and waxes are also present in trace amounts whereas relative proportions of cellulose, hemicellulose, lignin are critical factors in the determination of optimum energy conversion route but other contents can lead to a diminution of theoretical butanol yield [5]. Among different problems encountered during utilization of cellulosic or lignocellulosic material for hydrolysates production, chemical by-products generation results in ceasing of cell growth as well as fermentation. Biologically these lignocellulosic materials are difficult to hydrolyze. Moreover, the significant amount of waste produced during the hydrolytic process also adds to the economy of the process [6].

Recent research has shown that the fermentation of any polysaccharides needs to use an additional nutritional supplement. Lee *et al.* [7], reported the use of different supplements such as KH_2PO_4, K_2HPO_4, ammonium acetate, para-aminobenzoic acid, thiamin, biotin, $MgSO_4 \cdot 7H_2O$, $MnSO_4 \cdot H_2O$, $FeSO_4 \cdot 7H_2O$, NaCl, and yeast extract for biobutanol production. Pretreatment is a critical and limiting step which has a predominant effect on overall biobutanol production thus has to be optimized. While using wheat bran as a substrate for biobutanol production by *C. beijerinckii* species, Liu and Qureshi [8], used a combination of pretreatments where wheat bran was treated with sulfuric acid at high temperature followed by neutralization with calcium hydroxide. This procedure raised the cost of the butanol produced considerably, but the solution to this problem found by using a cheap raw material for production which decreased the cost. Combination of pretreatments like 1M HCl with high temperature for 2 hours or enzymatic hydrolysis (using α-amylase and β-amylase) was utilized for cassava flour and resulted in 23.98 and 13.78 $g.L^{-1}$ biobutanol production using enzymatic and acid hydrolysis, respectively [9]. In another study, biobutanol (12.0 g/L) was produced from wheat straw using enzyme mix of cellulose, β-glucosidase and xylanase with the process conditions of pH 5.0, 45°C for 72 h and 80 rpm. To hydrolyze the raw materials, use of other alternative mechanical and physicochemical technologies was also reported and those alternatives include microwave-assisted pretreatment processes, steam explosion, ozonolysis, oxidative delignification and pulsed-electric-field.

Qureshi *et al.* [10], believed that barley straw could be used for butanol production. However, the barley straw showed the presence of few inhibitors which interfered with the production yield of butanol and hence pretreatment step using lime (called as over liming) was carried out to achieve an efficient fermentation. Consequently, this pretreatment step resulted in higher butanol production when compared to the yield with glucose as a substrate. Al-Shorgani *et al.* [11], also reported the formation of inhibitors during the acid pretreatment of cellulosic raw material (rice bran and de-oiled rice bran). Similarly, other studies utilized over liming pretreatment and subsequent extraction of inhibitors with a nonionic polymeric adsorbent. These procedures remarkably improved the biobutanol production and yield. Qureshi *et al.* [6], concluded that the formation of fermentation inhibitors after hydrolysis of cellulosic raw material is substrate and pretreatment dependent. Thus, it is necessary for a specific study to be carried out for each substrate and treatment. Several authors are of the opinion that the industrial feasibility of biobutanol production can only increase if a low-cost substrate can be employed [12, 13]. Diversification of

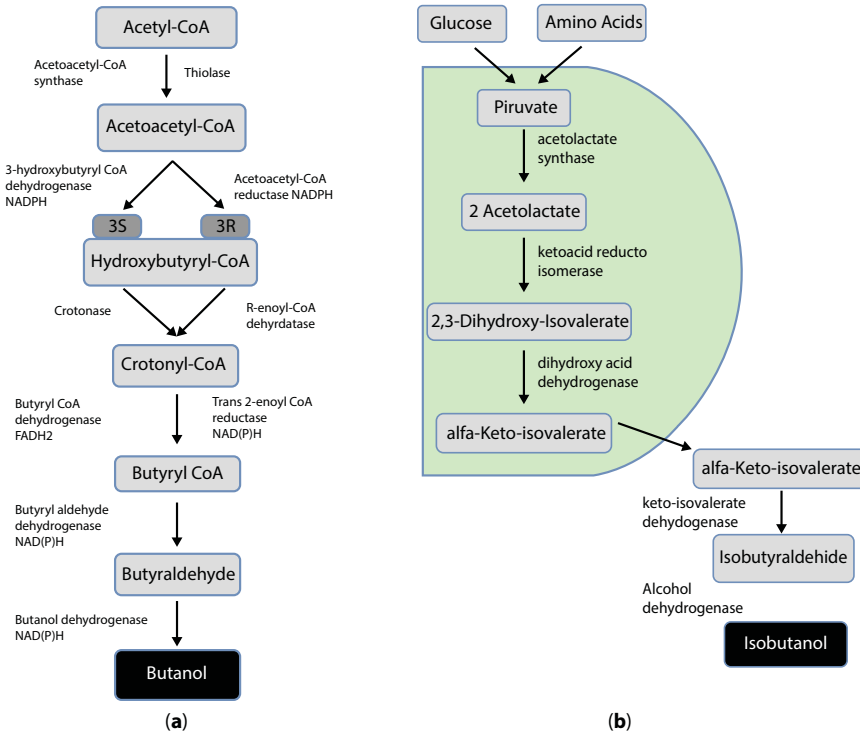

Figure 7.3 (a) Metabolic representation of CoA-dependent pathway for production butanol, (b) Isobutanol synthesis pathway.

substrates and the use of regional crops such as molasses, starch or cellulose for butanol production is one of the approaches to tackle the high-cost of the fermented substrate.

The metabolic representation of butanol (through CoA-dependent pathway) and isobutanol production is depicted under Figure 7.3.

7.4 Natural Producers of Biobutanol

Clostridium sp. is the primary/natural producers involved in the production of biobutanol through the CoA-dependent pathway. The various species utilized for the production include *C. acetobutylicum, C. saccharoperbutylacetonicum, C. beijerinckii, C. saccharoacetobutylicum, C. aurantibutyricum, C. cadaveris, C. sporogenes, C. pasteurianum, and C. tetanomorphum* [14].

In Clostridia sp., acetyl-CoA produced from various carbon sources such as lactose and sugars fermentation through acidogenesis and solventogenesis. Acidogenesis produce acetic and butyric acid whereas solventogenesis produce acetone, butanol and ethanol. To make the process more economical, it is necessary to find a suitable method which shifts the metabolism from acidogenesis to solventogenesis. The primary barrier in the biobutanol production attributed to the adverse effects of the compounds or products obtained after solventogenesis on the microbial cell membrane. Butanol manifests chaotropic effects on the bacterial cell membrane due to which even its concentration as little as 2%, compromises bacterial survival. Therefore it becomes a prime concern to get rid of the toxicity of the solvent products. Deviation of metabolic intermediates from biosynthesis of aliphatic amino acid in yeast is also one of the natural metabolic pathways for biobutanol production. In some yeast species, fusel alcohols are one of the fermentation by-products [15]. In the Ehrlich pathway, keto acids are decarboxylated to produce aldehydes which in turn to alcohols. Since keto acids are the amino-acids precursors such as n-propanol, isobutanol and n-butanol are the precursors of isoleucine, valine and non-valine, respectively. Since isobutanol has a better octane number, therefore, it is preferred over n-butanol for industrial use [16]. The industrial application of isobutanol is hampered by the meager intrinsic production in yeast, but this route of biobutanol production diverts the

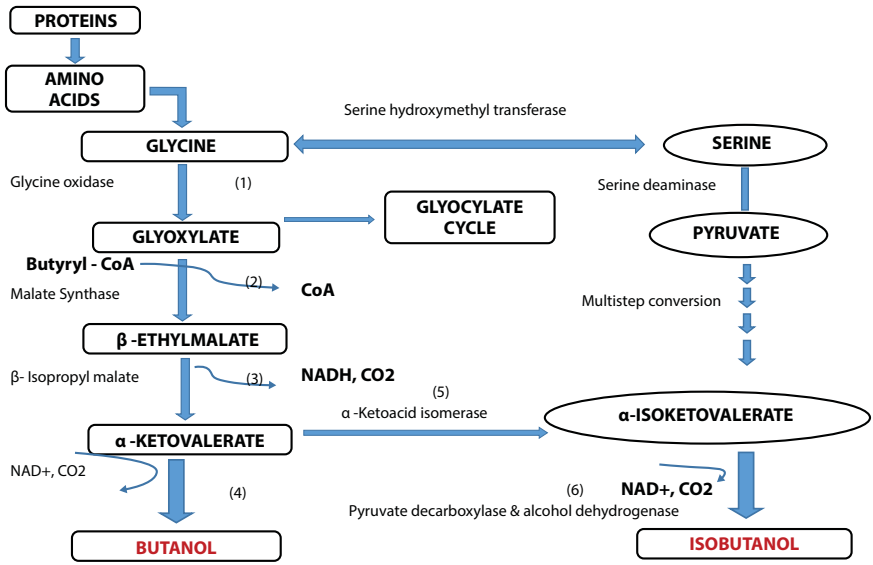

Figure 7.4 Production of butanol and isobutanol by using glycine as a substrate.

various pathway intermediates towards amino acid biosynthesis which usually is not possible naturally [8].

The steps involved in production of butanol and isobutanol are summarized in Figure 7.4.

7.5 Main Obstacles in the Biobutanol Production

The problems associated with biobutanol production were increased cost of feedstock, low butanol titer which further increases butanol recovery and downstream processing, reduced sugar loadings and increased water usage which increases the capital expense. High water usage is not sustainable which further increases the cost of production and it is energy intensive and relatively expensive, low butanol tolerance of the microbes as this much amount of alcohol destroys their cell wall [17].

7.5.1 Approaches to Overcome the Obstacles

To overcome the obstacles, metabolic engineering is one of the alternatives that could adapt for modified strains by overexpressing the butanol production genes such as BCS operon related genes and *add*, *bdh*. Overexpression of grosESL gene lead to improved strain tolerance and increase in butanol titer. Recently, Global transcription machinery engineering (gTME) is another promising approach to enhance biobutanol production. If there is any alteration in the transcription factor, there is a scope for gTME to change the metabolic strength and direction. The gTME system has been proved as an efficient solution to improve substrate utilization and product tolerance [18].

7.6 Engineered Pathways towards a Better Solventogenic Producer

7.6.1 Engineered Pathways in Bacteria

Mutagenesis is gradually becoming a method of choice to improve *C. acetobutylicum*. Several attempts are made in this direction since mutagenesis has helped in improving yield, tolerance to butanol, and sugar source utilization. To increase the efficiency of production, many species of Clostridium have been engineered so that they become capable of utilizing some other carbon sources (liquefied corn flour, glycerol and a mixture

of hydrogen and carbon monoxide) [19]. Acetone has to be removed to improve fuel alcohols in the ABE process which can be done by inactivating *adc* gene which codes for acetoacetate decarboxylase necessary for acetone synthesis [20].

Metabolic engineering is another approach which is used to obtain isopropanol from acetone. A mixture of isopropanol, butanol and ethanol (IBE) produced through engineering of *C. acetobutylicum* by overexpressing the dehydrogenase gene of *C. beijerinckii* in *C. acetobutylicum*. The modified strain is capable to produce more than 99% of fuel alcohol with a negligible amount of acetone. Metabolic engineering helps in improving metabolic fluxes of wild strain to improve yield [21]. The metabolic engineered solventogenic *Clostridia* is able to ferment starchy and molasses towards biobutanol production. Gaseous substrates also serve as carbon substrates for engineered acetogenic *Clostridia* strain; hence there is no competence with the nutritional feedstock as substrate. The major genes involved in the butanol synthesis pathway in *C. acetobutylicum* are *thlA*, *hbd*, *crt, bcd, adhE,* and *bdhA*, which codes for the thiolase, 3-hydroxybutyryl-CoA dehydrogenase, crotonase, butyryl-CoA dehydrogenase, butanol/butyraldehyde dehydrogenase, and butanol dehydrogenase enzymes, respectively. The *Clostridium* butanol pathway genes were introduced into other fast-growing bacteria such as *E. coli,* the engineered bacteria shown butanol toxicity tolerance and is able to metabolize alternative substrates [22]. *Pseudomonas putida* and *Bacillus subtilis* are another bacterial species which can serve as hosts with butanol toxicity tolerance through efflux pumps. *Lactobacillus brevis*, which has a high tolerance to butanol, and can digest C5 and C6 substrates, has also been used.

Another major hindrance to butanol production is the intrinsic kinetic characteristics and cofactor specify of all enzymes that occur naturally in the bacterial pathway. Synthetic pathways are a solution to this limitation which can be made by combining enzymes from different organisms into a synthetic butanol pathway expressed in *E. coli.* To manifest this, the modified strain of *E. coli* is transfected with the vectors carrying genes of two enzymes: 2-keto-acid decarboxylase of low substrate specificity along with an alcohol dehydrogenase. This manipulation resulted in high yields of isobutanol [23]. The 2-keto-acid pathway of *Corynebacterium glutamicum* has also been engineered, taking advantage of the high amino-acid production characteristic of the bacteria. The pretreatment of lignocellulosic materials is another costly affair which can overcome by using *Clostridium cellulolyticum* which can naturally digest lignocellulose. Gaida *et al*. [24], reported for the first time the metabolic engineering of *C. cellulolyticum* where the bacterium was engineered with the CoA-dependent pathway

to produce *n*-butanol directly from crystalline cellulose using NADH as a cofactor.

When natural producers of butanol are intended to use, then the best strategies are those based on the selection of strains, fermentation conditions and best product recovery techniques that may avoid toxicity or enhance the fuel concentration by avoiding the production of acetone or isopropanol. The introduction of the metabolic pathway for ABE fermentation in other bacteria possesses several advantages such as non-requirement of anaerobic fermentations with fast-growing or butanol toxicity tolerance abilities. A two-fold increase in the concentration of fuel has been observed in comparison to natural strains of *Clostridium acetobutylicum* when the non-natural producer bacteria engineered with the 2-keto-acid pathway. A metabolic approach is a promising area in biobutanol production to attain higher yields [25].

7.6.2 Engineered Pathways in Yeast

Although bacterial systems such as *E. coli* have been known to show more efficient systems for biobutanol production, the engineered *Sacchromyces cerevisae* system has also been proved as quite an efficient system to produce biobutanol. Production of biobutanol through yeast systems have some positive attributes such as adaptability in various application sectors and have greater reproducibility. Moreover, the bacterial-based biobutanol system suffered from disadvantages like the requirement of strictly anaerobic conditions, complex downstream processing, narrow pH requirements and infection prone due to phages and viruses. However, these limitations can be overcome by utilizing yeast-based systems especially *S. cerevisae*-based system.

S. cerevisiae have the enzyme machinery to synthesize isobutanol by a two-compartment *Ehrlich* pathway. In this pathway, keto-isovalerate, which is an intermediary product of valine synthesis in mitochondria, is catabolised into isobutanol. Genes *ILV2*, *ILV5*, *ILV3*, encode for the enzymes acetolactyl synthase, ketoacid reductasoisomerase, and dihydroxy acid dehydratase respectively, are majorly involved in isobutanol synthesis. Overexpression of these genes leads to enhanced biobutanol production. The above genes mentioned above are present in mitochondria, so this system can replace in cytosol which is done by overexpression of cytosolic form encoded by ILV2, ILV5, ILV3, ARO10 with deletion of mitochondrial ILV2 associated genes. To increase dihydroxyacid dehydratase encoded by ILV3 or to improve the cofactor associated with it, many additional genetic manipulations were researched to enhance other by-products besides

ethanol. With the combination of these strategies, more than 80% of the maximum isobutanol theoretical yield achieved. Codon usage linked with cytosolic pathway than using from associated mitochondrial systems has too proved to be a useful technique. In one of the alternatives, the catabolic pathway of amino acids which resulted from protein hydrolysis was utilized [26]. Many researchers have reported the use of glycine as the substrate for the synthesis of butanol and isobutanol in *S. cerevisiae* through glyoxylate pathway. Various genetic engineering approaches have been utilized to change the metabolic activities in *S. cerevisiae.* These include reconstruction of the 1-butanol biosynthetic pathway through increased flux towards cytosolic acetyl-CoA by means of the transformation with a plasmid expressing the genes (encode for *ADH2* (alcohol dehydrogenase), *ALD6* (acetaldehyde dehydrogenase), *ACS1/ACS2* (acetyl-CoA synthetase), and *ERG10* (acetyl-CoA acetyltransferase) enzymes). An endogenous 1-butanol pathway in *S. cerevisiae* which was dependent on catabolism of threonine, was proposed, discovered, characterized and engineered by Si *et al.* [27]. Various strategies have been introduced to achieve the higher 1-butanol titer in S.cerevisiae which include the overexpression of the Ehrlich pathway enzymes, and single gene deletion adh1delta (which cause a deficiency of alcohol dehydrogenase) was proposed [27].

Matsuda *et al.* [28], reported enhanced biobutanol yield by utilizing *S. cerevisiae*-based metabolic engineering approach. The strains engineered in such a way that they lacked the genes of pyruvate dehydrogenase complex LPD1 to reduce the competition between pyruvate supply for isobutanol and acetyl Co-A biosynthesis in mitochondria. The genes of the enzyme transhydrogenase-like shunts (converts NADH to NADPH) were overexpressed to resolve the cofactor imbalance. Endogenously, α-ketobutyrate is a key intermediate in n-butanol production pathway. Usually, α-ketobutyrate is synthesized from catabolism of threonine and alternately it can be synthesized from acetyl Co-A via Citramalate synthase (Cim A) (Figure 7.5). Through this approach, a maximum theoretical n-butanol yield of 411 mg/g glucose was achieved. The maximum theoretical n-butanol yield reported a value of 411 mg/g glucose through this approach. Further research has been done to improve the n-butanol production by cloning and overexpressing the CimA genes from *Methanococcus jannaschii*, *Leptospira interrogans*, and *Geobacter sulfurreducens* with previously confirmed α-ketobutyrate utilizing genes (mLEU1, mLEU4, mLEU2, and LEU5). The strain *LI* with overexpressed *Cim A* from *L. interrogans*, showed high improved n-butanol titer of 349 mg/L. The yield obtained was far higher than the strain *THRm* solely

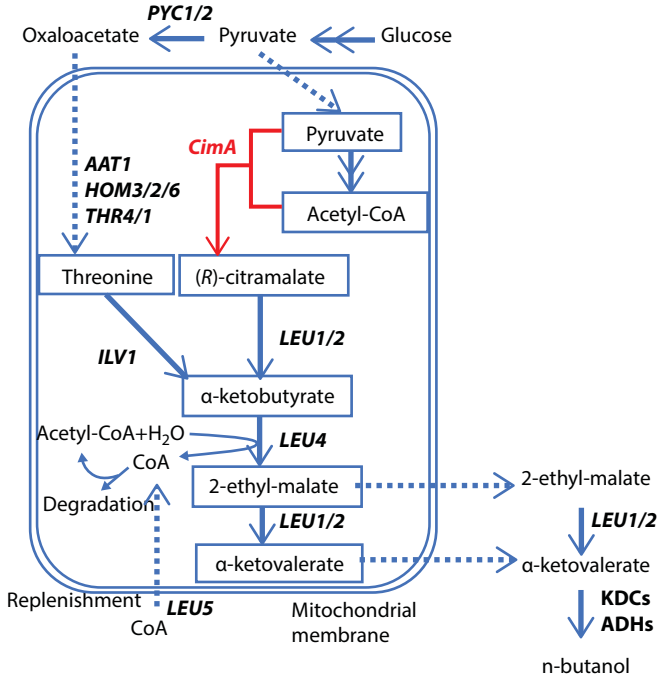

Figure 7.5 The synergistic pathway for *n*-Butanol production via the endogenous threonine pathway and an introduced CimA mediated pathway (Atsumi *et al.* [29]). Single and double arrows represent single and multiple enzymatic steps, respectively; red arrows represent heterologous pathways; overexpressed genes are marked with red colour. KDCs: keto-acid decarboxylases; ADHs: alcohol dehydrogenases.

overexpressing the threonine pathway. The strain LI, uses two metabolic pathways to synthesize butanol, i.e., the endogenous threonine pathway and the introduced citramalate pathway. This synergistic path leads to a maximum theoretical yield of 411 mg/g glucose n-butanol [30].

7.7 *In-Situ* Butanol Recovery Integrated with Batch and Fed-Batch Fermentation

There were many problems and disadvantages associated with the traditional fed-batch system. One of such problems was increased solvent toxicity during the biphasic batch butanol fermentation. *In-situ* recovery process integrated with fed-batch culture is the ideal setup to overcome the

solvent toxicity using silicone and oleyl alcohol as pre-extraction solvents along with the utilization of silicon membrane [31]. The butanol extraction process through diffusion was carried out using silicone membrane which limits the diffusion of acetone and acids that subsequently results in higher biobutanol yield. Gas stripping was another batch process method where a semi-synthetic medium with embedded lactose which was entirely fermented by *C. Acetobutylicum*. The integration of gas stripping setup with the liquid-liquid extraction process results in higher utilization of lactose which led to the enhanced biobutanol production [32].

The lower yields of butanol production through traditional fermentation process were mainly due to the accumulation of butanol in the fermentation broth. Butanol removal from the fermentation broth and its separation was a costlier process. To avoid such problems addition of butyrate as a precursor to the system is the ideal approach to trigger the metabolic pathway towards the butanol production and further promising results were attained through the integration with *in-situ* butanol removal via vacuum membrane distillation [33] which alleviates the butanol toxicity issues. This integration is a very effective method to enhance the butanol yield with higher economic feasibility with easier downstream processing**.** Another approach for enhanced biobutanol titers was opting for adsorbent based fermentation along with renewable carrier [34]. Alkali-treated steam explodes straw showed as a suitable carrier for adsorbent fermentation of biobutanol. The adsorption of ABE solvent on substrate facilitates the increased bacterial concentration alleviation of the end product inhibition with improved biobutanol production features.

7.8 Future Prospects

The future of the industrial process for the production of biobutanol can improve by utilization of novel omics-based approaches and sophisticated downstream processes. *Clostridium acetobutylicum* is the most intensively studied solvent-producing species involved in biobutanol production. A thorough investigation of existing metabolic pathway towards biobutanol production helps in pinpointing the responsible genes, and its overexpression in different hosts. Advances in continuous culture technology, integrated fermentation processes, *in situ* product removal and improved downstream processing can also provide new approaches to improve the substrate utilization that also provides a future direction of economic biobutanol production by reducing butanol toxicity and process stream volumes towards the enhanced bioreactor performance.

7.9 Conclusions

Biobutanol is also a superior biofuel and in a very long term has been shown to meet the demands for the next-generation biofuels. Production of biofuels is even considered as a useful means to slow down carbon dioxide emissions; this is also a green industry with ecological benefits to humankind, and that could also contribute to decreasing the present concerns over global climate change. Production of biobutanol through Clostridium sp. in higher volumes is a viable strategy to compete with the chemical-based butanol production. Recent advances in bioethanol plants could be cost-effectively retro-fitted for biobutanol production requiring relatively minor changes to fermentation. The lower titers associated with the biobutanol production with the Clostridium sp. can resolve by utilizing the novel engineering, metabolic approaches coupled with integrated recovery processes.

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Comparative Analysis of Ensemble Methods for Classification of Android Malicious Applications

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Abstract. Currently, Android smartphone operating systems are the most popular entity found in the market. It is open source software which allows developers to take complete benefit of the mobile operation device, but additionally increases sizable issues related to malicious applications. With the increase in Android phone users, the risk of Android malware is increasing. This paper compares the basic machine learning algorithms and different ensemble methods for classifying Android malicious applications. Various machine learning algorithms such as Random Forest, Logistic Regression, Support Vector Machine, K-Nearest Neighbor, Decision Tree and Naive Bayes and ensemble methods like Bagging, Boosting and Stacking are applied on a dataset comprising of permissions, intents, Application programming interface (API) calls and command signatures extracted from Android applications. The results revealed that the stacking ensemble techniques performed better as compared to the Bagging, Boosting and base classifiers.

Keywords: Android malware classification · Machine learning · Ensemble techniques · Bagging · Boosting · Stacking

1 Introduction

Android is the widely used mobile platform across the world with more than 85% of the market share [1]. The increasing use of Android-based applications (apps) is causing the growth of malware. Nearly 17.5 million Android users downloaded malicious applications from the official Google Play Store in 2017 [2]. These malicious apps create several serious threats such as information leakage, system damage and financial loss etc. According to the McAfee report [3], the growth of Android malware is increasing rapidly with approx 750 million in 2018. Android malware may be embedded in various applications such as gaming, educational and banking apps etc. These infected applications can compromise privacy and security by permitting unauthorized access to rooting devices, private sensitive information, etc. Earlier, most of the malware detection methods were based on signature-based approach. It uses a database of known malware signatures and compares each application against this database. The drawback of this method is that it is not suitable for detection of new

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malware (i.e. zero-day malware) whose signatures do not exist in the database. Recently, researchers started to use machine learning methods for malware classification. The problem in machine learning technique is that it gives high false positive and false negative rate [4]. Ensemble techniques such as Bagging, Boosting and Stacking are applied in order to improve accuracy. The goal of this paper is to compare the different ensemble methods for Android malware classification. The paper is organized as follows: Sect. 2 provides an overview of related work. Section 3 presents the approach used. Section 4 provides the experimental results and their comparative analysis. Finally, Sect. 5 presents the conclusion.

2 Literature Review

In this section, numerous contributions have been explored with the aid of the researchers in the field of Android malware detection using machine learning. Zhou and Jiang [5] characterized existing Android malware from diverse components, including the permissions requested. They recognized the permissions which are extensively asked in both benign and malicious apps. The author found that malicious apps have a tendency to request extra permissions than benign ones. In 2012, Sanz et al. [6] introduced a new technique to detect Android malware applications through machine learning strategies with the aid of analyzing the extracted permissions from the application itself. In [7], the author presented a method MAMA that extracts numerous features from the Android manifest to build classifiers and detect malware. Huang et al. [8] presented a technique for detection of Android malicious applications based on 20 features. Their experimental results show that an individual classifier is able to detect about 81% of malware applications. In [9], the author developed a tool named Marvin that creates a risk by examining an application using static and dynamic features. In 2015, Bhandari et al. [10] developed an approach DRACO that combines both static and dynamic analysis. It explains the features that contributing to the maliciousness of the examined application and generates the score. In [11], the author introduced SigPID named as Significant Permission Identification for detection of Android malware. The detection device based totally on permission usage to deal with rapid growth in Android malware. SigPID used machine learning based classification method such as SVM and Decision tree to classify the apps into malware or benign. The results show that SVM achieves 90% of recall, precision, F-measure and accuracy. In 2015, Cen et al. [12] proposed a malware detection method primarily based on permissions and API calls. They applied probabilistic discriminative model based on RLR (Regularized Logistic Regression) and compared with other classifier named as K-NN, decision tree, SVM and Naive Bayes. Yerima et al. [13] proposed a novel classifier fusion approach named as DroidFusion which is based on the multilevel architecture that enables the combination of algorithms for improving the accuracy. They applied the various ranking algorithm on their predictive accuracy in order to drive final classifier. Their experimental results show that the fusion method performs better for improving accuracy than the ensemble learning algorithm. Wang et al. [14] applied a different machine learning algorithm named as SVM, Random Forest and Logistic regression with static analysis for detection of Android malware apps. For training machine

learning algorithms they used platform-specific static features and app specific static features. Experimental results demonstrate that logistic regression performs better in comparison to other classifiers with 96% of TPR (True Positive Rate) and 0.06% of FPR (False Positive Rate). In [15], the author introduced a novel dynamic evaluation framework, referred to as EnDroid, which automatically extracts multiple varieties of dynamic features to implement effective malware detection. For effective detection of malware, they applied the stacking ensemble technique. Their experimental outcomes show that stacking perform better for the detection of Android malware. This paper presents a comparative analysis of base classifiers and ensemble methods for classification of Android applications.

3 Methodology Used

This section discusses the approach followed for comparing the machine learning algorithms and ensemble methods for detecting and classifying Android applications into malicious and benign. First of all, a dataset [5] comprising of permissions, intents, API calls and command signatures extracted from Android malicious and benign applications is downloaded. Six machine learning algorithms i.e. Naive Bayes (NB), Random Forest (RF), Logistic Regression (LR), K-Nearest Neighbor (K-NN), Decision Tree (DT) and Support Vector Machine (SVM) and three ensemble technique i.e. Bagging, Boosting and Stacking are applied on the dataset using WEKA (Waikato Environment for Knowledge Analysis) [16] library and their performance is evaluated based on different parameters. For stacking ensemble technique, the topmost four classifiers (on the basis of accuracy) are combined in the group of three making four different combinations. The LR is used as level-2 meta-classifier in stacking. Afterward, comparative analysis is carried out on the results obtained. The details of the dataset used, machine learning and ensemble algorithms used are given in the following sub-sections. Figure 1 depicts the methodology of the proposed work.

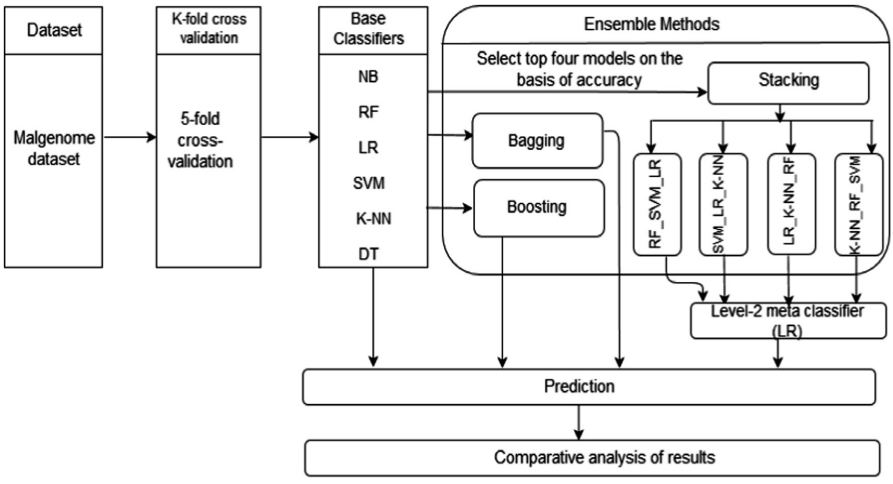

Fig. 1. Workflow of methodology used

Dataset Used
Malgenome [5] dataset is used for this work. It consists of 3800 number of instances which includes 1260 malware and 2539 benign. There are total 215 attributes which are categorized into 4 parts i.e. API Call Signature, Manifest Permission, Command Signature, and Intent. At the time of installation, the permission is granted by the users and these are declared in Android-Manifest file. API calls are needed to interact with the device. Intents are also described in the Android Manifest file. It is the conceptual information about an operation, with which we can infer the intentions of the apps.

Base Classifiers

Decision Tree
The DT [17] is used for building regression and classification model in the form of a tree structure. It focuses on an easily understandable representation form and is one of the most common learning methods. It can easily be visualized in tree structure format. A decision tree is built by iteratively splitting the dataset on the attribute that separates the data into the different existing classes until a stopping criterion is reached.

Random Forest
RF [18] is an ensemble learning method that creates numerous regression trees and aggregates their results. It trains every tree independently by the usage of a random sample of the data. This randomness allows making the model more powerful. The random forest model is excellent at managing tabular records with numerical functions or categorical functions with fewer than loads of categories.

Support Vector Machine
The SVM [19] algorithm, uses hyperplane to divide the n-dimensional space data into two regions. It calculates the maximal margin between all dimensions i.e. it is creating the largest distance between instances, which is reducing the generalization Error. The basic approach to classify the data starts by trying to create a function that splits the data points into the corresponding labels with (a) the least possible amount of errors or (b) with the largest possible margin.

Naive Bayes
NB [20] is a classification technique based on Bayes' theorem. This classifier is widely using in text estimation. For instance, many spam filters are using it in order to divide acceptable content from unacceptable. Usually, the accuracy of this method is relatively low in contrast with other approaches. However, an advantage of this technique is a very high speed of classification and also a very good level of tolerance to missing values. Additionally, NB algorithm characterized by low tolerance to redundant attributes. Continuous features are not permitted here.

K-Nearest Neighbor
K-NN [21] model is also a type of supervised learning algorithm. It is the simplest and easy than other machine learning techniques. This algorithm is representative of lazy algorithms. It is based on the assumption that records within a dataset are generally having the same properties. K-NN algorithm is relatively slow in the classification of

new instances coming into the model but fast during the training process. Also, this algorithm is very sensitive to noise in the dataset.

Ensemble Techniques

Bagging: Bagging is also known as **B**ootstrap **Agg**regat**ing**. Multiple models of the same learning algorithm are generated over a subset of the training dataset using random sampling with replacement. For combining the models, the two methods are used i.e. majority voting and averaging. In majority voting, the final prediction is done on the basis of votes of each classifier. In averaging, it takes an average of the predictions of each classifier. In our work, we have used the majority vote method. Bagging helps to avoid the problem of overfitting and can reduce variance [22].

Bagging Algorithm

For training:

1. Repeat step 2 to 3 for each iteration i = 1, 2, …, n
2. Create bootstrap samples of the training dataset using random sampling with replacement.
3. Train different classifiers on these samples (NB, K-NN, DT etc.)

For testing:

1. Use a new dataset, to make predictions using base classifiers.
2. Combine the results of all models on the basis of majority voting.

Boosting: This method is used for improving the predictions of the model. Boosting technique selects instances which give the wrong prediction and modify the weights. Boosting is a little variation on bagging. In boosting, firstly equal weights are assigned to all instances. Train the classifiers to make predictions of wrongly classified instances then modify the weights of incorrectly predicted instances. In the end, take the weighted mean of all weak learners to make a strong learner i.e. final model [23]. There are different boosting algorithms such as AdaBoost, Gradient Tree Boosting and XGBoost. The AdaBoost (**Ada**ptive **Boost**ing) algorithm is used to perform boosting in our work.

Boosting Algorithm

1. Assign equal weights to all instances.
2. Train the classifier to make predictions.
3. Assign higher weights to wrongly classified instances.
4. Repeat step 2 & 3 till the classifier correctly predict the instances.

Stacking: Stacking is also known as stacked generalization. It deals with combining multiple classifiers generated by different machine learning algorithms. The process of stacking can be divided into two phases: In the first phase, all the algorithms are trained using the training data. In the second phase, the predictions from multiple models are used as input to the second level to build a new model. This model is used for the prediction on test data [24].

Stacking Algorithm

1. Select topmost four classifiers (on the basis of accuracy) combine these in the group of three making four different combinations.
2. Train these models using a complete training dataset.
3. Construct a new dataset of predictions made from multiple base-level classifiers.
4. Train a meta-model i.e. LR using the new dataset created in step 3.
5. Make predictions using this newly formed model.

4 Experimental Results

This section discusses the experimental results obtained. Six different classifiers i.e. NB, LR, RF, K-NN, DT and SVM (explained in Sect. 3) are executed on WEKA 3.8 under Intel Core i3 processor, 64 bit, 2 GB RAM. All the classification models and ensemble methods are trained using 5-fold cross-validation. The parameters used for evaluating various models are True Positive Rate (TPR), False Positive Rate, Precision, F-measure and Accuracy.

Table 1. Performance evaluation of base classifiers

Classifier	TPR	FPR	Precision (%)	F-measure (%)	Accuracy (%)
NB	0.959	0.044	95.9	95.9	95.8
RF	0.991	0.016	99.1	99.1	99.0
LR	0.974	0.026	97.4	97.4	97.3
SVM	0.990	0.011	99.0	99.0	99.0
K-NN	0.986	0.015	98.6	98.6	98.5
DT	0.970	0.037	97.0	97.0	96.9

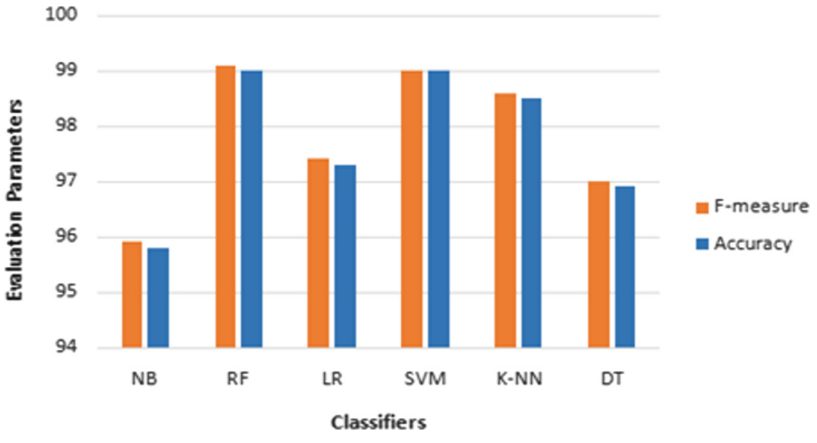

Fig. 2. Comparative analysis of base classifiers

Table 1 represents the result of six base classifiers. The results show that SVM and RF give the best accuracy i.e. 99% followed by K-NN which gives an accuracy of 98.5%. The TPR of RF and SVM is also high i.e. 0.99 and FPR is low i.e. 0.016 (RF) and 0.011 (SVM) respectively.

Figure 2 represents the comparison of six base classifiers on the basis of F-measure and Accuracy. Herein SVM and RF classifiers are proved to be the best among used base classifiers for the Malgenome dataset.

Table 2. Performance evaluation of classifiers using bagging ensemble technique

Classifier	TPR	FPR	Precision (%)	F-measure (%)	Accuracy (%)
NB_Bagging	0.961	0.042	96.1	96.1	96.0
RF_Bagging	0.992	0.016	99.2	99.2	99.1
LR_Bagging	0.979	0.021	97.9	97.9	97.9
SVM_Bagging	0.989	0.011	99.0	98.9	98.9
K-NN_Bagging	0.988	0.015	98.8	98.8	98.8
DT_Bagging	0.985	0.021	98.5	98.5	98.4

Table 2 represents the performance of six different classifiers using Bagging ensemble technique. The results show that classifiers with bagging namely NB, LR, RF, K-NN and DT give better results as compared to base classifiers. There is no improvement in results using the bagging technique in case of SVM because bagging work well with unstable classifiers. There is a minor improvement in TPR and FPR for classifiers with Bagging as compared to the base classifiers.

Table 3 depicts the performance of six classifiers using Boosting ensemble technique. The results show that all the classifiers with boosting except SVM give better results as compared to base classifiers. It is found that classifiers with AdaBoost algorithm have performed better than classifier with bagging ensemble technique with majority voting. There is an improvement in TPR and FPR for classifiers with AdaBoost algorithm as compared to the classifiers with bagging.

Table 3. Performance evaluation of classifiers using boosting ensemble technique

Classifier	TPR	FPR	Precision (%)	F-measure (%)	Accuracy (%)
NB_Boosting	0.977	0.030	97.7	97.7	97.7
RF_Boosting	0.992	0.013	99.2	99.2	99.2
LR_Boosting	0.974	0.026	97.4	97.4	97.3
SVM_Boosting	0.988	0.014	98.8	98.8	98.8
K-NN_Boosting	0.986	0.015	98.6	98.6	98.6
DT_Boosting	0.991	0.012	99.1	99.1	99.0

Figure 3 represents the comparison of the base classifiers with bagging and boosting ensemble technique on the basis of F-measure. Both Bagging and Boosting showing better accuracy than base classifiers. Adaboost with NB and DT are performing better than their bagged versions. Bagging with LR and K-NN has better accuracy than their boosted version. Bagging and Boosting with RF is giving almost same result.

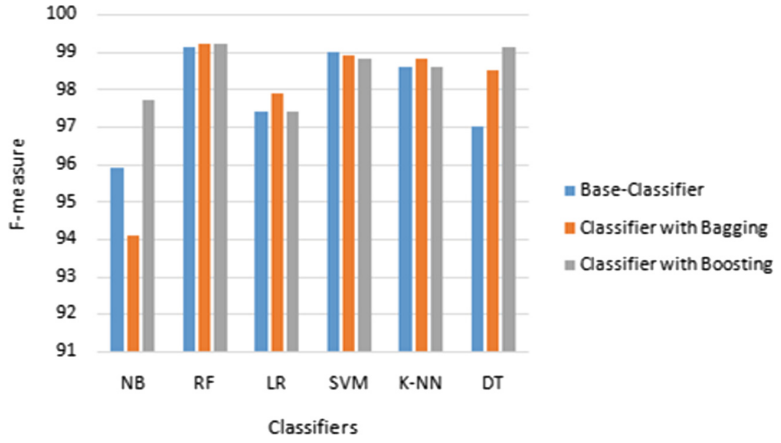

Fig. 3. Comparison of the base classifiers with bagging and boosting ensemble techniques on the basis of F-measure

Herein classifier with boosting i.e. NB, RF and DT are the best among other classifiers. The classifier with bagging is also performing better with some classifiers i.e. RF, LR and K-NN.

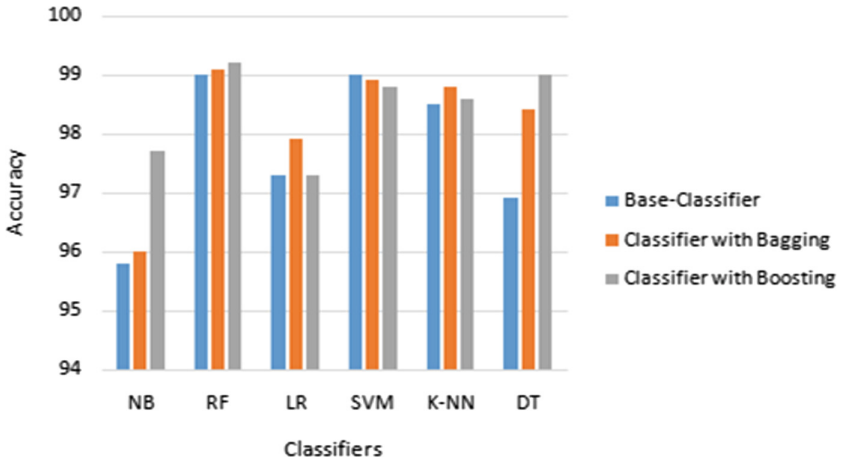

Fig. 4. Comparison of the base classifiers with bagging and boosting ensemble techniques on the basis of Accuracy

Figure 4 represents the comparison of the base classifier with bagging and boosting ensemble technique on the basis of Accuracy. Herein classifier with boosting namely NB, RF and DT are shown to be the best among other classifiers. The classifier with bagging is also performing better with some classifiers i.e. LR and K-NN.

For applying stacking ensemble method, we ranked the base classifiers on the basis of their accuracy. The ascending order of top four base classifiers is LR, K-NN, RF and SVM. Following four stacked ensemble models (each consisting of three base classifiers out of the top four) are designed and tested on the Malgenome dataset using 5-fold cross-validation.

M1 (RF_SVM_LR)
M2 (SVM_LR_K-NN)
M3 (LR_K-NN_RF)
M4 (K-NN_RF_SVM)

Table 4. Performance evaluation of four stacking ensemble models

Ensemble models	TPR	FPR	Precision (%)	F-measure (%)	Accuracy (%)
RF_SVM_LR	0.993	0.008	99.3	99.3	99.3
SVM_LR_KNN	0.992	0.011	99.2	99.2	99.1
LR_KNN_RF	0.993	0.009	99.3	99.3	99.2
KNN_RF_SVM	0.993	0.009	99.3	99.3	99.2

Stacking ensemble method uses a stack of classifiers in order to achieve better results as compared to the individual classifier. The Logistic regression is used as level-2 meta-classifier. Table 4 represents the performance of four ensemble models. The results show that almost all the four models designed using stacking ensemble techniques perform better than the base classifiers and other ensemble methods i.e. Bagging and Boosting. The accuracy obtained by RF_SVM_LR is 99.3% followed by LR_K-NN_RF and K-NN_RF_SVM which provide an accuracy of 99.2%.

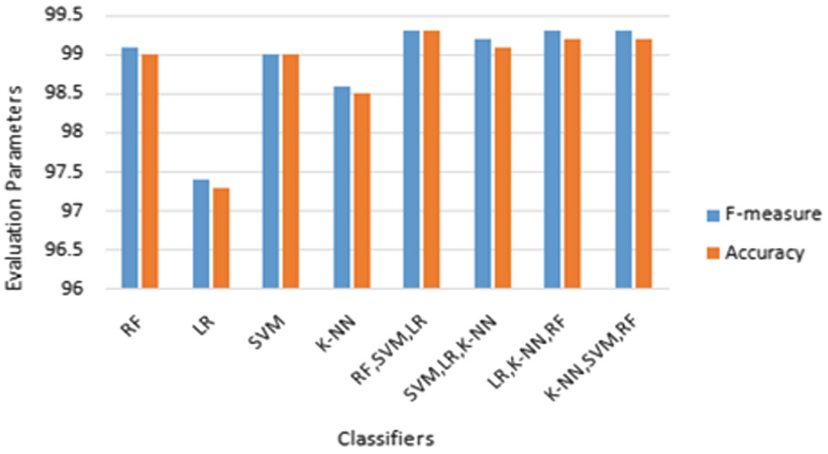

Fig. 5. Comparison of top four base models and stacking ensemble models

Figure 5 depicts the comparative analysis of the top four base models with the stacking ensemble approach in terms of F-measure and Accuracy. The stacking ensemble approach gives the highest accuracy to classify malicious apps. It is clear from the results that the models designed with stacking ensemble technique show significant improvement over base classifiers.

5 Conclusion

With the increase in Android phone users, the risk of Android malware is increasing. So there is a need to develop an effective technique for better classifying the malware. This paper presented a comparative analysis of base classifiers and three ensemble techniques i.e. Bagging, Boosting and stacking for classifying Android apps. It is concluded that ensemble techniques perform better as compared to the base classifiers. Further stacking ensemble technique outperforms in comparison to Bagging and Boosting ensemble technique. The comparison is done on the basis of F-measure and Accuracy. It is revealed from the results that the overall stacking ensemble model has improved accuracy in contrast to the base classifier accuracy. The result shows that the combination of RF_SVM_LR performs better as compared to the other ensemble models. The accuracy obtained is 99.3%.

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QoS Based Resource Provisioning in Cloud Computing Environment: A Technical Survey

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Abstract. Cloud computing is one of the computing methodology that can address the on demand requirement of most of the applications in efficient manner. This system also permits the pay-per usage rating model for the purpose of computing services which are delivered to the end users throughout the globe using Internet. Because of reduced resources it becomes very difficult for the cloud purveyors to offer all the end users their required services. One such challenge raised by the cloud application is management of Quality of Service (QoS) that is the matter of allocating resources to provide assured service on the basis of availability, performance and reliability. From the cloud vendors impression of cloud resources can be assigned in a reasonable manner. Thus it is at most importance to meet the QoS requirement and satisfaction level of cloud users. This paper aims at the study of various researchers in the field of Resource allocation and resource availability in cloud computing environment based on QoS requirements.

Keywords: QoS · QoE · Cloud computing · Resource availability · Resource allocation · Scheduling

1 Introduction

With the recent advancement in various technologies, cloud computing has emerged as a new paradigm providing various services to the end user. It has various characteristics which include multitenancy, scalability, productivity and performance [1]. Cloud computing refers to operations such as distribution of services over the web, hardware, and system software that grants the various required services in the data centres. At the same time cloud computing also faces some challenges like limited control to the end user, security, privacy and many quality issues [2]. Some of the quality issues are like Quality of Service (QoS) and Quality of experience (QoE) have a huge impact on cloud computing environment. Basically QoE is a subset of QoS that also endeavors the amount of service parameters. Services like cloud computing storage or computer network

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falls under QoS which is defined as the amount of overall performance of the service. Further emergence of IoT has made this challenge more critical to tackle due to continuous interaction of user with the system.

IoT and cloud have developed into two very closely related internet technologies providing support to one another. Some previous studies have provided the evaluation model for QoS but to our knowledge no evaluation models have been proposed for IoT based applications based on QoE [3,4]. IoT based application are devices on web that collect data on real time basis which some time can result in late delivery of data. This late delivery of data affects QoE in many ways as it is not efficient enough for the end user to use IoT application devices [5]. To overcome from this issue one can do computations near to data generating devices which improves QoE in turn.

QoS is defined as the estimation on the whole performance of a service whereas QoE is defined as the level of user satisfaction over a service or product. QoS is basically a set of procedures that helps to manage the network resources based on some attributes. There are various attributes in QoS which are helpful in making the quality of services or applications better than their previous results. QoS and QoE are two quality issues which are interlinked with each other as they both helps in improving the quality of services and applications used in cloud [5]. Figure 1 shows the relation between various qualities aspects related to one single quality issue that is quality of service (QoS). All these quality aspects such as quality of data (QoD), quality of information (QoI) and quality of performance (QoP) share some indistinguishable attributes. As we know that QoE is directly related to QoS which results in mapping of the QoS into the users perceived QoE. Also, QoS is affected by various aspects of QoS which can be technical or non-technical. Technical aspects include the end to end network delay, coverage area and equipment flexibility whereas non-technical includes the support to customers, price decision based on service and providing services to the end user. QoS and QoE are equally important in providing good quality services to the applications.

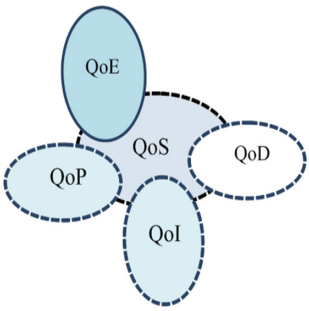

Fig. 1. Relationship of various quality metrics with QoS.

2 QoS Models

For delivering good quality characteristic, QoS is useful for cloud consumers who expect this and for the cloud purveyors, whoever requires the trade-off between the QoS levels and the operational cost. Various QoS based models have been proposed in the field of cloud computing to handle the challenges like security and privacy, latency, resource scheduling, fast internet speed, energy consumption, load balancing, service composition and performance, as represented in Fig. 2 [6]. The major issue in cloud is of security and privacy, as there is no control on data which is being transferred or received. Performance is another issue in cloud computing that consider the capability of cloud organisation. Resource scheduling in cloud is considered at various levels namely hardware, software, security and privacy and further other features are dependent on management and resources. The QoS here means the availability, reliability and level of concert on hand with the help of a platform. QoS is basic for cloud users and expect from the purveyors to deliver the declared features. In this technical survey we have discussed the issues related to resource allocation based on QoS in cloud computing environment. QoS can be improved by balancing the load on various machines by consecutively reducing the delay. Further using these system models the values of QoS such as availability, reliability and response time are evaluated. There are various QoS methods like resource management, admission control mechanism, scheduling mechanisms, performance models and monitoring mechanisms [8]. All these mechanisms provide a closer view about the current methods, techniques and the applications to cloud computing problems.

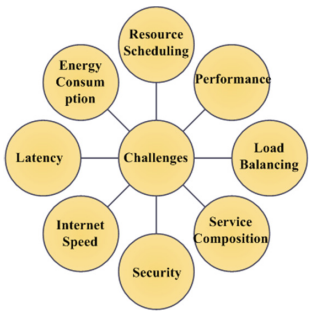

Fig. 2. Relationship of various quality metrics with QoS.

2.1 Cloud Based Model

The term cloud computing can be portrayed as the organised device mechanism in which the users would be able to utilize the computing applications [9–12]. The main objective is to make the storage infrastructure and computing available for

the end users regardless of their location and time. However, various cloud based models have been proposed in the field of the trust management, load balancing and queuing model but still a lot of improvement is required to obtain better QoS [13]. Here, Table 1 summarizes various cloud based models proposed over the period of time.

2.2 Cloud Computing Challenges

There are various challenges [30] which have serious risk to the end user satiability factor. All these challenges are listed as follows:

- **Resource Scheduling** [6]**:** It is a challenging job and scheduling particular resources to cloud efforts relies on the QoS demands of cloud appliances. In cloud computing environment issue such as uncertainty, heterogeneity and dispersion of resources discovered the resource allocation problem which cannot be considered with available resource allocation strategies.
- **Security** [6]**:** It is one of the main issue which leads to causing risk for a huge amount of data stored on cloud in different locations even in all over globe. Through many approaches on the subject in cloud computing, data privacy and security are more significant for the forthcoming growth of cloud computing technology in industry and government.
- **Performance** [6]**:** It is also one of the important issue which measured the power of cloud organisation. The results might not come out to be good enough with respect of some parameters such as memory, CPU speed and bandwidth.
- **Load balancing** [6]**:** With the help of this technique in cloud computing workload has been scattered among all the nodes. Basically it is used to get in touch with great consumers and evaluate the proportion of resources to make sure none of the nodes are overloaded.
- **Service Composition** [13]**:** Due to ebullient development of the services which are offered cloud service agents faces some difficulties in delivering the quality of service advancements.
- **Fast internet speed** [6]**:** With the support of cloud systems, business gets the ability to keep money on hardware and software however requires overspending on bandwidth. This is not feasible to fully utilize the services of cloud with low speed communication channels.
- **Latency** [6]**:** One of the major issues in cloud computing environment which causes difficulties in the enjoyable and usable devices. Latency in the data exchanges over the Internet can be much higher. This delay can cause increase in the costs to users of several cloud services.
- **Energy Consumption** [16]**:** Amazon conducted a survey which conveys the cost depletion of its data centres to be 53% and the entire cost is used by the servers. The CPU, memory, disk storage and network are important consumers of energy in a server.

Table 1. Cloud based models

S.No.	Category	Authors	Proposed model	Description/advantage	Challenges
1.	Trust model	Manuel [9]	Trust Management system	Considers only four parameters like turnaround time, availability, reliability and data integrity	No information about parameters like Honesty, utilization of resources, and return on investments
		Chandrasekar [14]	To monitor QoS and trust using Markov chain model	Proposed model is used to establish the trust and compression technique	Issue of trust on service provider need to be considered
		Abbadi and Alawneh [15]	Proposed a framework for developing trust in cloud	Framework helps in addressing the identified challenges	Issues related to scheduling need to be improved
2.	Load balancing	Zhao and Huang [13]	Developed a load balancing model COMPARE AND BALANCE	The problem of intra cloud load balancing is resolved using proposed model through the adaptive live migration of virtual machines	This model does not support affinity and anti-affinity
		Maguluri et al. [6]	Proposed a stochastic model for cloud computing cluster	This model discusses resource allocation problem for scheduling and load balancing in cloud computing	Proposed model disscusse only about resource allocation and consider the parameters like throughput and delay for performance improvement

(*continued*)

Table 1. (*continued*)

S.No.	Category	Authors	Proposed model	Description/advantage	Challenges
		Peng et al. [7]	Proposed a bee colony load balancing algorithm based mathematical model	Discusses about the cloud task scheduling process	Discussed load balancing issue in cloud using bee colony algorithm only
		Bhandari and Kaur [16]	Proposed an algorithmic model based on the availability of Virtual machine (VM)	Availability index value is calculated for each and every VM over a to assign tasks	They have not evaluated appropriate load in real time
3.	Security and privacy	Choi et al. [17]	Proposed an ontology based access semantic model	This model help in identifying the variation between service provider and user in permitted access control	This model can address the limitation of cloud computing only for dynamic access control
		Wei et al. [18]	Proposed a secure computation auditing and privacy cheating discouragement protocol is proposed	This protocol provides data security in cloud	They have not formalized the security model in cloud
		Kavin and Ganapathi [19]	Chinese Remainder theorem (CRT) based data storage model	This model helps in storing data more securely using cloud database	Implements traditional encryption and decryption techniques only
		Al-Sharhan et al. [20]	Proposed a security framework for cloud computing environment	This model helps in providing various security mechanisms such that the benefits of cloud computing are realised	Issue of access control, identity, and authentication management need to addressed

Table 2. Resource provisioning in cloud computing

Category	Author	Proposed technique	Advantages	Challenges
Resource availability	Samimi et al. [21]	Combinatorial Double Auction Resource Allocation (CDARA)	This model helps in evaluating the efficiency from an economic perspective	The model evaluate on only two criteria's
	Goiri et al. [22]	Proposed a resource level metric	This model helps resource suppliers to allocate their resources dynamically	Need to consider resource utilization of the services in real-time
	Calheiros et al. [5]	Proposed a technique for distributing resources to software as a service (SaaS) applications	This technique adapts to the workload variations associated to applications	Need to address changes in VM's and their capacity
	Calheiros et al. [5]	Proposed a technique to extend the capacity of desktop grids	Discusses features and key concepts that maintains this integration	Requires some new policies for scheduling service
Resource allocation	Zhou et al. [23]	Resource evaluation and selection algorithm (RESA)	This method helps in providing multi QoS Constraints	Focuses only on scheduling method and combined preference matrix
	Wang et al. [24]	An adaptive scheduling with QoS satisfaction Algorithm (AsQ)	Designed fast scheduling strategies	Need to discuss various factors like energy efficiency and operation cost

Table 3. Various algorithms for resource provisioning in cloud computing

Algorithms	Author	Technique used	Challenges
Offloading algorithms	Xiao et al. [8]	Proposed an offloading forwarding approach	Need to include the wireless network supported system
	Wang et al. [24]	Proposed a technique to minimize average response timefor events reported by vehicles	The utilisation of vehicles outside the communication range is not considered
	Wang et al. [25]	Proposed an optimal allocation techinique	Doesn't discusses any online mechanism to allocate the computing service
Cloud computing algorithms	Ye et al. [26]	Proposed an approach based on genetic algorithm for composition of services	QoS values are already known needs to be eliminated
	Xu et al. [27]	Proposed a Berger model based algorithm	Based on the mapping relation between QoS and resource
	Li et al. [28]	Proposed an optimizing chord algorithm	Need to consider interaction with storage resources
	Dutta et al. [29]	Some popular genetic cross over operators like PMX, CX and mutation operators are used	Need to consider more real time job allocation restriction like machine failure and political concern

3 Resource Provisioning in Cloud Computing

Resource provisioning in cloud computing as presented in Table 2, is supported with two major factors known as resource availability and resource allocation. Resource availability is the vision to make available the resources anywhere and anytime. If the allotment to the resources is not organized accurately then the services gets starve for allocation of their required resources. Thus by analyzing a single cloud service resource and therefore on the basis of some models the availability of cloud computing services gets evaluated [31]. Samimi et al. [21] have proposed a new technique for allocating resources in cloud computing environment known as Combinatorial Double Auction Resource Allocation (CDARA) technique. This model is helpful in evaluating its efficiency with an economic perspective. Later new approaches have been proposed for allocating resource with less amount of wastage and more profit. These approaches consider various parameters like time, number of processor requests, cost, resource assigned,

resource availability, resource selection etc. In [22], Goiri et al. have presented a resource level metric that enables the users to allocate their resources dynamically between the running services with respect to their demands. This metric helps in performance of CPU by managing and specifying fine grain guarantees. So with the help of this metric resources can be allocated dynamically. In [5], Calheiros et al. have proposed a technique for distributing resources to software as a service (SaaS) applications. The main aim of this model is to fulfill the QoS targets related to service time and usage of available resources. They have used Aneka platform for developing scalable applications and for integration between the Desktop Grids and cloud [5]. In [23] an algorithm for resource evaluation and selection is presented with an extensible QoS model. In private cloud to increase the rate of resource utilization an algorithm is proposed to reduce task response time in [24].

3.1 Resource Provisioning Algorithms

To improve the QoS and QoE various types of algorithms such as offloading algorithm, cloud computing based algorithms [32,33] and scheduling algorithms [34] are being used as presented in Table 3. The development in cloud computing technologies has led to provide distinct cloud services to its service subscribers. These services can be classified into two groups: Application services and Utility computing services. These services are measured with the help of some QoS parameters and QoS model [26]. Further, considering the characteristics of the cloud computing a job scheduling algorithm based on Berger model has been proposed. This algorithm can execute the user tasks [27]. The main aim of the cloud provider is to achieve greater benefit and, satisfy the various QoS for user's jobs. A genetic algorithm has been proposed for a much better scheduling in the cloud environment in. Proposed technique is helpful in maximizing the profit of cloud providers which is supported by a number of evaluations and results [29]. In a system, resources also need to be scheduled such as they are not creating problems for the user in future works. Thus QoS differentiate system model has been presented in [28] for allocating resources in cloud computing system among various QoS - constrained users. To model the problem of cloud service composition an approach based on Genetic Algorithm is proposed in [35].

4 Challenges and Discussions

QoS main objective is to enhance the QoS by maintaining the delay to a smaller quantity by weighing the load in cloud computing environment. Audio, multimedia video conferencing etc. are planned to be the primary applications of this area where some improvement in delay might be useless. This section describes some challenges such as security and privacy, latency, resource scheduling, fast Internet speed, energy consumption, load balancing, service composition and performance which are described as follows:

- Strictly providing the required resources to the cloud and by proper scheduling of the resources would make the resources more organised.
- Exponential increase in the links which are harmful and can be utilised by the invaders for malicious activities. Also increasing usage of data can led to sensor based connectivity and these nodes can further misuse the data collected from the users.
- By fulfilling the user demands and services of the end users from the cloud, the performance can be improved.
- Data in the cloud is dynamically stored among all the nodes resulting in reduce in load balancing problem in cloud computing.
- Difficulties as faced by the cloud service purveyors for delivering an extensive range of composite cloud services, the purveyors requires to setup a shared understanding on large scale cloud scheme leading to a proper service composition.
- To make the network speed work faster for the cloud the computer, servers and routers must be able to communicate continuously sharing information.
- In resource allocation there are two types of workloads in cloud known as homogeneous and heterogeneous. Thus the cloud systems should be prepared such that both of these types of workloads can be allocated.
- Latency is the main issue which can be improved by using a wired connection and thus resulting in reduce costs which improves the satisfaction level of the customers.
- A server is built consisting of various components such as CPU, power supply, fans, memory and disks whose power intake can be enhanced by using hardware optimization leading to less energy consumption.

5 Conclusion

Cloud has extremely eased the provisioning of capacity method, at the same time it also produces various issues in the administration of the QoS. QoS includes availability, the levels of performance and reliability provided by the application or platform or the infrastructure that serves it. Research in modeling of workload and their applications in QoS supervision in cloud computing. Various QoS related parameters have been addressed in this work in which throughput, availability, and response time are some of the essential factors considered for cloud computing. QoS attributes consumer class supplies a structure for the choice of the better matched service according to the end user. The security class is helpful in the assessment of security and privacy issue in service associates. Eventually, the network architecture and service execution time groups provisions a structure for evaluating hardware functioning and sketching an understanding of the network architecture. This paper also discusses the various research actions that are being considered in the system and workload modeling, their distinct applications in managing QoS in cloud computing environment. In this paper, we have provided the technical measures for provisioning of resource allocation and resource availability in cloud computing environment. Further, we have discussed the various challenges in cloud computing environment and how these

challenges could be important in proposing future designs and algorithms. Also, a detailed discussion related to various cloud based QoS models for developing trust in cloud, designing load balancing algorithms and most importantly for security and privacy preparing such algorithms which help in detecting the difference between the service suppliers and the authorised access control users.

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Preface

Computing techniques like big data, cloud computing, machine learning, the Internet of Things etc. are playing the key role in processing of data and retrieval of advanced information. Several state-of-art techniques and computing paradigms have been proposed based on these techniques. This volume contains papers presented at the Third International Conference on Advances in Computing and Data Sciences (ICACDS 2019) held during April 12–13, 2019, at Inderprastha Engineering College, Ghaziabad, UP, India. The conference was organized specifically to help researchers, academics, scientists, and industry come together and to derive benefits from the advances of next-generation computing technologies in the areas of advanced computing and data sciences.

The Program Committee of ICACDS 2019 is extremely grateful to the authors who showed an overwhelming response to the call for papers submitting over 621 papers in two tracks in advanced computing and data sciences. All submitted papers went through a peer review process and finally 112 papers were accepted for publication in Springer's CCIS series. We are very thankful to our reviewers for their efforts in finalizing the high-quality papers.

The conference featured many distinguished personalities including Prof. K. K. Agarwal, Chairman-NAAC, Prof. J. S. P. Rai, Vice Chancellor Jaypee University of Engineering and Technology, Raghogarh, Guna; Prof. Rajkumar Buyya, University of Melbourne, Australia; Prof. Viranjay M. Srivastava, University of KwaZulu-Natal, Durban, South Africa; Prof. Baisakhi Chakraborty, National Institute of Technology, Durgapur; Prof. Parteek Bhatia, Thapar Institute of Engineering and Technology, Patiala, India; Prof. S. K. Mishra, Majmaah University, Saudi Arabia; Prof. Arun Sharma, Indira Gandhi Delhi Technical University for Women, India; Prof. Prathmesh Churi, NMIMS University, Mumbai; Dr. Anup Girdhar, CEO and Founder, Sedulity Solutions & Technology, India, among many others. We are very grateful for the participation of all speakers in making this conference a memorable event.

The Organizing Committee of ICACDS 2019 is indebted to Prof. B. C. Sharma, Director Inderprastha Engineering College, for the confidence that he invested in us in organizing this international conference, and all the faculty and staff of the CSE Department, IPEC, Ghaziabad for their support in organizing the conference and for making it a grand success.

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Effect of Vaccination in the Computer Network for Distributed Attacks – A Dynamic Model

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Abstract. In this reviewed endeavour, a mathematical model is formulated to assess the spread of a distributed attack over a computer network for critical targeted resources. In this paper a mathematical model is formulated, the two sources susceptible, vaccinated, infected, recovered nanonodes in the target population (e-$S_tV_tI_tR_t$) and susceptible, infected, susceptible nanonodes in the attacking population (e-SIS) epidemic model generated in order to propagate malicious object in the network. Further the analysis of the model has been concentrated upon the basic reproduction number. Where threshold value has effectively examined the stability of the network system. This work is verified for both asymptotical stable, that is the basic reproduction number less than on when the infection free equilibrium express the stability and basic reproduction number is more than one when endemic equilibrium is stable. A very general recognized control mechanism is regarded as vaccination strategy, which is deployed in order to defend the malicious object in the computer network. Finally we examine the effect of vaccination on performance of the controlling strategy of malicious objects in the network. The simulated result produced has become compatible with the overall theoretical analysis.

Keywords: Reproduction number · Stability · Vaccination · Malicious objects · DDoS attack

1 Introduction

In the Modern society the ever growing dependence on computer network is accompanied by ever growing concern about the network vulnerability to information attacks and dependability of existing network security system. Many organizations are well recognized to threats to the society. The attacking agents are like worm, virus, etc. Recently our society has witnessed drastic changes catalyses by cyber world. Presently

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it is threaten by malevolent things, like worm, viruses etc. Frequent use of electronic mails, floppy disk and internet is facilitating in propagation of spiteful virus in the network. Consider the contagious trait; malicious objects spread their tentacles in many ways. To counter the propagation and its dangerous impact, can observe the positive and negative the characteristic of those harmful objects. There are different types of internet based attack, out of which DDoS attack is dangerous and continuous in the cyber security domain. These type of attack is operated by consuming the resources like memory, network bandwidth [19, 20] etc. paralyzing the target sources and consequently which can no longer provide its service to users. The DDoS operates through the host computer systems to attack the target computers. In 2004 for the first time DDoS attack called Cabir, emerged. It used Bluetooth channel of cell phone to infect other phone by running the Symbian Operating System. It is capable of spreading through infected of mobile phones. It drains out the battery of affected devices by intensive scanning operations and blocking the wireless channels. They have not breached in security as it carries a malicious payload. However security threats over Bluetooth DDoS attack [1, 2] cannot rule out. The moment a DDoS attack affects the cell phone placing bough calls, sending spam mails and taking confidential information stored on the cello phone would be easily. DDoS attack might get upper hand over large number of cell phone in which embed Zombie. The wireless botnets can be used as a deterrent against the DDoS attack on base station, cellular switch, and exact IP address or emergence phone numbers.

Several attempts have been made mathematically to understand and analyze such attacks. It has been verified that the epidemic models are useful methods for understanding the transmission of virus malicious affected network in cyber space domain. The malicious objects can disseminate throughout the network rapidly and they pose serious threat. Continuous quarantine method can immunized against DDoS attack. The term vaccination means to compelled termination of infection. From the physiological aspect, vaccination is supposed to be employing in order to lessen the contamination [3, 4] of human ailments e.g. H1N1, Leprosy, Measles, and Smallpox etc. This perception prominently installed in the cyber domain [24, 28–30]. In particular the highest contaminated nodes are separated out from the system domain till the rehabilitation here.

2 Nomenclatures

S_t: Susceptible compartments of target population
I_t: Infected compartments of target population
V_t: Vaccinated compartment of target population
R_t: Recovered compartments of target populations
S: Susceptible nodes from the attacking population
I: Infected nodes from the attacking population
β: Probability of transmission infection rate from susceptible
γ: The rate coefficients from vaccinated to infected class of target population
ε: The rate coefficients from infected to recovered class in target population.
σ: The rate of coefficients from recovered to susceptible class in target population.
α: The rate coefficients from infected to susceptible class in attacking population

3 Mathematical Model and Assumptions

Consider the entire population of nodes is divided in two sections like attacking population and target population [5, 6]. The preliminary object of the attacker is to find more and more sensitive nodes then it unleash attack the precise target population. As the total number of the target population remains constant, the loss of any nodes due to DDoS attack is considered to be replaced instantly by the supporting nodes. The target population remains constant. The vulnerable hosts work on dual approach: one for attacking target and secondly looking for new hosts to begin the attack [7–10]. The susceptible hosts do not recover permanently and it revolt to susceptible. Whereas the target resource of susceptible compartments will move to vaccination compartment with the help of screening or scanning then moves to infected compartments and after treatment of anti malicious object goes to recovery compartments. As soon as these recovered compartments again start net-surfing or receive suspicions emails or other malware factors are accessed, it again becomes susceptible. The repercussion of such attack on critical infrastructure is anticipated. Therefore the target hosts must have much stronger defence mechanism.

Based on assumption we can total population can categorized in to two groups i.e. attacking population and target population. The target population can be divided in to susceptible, vaccinated, infected, and recovered. As well as the attacking population

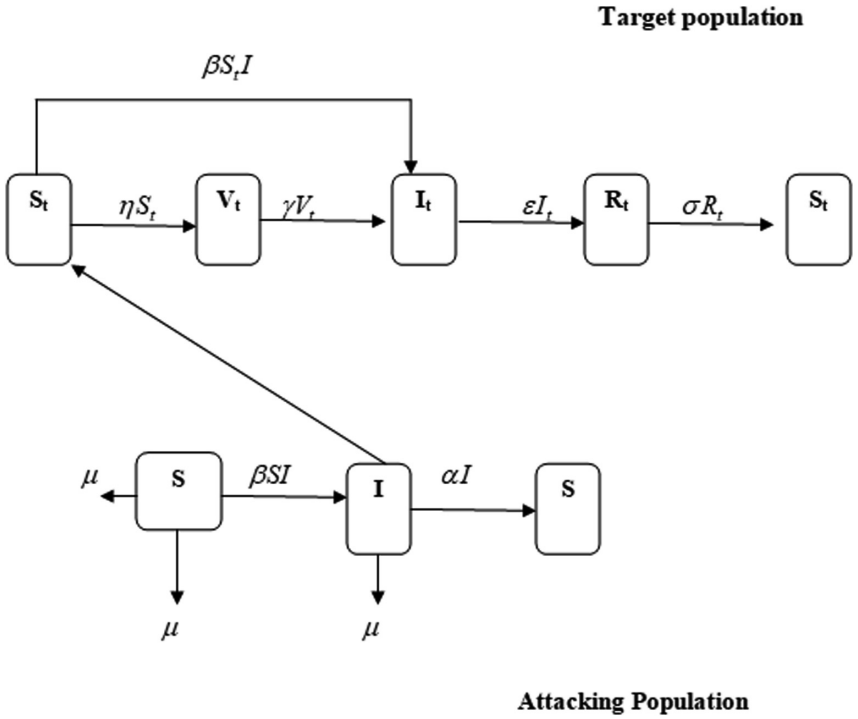

Fig. 1. Schematic diagram for flow of malicious objects in Target/Attacking population

can be categorized into two i.e. either susceptible or infected. The new nodes added in to network is susceptible. Death rate other than attack of malicious objects is constants. The natural death of the nodes as they are once susceptible to any malicious objects decreases. The infectious nodes recover from infection without immunity back to susceptible compartment. Our assumption on transmission of malicious objects in computer network is depicted in Fig. 1.

For the Target population the mathematical model can express as

$$\begin{aligned}
\frac{dS_t}{dt} &= -\beta S_t I - \eta S_t + \sigma R_t \\
\frac{dV_t}{dt} &= \eta S_t - \gamma V_t \\
\frac{dI_t}{dt} &= \beta S_t I + \gamma V - \varepsilon I_t \\
\frac{dR_t}{dt} &= \varepsilon I_t - \sigma R_t
\end{aligned} \tag{1}$$

In similarly for the Attacking population the mathematical model as

$$\begin{aligned}
\frac{dS}{dt} &= \mu - \beta SI - \mu S + \alpha I \\
\frac{dI}{dt} &= \beta SI - \mu I - \alpha I
\end{aligned} \tag{2}$$

Where $S_t + V_t + I_t + R_t = 1$ and $S + I = 1$

The above system of equation can be represented as

$$\begin{aligned}
\frac{dS_t}{dt} &= -\beta S_t I - \eta S_t + \sigma(1 - S_t - V_t - I_t) \\
\frac{dV_t}{dt} &= \eta S_t - \gamma V_t \\
\frac{dI_t}{dt} &= \beta S_t I + \gamma V - \varepsilon I_t \\
\frac{dI}{dt} &= \beta(1 - I)I - \mu I - \alpha I
\end{aligned} \tag{3}$$

When adding all the equations in the model (2) & (3) we have $S_t + V_t + I_t \leq 1$, $I \leq 1$. This inequality satisfies the condition $\limsup_{t\to\infty} S_t + V_t + I_t \leq 1, and\, I \leq 1$. Thus system (3) is defined on the closed, positive invariant set.

That can further represented as $D = \{(S_t, I_t, V_t, I) : S_t > 0, V_t > 0, I_t > 0, S_t + V_t + I_t \leq 1 : I \leq 1\}$.

As a results we discuss the stability of the model (3) on the set D.

4 Basic Reproduction Number (R_0)

It is the one of the theoretical foundation of the mathematical epidemiology as well as technological epidemiology. It permits for the classification of e- dynamic model. The stability of the system as well as eradication of the malicious objects depends on basic reproduction number. It gives the behaviour of the model stability and prediction of malicious object spread to some extent [21, 23, 25–27].

So, basic reproduction number can play the vital role in both biological as well as technological attack. So it is defined as the t during its life time a single malicious objects affected computer can produce total susceptible class caused by secondary infection. This can approach by Jones. Here it is calculated by two populations

Basic reproduction number for the target population

$$R_{0t} = \frac{\beta}{\varepsilon}$$

Similarly for the attacking population

$$R_{0a} = \frac{\beta}{(\mu + \alpha)}$$

In the epidemiology the value of basic reproduction can be calculated by taking the geometric mean of the attacking and target population reproduction number. Which can expressed as

$$R_0 = \sqrt{\frac{\beta^2}{\varepsilon(\alpha + \mu)}}$$

5 Stability Analysis

The positive invariant set D has two possible equilibriums. First the infection free equilibrium and second is the endemic equilibrium [11–18]. In this section we discuss the locally stability for infection free equilibrium and endemic equilibrium.

For the infection free equilibrium - $(S_t = 1, I_t = 0, V_t = 0, I = 0)$.

On the set D, endemic equilibrium $(S_t^*, V_t^*, I_t^*, I^*)$ can be achieved by considering all the equation of the system to zero.

$$\begin{aligned} &-\beta S_t I - \eta S_t + \sigma(1 - S_t - V_t - I_t) = 0 \\ &\eta S_t - \gamma V_t = 0 \\ &\beta S_t I + \gamma V - \varepsilon I_t = 0 \\ &\beta(1 - I)I - \mu I - \alpha I = 0 \end{aligned} \tag{4}$$

Solving simultaneously the above equations we have for the endemic state $(S_t^*, V_t^*, I_t^*, I^*)$

$$S_t^* = \frac{\varepsilon\gamma\sigma}{[\eta\gamma\sigma - \varepsilon\sigma\eta - (\beta+\eta) - (\mu+\alpha+\sigma)\varepsilon\gamma]}$$
$$V_t^* = \frac{\varepsilon\eta\sigma}{\eta\gamma\sigma - \varepsilon\sigma\eta - (\beta+\eta) - (\mu+\alpha+\sigma)\varepsilon\gamma}$$
$$I_t^* = \frac{\eta\gamma\sigma}{[\eta\gamma\sigma - \varepsilon\sigma\eta - (\beta+\eta) - (\mu+\alpha+\sigma)\varepsilon\gamma]}$$
$$I^* = \frac{\beta - \mu - \alpha}{\beta}$$

Theorem 1
The infection free equilibrium is locally asymptotically locally stable in the region D if $R_{0a} \leq 1$. And it is unstable if $R_{0a} > 1$.

Proof: Linearization of the system (3) for $S_t = 1, I_t = 0, V_t = 0, I = 0$

$$J_{IFE} = \begin{pmatrix} -\eta-\sigma & -\sigma & -\sigma & -\beta \\ 0 & -\gamma & 0 & 0 \\ 0 & 0 & -\varepsilon & 0 \\ 0 & 0 & 0 & \beta-\mu-\alpha \end{pmatrix}$$

The Eigen values are

$$\lambda_1 = -\eta - \sigma$$
$$\lambda_2 = -\gamma$$
$$\lambda_3 = -\varepsilon$$
$$\lambda_4 = \beta - \mu - \alpha$$

Here first three Eigen values are negative and fourth Eigen value is also negative if $\beta - \mu - \alpha < 0$. i.e.

$$\beta < \mu + \alpha$$
$$R_{0a} < 1$$

Hence the infection free equilibrium is locally asymptotical stable in the region D.

While $R_{0a} > 1$, which means $\beta > \mu + \alpha$. So $\lambda_4 > 0$. Therefore the infection free equilibrium is unstable.

Theorem 2
For the endemic equilibrium is asymptotically stable in the region D when $R_{0a} > 1$.

Proof
Linearization of the model about the endemic equilibrium $(S_t^*, V_t^*, I_t^*, I^*)$

$$J_{EE} = \begin{pmatrix} -\beta I^* - \eta - \sigma & -\sigma & -\sigma & -\beta S_t^* \\ \eta & -\gamma & 0 & 0 \\ \beta I^* & \gamma & -\varepsilon & 0 \\ 0 & 0 & 0 & -2\beta I^* - \mu - \alpha \end{pmatrix}$$

Solving we get the Eigen values

$$\lambda_1 = -2\beta I^* - \mu - \alpha$$

The other three Eigen values can be obtained by solving

$$\lambda^3 + A\lambda^2 + B\lambda + C = 0$$

Where

$$A = \beta I^* + \eta + \sigma + \gamma + \varepsilon$$
$$B = \sigma\eta + (\beta I^* + \eta + \sigma)\gamma + (\beta I^* + \eta + \sigma)\varepsilon + \gamma\varepsilon - \sigma\beta I^*$$
$$C = (\beta I^* + \eta + \sigma)\varepsilon\gamma + \sigma\eta\varepsilon + \sigma\eta\gamma - \sigma\gamma\beta I^*$$

Where A, B and C are positive when $R_{0a} > 1$.

Furthermore $AB > C$.

Hence, by Routh-Hurtwitz condition [22] the endemic equilibrium is locally asymptotically stable.

6 Numerical Simulations

The Fig. 2 using the different parameter, we can obtained that the basic reproduction number for attacking population is below the unity the malicious object gradually eliminated. Which is agree with the Theorem 1. This figure also clearly explain that spread of malicious objects is depressive, which consists with the analysis of theory. Lastly the infected nodes will vanishes and reached the recovered level.

Similarly the Fig. 3 using the different parameters remains unchanged, we can seen that the basic reproduction number for attacking population is above the unity, the all the nodes are maintain positive values between the range. Which indicates the malicious objects does not vanish if the objects are initially present. Hence finally theses state reaches their endemic equilibrium point. It agrees with the Theorem 2. This is consistent and asymptotical stable. To reveal the effect of partial vaccination rate on infected nodes. So, we give the partial vaccination, which all the nodes get vaccinated. However, in the real world network, as a result, we expected the use of vaccination process, the rate of spread malicious objects slowly down and decrees the infected nodes in the network.

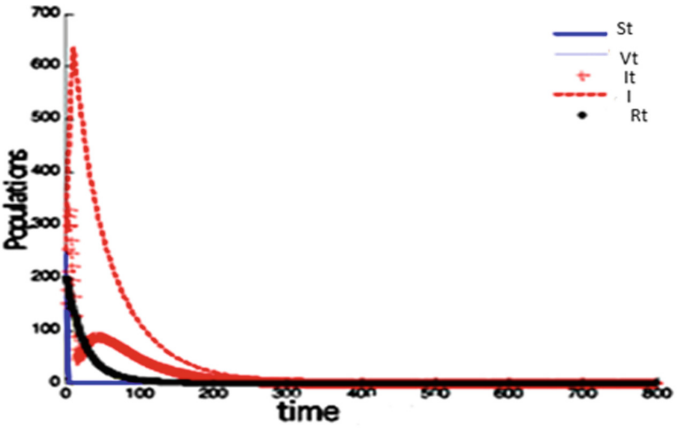

Fig. 2. Dynamic behaviour of the model for infection free equilibrium ($R_{0a} \leq 1$)

In order to simulate the behaviour of spread of the malicious objects the parameters in the experiments are practical values for dies the malicious object in the computer network in real life. Here by using the Range kutta fourth and fifth order to solve the system of ordinary differential equation with the help of MATLAB. Here by applying the MATLAB we can observe the behaviour of different nodes with respect to time. This simulated result agrees with the real life situation.

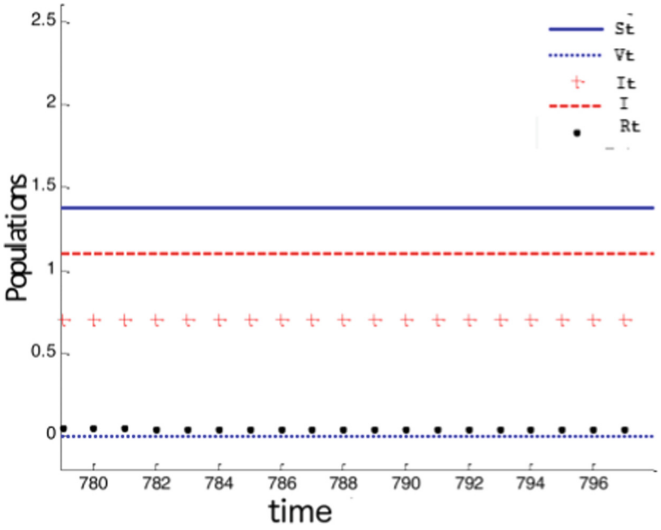

Fig. 3. Dynamic behaviour of the model for endemic equilibrium ($R_{0a} > 1$)

7 Conclusion

The aim of this work is to model the malicious object control in the network. It also finds out the particular workable means of controlling the spread of malicious object in the network. Here a dynamic two population e-epidemic model has been generated for the transmission of the malicious object in the network. The investigation over the dynamic behaviour of the specified model with partial immunizations has been systematically expressed. The derivation of the basic reproduction number which determines the worm extinguished has been solidified. Again the fact behind basic reproduction number is that it exclusively depends on the stability of the system. Considering the consequence of the analysis the infection free equilibrium as well as endemic equilibrium which are locally asymptotically stable have become confirmed. The defence measure i.e. vaccination (filter, scanning) against malicious object in the network has been successfully deployed. Latest version of antivirus with latest signature has made the DDoS attack minimum in the network. The numerical simulation results have optimistically explained the positive impact of increasing the security of DDoS attack. We imagine that our analysis can provide a quantity of close into malicious object counter measure. In the real world, the result can supportive to antivirus companies on related organization to make cost useful countermeasure to work well. Finally the foremost future endeavour will be verifying the model in scale free network. And it can be extended to time delay parameter.

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Third International Conference, ICACDS 2019, Ghaziabad, India, April 12–13, 2019, Revised Selected Papers, Part II

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Optimizing Smart Parking System by Using Fog Computing

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Abstract. Finding the vacant space for parking a vehicle during peak hours is becoming a difficult task at ones end. Parking process whether in shopping malls, restaurants, or offices etc. is a long process and also leads to waste of gasoline. Smart car parking helps in finding the parking slot through Vehicular Ad Hoc Networks (VANET's). For vehicle communication, some devices such as roadside units and on-board units are present that provides parking slot information. In the proposed work, we have introduced an online reservation facility for parking slot. People can reserve their parking space in advance before reaching to their venues in advance. This will help in reducing the waiting time for the parking allocation to the particular vehicle. This will also help to enhance the parking capabilities and will increase the efficiency when compared to other parking strategies. Our proposed approach can minimize the cost of parking on per person basis, exhaust of vehicle, and indirectly it will impact on save of wastage of gasoline and will keep the environment green.

Keywords: VANET · Fog computing · Cost · Vehicles

1 Introduction

Recently with the growth of technology in every possible dimensions of human life, the quality of life has been improved a lot and one can not deny the contribution of various smart applications in this improvement. Several studies have already been performed on these smart applications designed for vehicle parking allocation and management. Finding the best location for vehicle parking in the parking area is one of the time consuming process and also becoming one of the major problem in almost every countries. There are two major problems faced by most of the vehicle owner (1) wastage of time (2) wastage of gasoline [1]. One has to keep on waiting or roaming near parking area unless and until they find any space for parking their vehicle. This scenario leads to vehicles keep on waiting outside the parking space for getting their turn but they have no way to get the information that when their turn will come for parking their vehicle or when an already parked vehicle will leave the parking premises. This results

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into traffic jams outside of most of the parking area. So to overcome from this worst scenario, there is a requirement of an effective and efficient vehicle parking system.

In the proposed smart vehicle parking system and ad-hoc networks and road-side units have been used. Communication devices such as on-board units have also been used for collecting the information regarding availability of parking space and the same has been shared with other vehicles. Number of sensor based devices have been used to implement this smart parking system. Still there are few challenges for VANET based parking system like collection of information and sharing it with other vehicles by using ad hoc network may not support timely updation of information, which can be a critical issue. Thus for real time smart parking systems, VANET based parking system provide a perfect solution for many types of parking related problems [2]. In order to overcome from the above-mentioned problems of allocation of parking space using VANET, fog computing archetype has been introduced in this paper for designing smart parking system.

Fog computing model provides all the resources at the edge of the network. Various fog nodes will be available near each parking premises that will provide the information related to availability of parking area to the vehicles and help them to take parking decision. Also in addition to that, an online facility has also been provided for the reservation of the parking space in advance. Users can reserve their parking before reaching to any parking premises. User has to register himself first if he is using online reservation for parking. Once he is registered for that online facility, then he can simply login to reserve his parking area before reaching to that place. User can also cancel the reserved parking area and in that case that parking area will be allocated to another vehicle from the waith list. Parking cost will be lesser for the online reservation parking as waiting time is lesser. The information regarding online reservation parking gets updated using fog nodes and also the availability of parking space is checked by considering both the information about online and on spot parking reservation. All the information regarding parking gets up-to-date using fog nodes. Parking requests are processed for both online and on spot parking area by using fog nodes. Requests that are in waiting list gets uploaded to the cloud for their further later processing as per the availability of the parking space. Allocation of parking area is provided by applying fog computing to VANET based real time parking systems.

2 Related Work

For finding parking area, smart parking makes use of information and communication technologies, fog computing, and cloud computing. Previously, a number of studies have been done to resolve the issue of allocation of parking space by number of researchers [3–8]. However, smart transportation is getting more attention nowadays. In [9–14], for smart parking, fog computing was applied that

support various computations and also reduces the response time. Fog computing provides various resources at the edge of the network that is closer to the sensors and IoT devices.

2.1 Smart Parking Models

In [15], Zhu et al. have introduced five sensor cloud pricing models. Each model of sensor cloud pricing examines the following aspects: contract span of each sensor cloud user, running schedule of sensor cloud, resources utilization of sensor cloud by each sensor cloud user, sensitive data volume and the path that sensor cloud follows to communicate sensitive data to sensor cloud user through wireless sensor network. In [9], Balzano and Vitale have presented a model in which vehicle to vehicle, distance geometry problem and wireless positioning have been considered. Proposed model was aligned for the indoor navigation in the parking areas. This model also provides facility of anti-theft and anti-collision protection and helps in finding the area and location for the parking of a vehicle. In [16], Hou et al. have discussed a novel system model for computation and communication of available resources. They have introduced the vehicular fog computing model for the direct communication between vehicles. In [17], Huang and Xu have used adaptive content reservation scheme model for the reservation of data in vehicular cloud-fog network. The proposed scheme is used for the quality of service in real time streaming. Tokens are used for preallocating the content in the real time streaming in the proposed model. In [18], Kim et al. have introduced a shared parking model based on roadside cloud and fog computing parking slot repository (RFPARK) in which vehicles will directly communicate with the fog servers. User can make request for parking anytime that will be processed using fog server. In [19], Mukherjee et al. have introduced a framework model for reducing the traffic overhead in industrial applications. This framework helps in preventing the uploading of irrelevant data to the cloud data centres. In [20], Zhang et al. have proposed hierarchical resource management model for optimizing the performance of cooperative fog-computing based intelligent vehicular network. Distributed computation and storage is possible using this model. Inter-fog and quality of service resource management has also been included in this proposed model. In [21], Park and Yoo have used fog computing, Software Defined Networks (SDN), and Fifth-Generation (5G) networks based model for managing the network state information, connection recovery and server failure recovery process. In [22], Rajabioun and Ioannou have used multivariate spatiotemporal models for predicting the available space in the parking lot. The proposed model is also used for recommending the location for the parking of the vehicles. The availability for the parking location is checked in both context i.e. on-street and off-street. In [23], Mei and Tian have introduced a parking choice behavior model for analyzing the parking choices of the users. Parking guidance model is also used for the prediction of parking guidance and information.

2.2 Smart Parking Algorithms

In [10], Wang et al. have discussed the distance geometry problem (DGP) algorithm for determining the graph that will represent best network for the parking. This algorithm also helps in finding the location of the vehicles in the parking area. Availability of parking area will be easily shown to the user by using DGP algorithm. In [18], Kim et al. have used the parking slots association (PSA) algorithm for finding available area for parking. This algorithm helps in allocating the parking area to the vehicles in the fair manner. Also fair tradeoff is also discussed between vehicles and parking areas by the discussed PSA algorithm. In [20], Zhang et al. have used the inter-fog quality of service aware resource management algorithm for enhancing the load balancing and stability of fog network. Resource management behavior is managed by the coordinator through balancing data flow of local fog servers. In [23], Mei and Tian have discussed the standard genetic algorithm for finding any illegal parking in the parking space. Proposed algorithm is responsible for finding the available space and location of the parking space in the parking area for the vehicles. In [24], Zoeter et al. have used an algorithm for calculating the parking charges of the parked vehicles in the parking area. Parking rates will be high if there is any congestion otherwise reduced rates will be applied accordingly.

3 Methodology

To overcome from the various issues related to allocation of parking area as discussed in the previous section, we have proposed a fog computing based system model for smart vehicle parking as shown in Fig. 1. Fog servers have been used whether the space is vacant or filled will be informed to each fog node and similar information is updated throughout all the fog servers. The information for available space is delivered to all the roadside units (RSUs) by fog servers which is independent of geographical location of parking area. proposed system model consist of following layers:

- ***Parking area*** - represents both public and private area for vehicle parking. Here, parking of vehicles is under the surveillance of CCTV cameras and sensors and are also embedded for the monitoring purpose. With the help of sensors available spaces for the parking can be detected. Benefits of smart parking can be for both owner of the vehicle and the parking in-charge.
- ***Fog Nodes*** - In the proposed system model, we have used fog computing for the smart vehicle parking system. Fog computing is an extension of cloud computing that can easily process the user requests as it provides resources at the edge of the network. In the proposed model, fog nodes consist of sensors and fog servers. Information regarding available and occupied spaces in the parking area is further updated with all the fog servers.
- ***Roadside units*** - It help the vehicles to communicate with each other. Roadside units find the parking related information on availability basis and send

it to the requesting vehicles. Vehicle owner can also make requests accordingly. Request is further processed by the fog nodes and information regarding request gets stored in the cloud for future purpose.

– ***Cloud*** - All the information related to the vacant spaces and occupied spaces in parking area gets collected on timely basis and sent to cloud via fog-nodes, for information storage. Requests of all vehicles gets processed according to the updated information present in the cloud.

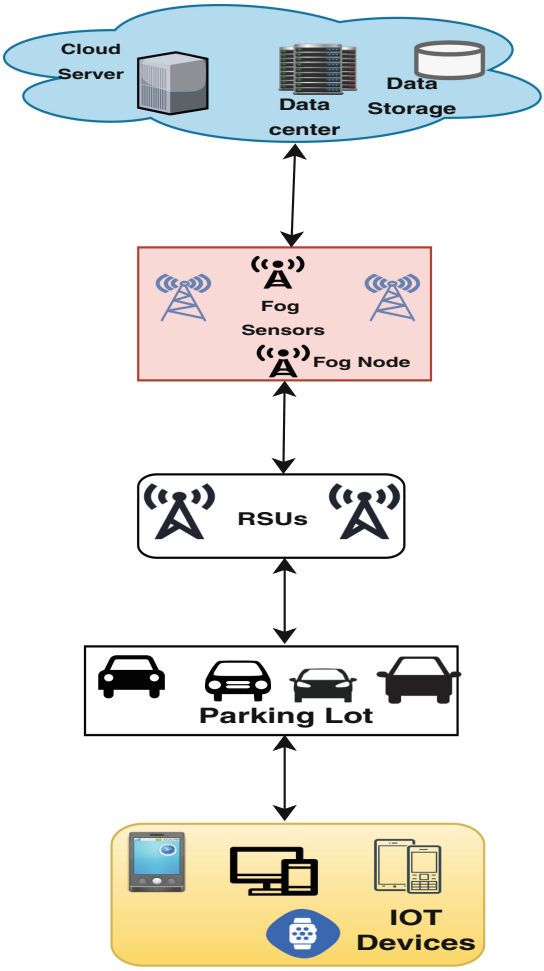

Fig. 1. Proposed smart vehicle parking model using fog environment.

3.1 On-Line Vehicle Reservation Parking

On-line reservation for vehicle parking facility has been provided in the proposed model. User can register for reserving the vehicle parking on-line. Once vehicle owner completes the one time on-line registration process, they can reserve the parking area before reaching to that place. One can also cancel the reservation for parking if there is any previous reservation done for parking area. In this case, user who is in waiting list gets allocated the space in the parking area. The information regarding on-line reservation also gets updated to the cloud so that other vehicle owner who have requested for the parking area can be allocated the space in the reserved parking area. This parking information has to be synced with the parking model of fog environment for smart parking purpose. The on-line process for the parking reservation of the vehicles gets tracked using fog nodes. Fog nodes frequently updates the availability of parking space on the clouds. Vehicle owner whose parking space is reserved before hand, must reach timely to the parking area otherwise that parking area gets allocated to other from the wait list. On-line vehicle reservation parking system is more beneficial as compared to on-spot parking system which is still in use in most of the countries. In on-line reservation parking, one can reserve the parking area for any particular day. Once the parking space is reserved and confirmed, then one need not to wait in the long waiting queues for parking a vehicle and will obtain the location for parking his vehicle (Fig. 2).

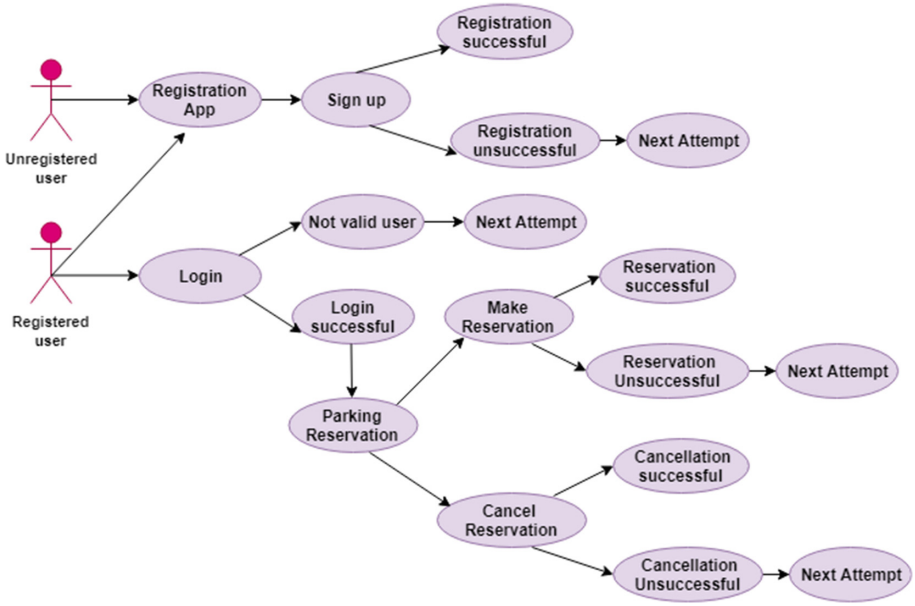

Fig. 2. A use case diagram for on-line vehicle reservation parking.

3.2 Proposed System Design

In this section, we have considered reservation parameters for parking so that the waiting time of vehicles could be minimized. In this paper, we have mentioned how the parking requests are further processed. Fog nodes have been used for storing and managing the below parameters and status of parking lot. For the proposed work we have considered the following parameters:

- ***Parking ID (PID)*:** Smart parking premises in the cities are assigned with unique identification that differentiates one parking area from other.
- ***Parking area status (PS)*:** Status of the parking area gets checked whether the requested space is occupied or not. If space is occupied during the requested period then set $PS = 1$ otherwise set $PS = 0$.
- ***Vehicle ID (VID)*:** Each vehicle is represented by unique identification number via its number plate. This identification can also be used to find which vehicle is parked at particular parking slot. On board units present in the vehicles can also be used as unique identification for the vehicles.
- ***Time Stamp (TS)*:** At parking place when vehicle owner starts to park their vehicles, the time taken is recorded in this time stamp field. If PS is zero, this field will be kept empty.
- ***Time duration (TD)*:** When fog-nodes interact with vehicles, they can find out the parking slot status. So time duration can also be used to find the approximate parking time.
- ***Special quota (SPL)*:** Some parking space in the parking area is reserved for special purpose. So that parking comes under special quota for granted people.

Vehicles that want to send parking request first has to initialize the connection with roadside units and fog-nodes. Once the connection has been established, request for parking could be sent by vehicle to fog-nodes. Fog-nodes further send that request to cloud for checking the status of parking area for the mentioned period. If the space is available then this information is delivered to the requesting entity through the fog-nodes. If the space is fully occupied for the mentioned period then the request for parking will be processed later and updated information is provided to the requested vehicle once the wait list gets cleared (Fig. 3).

- ***Parking allocation cost*:** Here, many factors affect the decision making for assigning parking space to the vehicles like parking priorities, parking fees, wait time and number of requests for parking space. Parking requests are processed according to the availability of the parking area. The total cost for allocation of parking area can be calculated as follows:

$$Totalcost = cost_{waiting} + cost_{timeduration}$$

Sensors like surveillance cameras will monitor the vehicles and fog-nodes will keep the track of vehicles that are waiting at the parking entrance. The parking request will be processed based on the confirmed information sent by the vehicle.

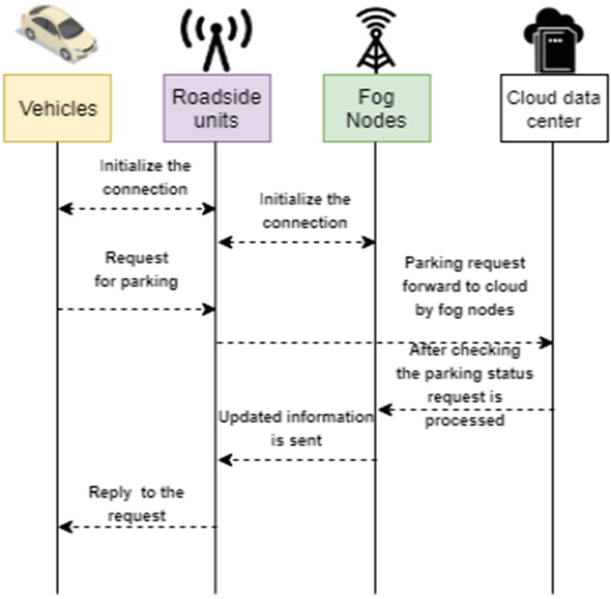

Fig. 3. Vehicles request for parking.

Waiting queue can also be monitored. Estimation time for each vehicle as it arrives can be calculated by fog-node based on the parking request of vehicles. Parking space information is further upgraded after every fixed time interval and is denoted by T_{inv}. The count of number of vehicles that are waiting at the parking entrance is denoted by Num_{Vi}. Total waiting time is expressed as T_{Wi}. We have calculated the minimum number of updates for parking space:

$$M_{min} = mi \left\{ M | \sum_{n=1}^{M} VCSL[j] \geq Num_{vi} \right\} \tag{1}$$

where $VCSL[j]$ = Number of vacant slots for parking

Waiting time can now be expressed as follows:

$$T_{wi} = M_{min} \times T_{inv} + T_{dur}$$

where T_{dur} is the time duration that starts when vehicle begins to park till whole parking procedure is finished. Waiting cost for vehicle i can be expressed as $Cost_{waiting}$ and is calculated as follows:

$$Cost_{waiting} = L \times T_{Wi} \tag{2}$$

where L is the waiting cost per time unit.

3.3 Proposed Algorithm for Parking Area Allocation

In this section, we have used modified greedy algorithm for the allocation of parking area to the vehicles. Fog-nodes keep the track of all the requests made by vehicle owners. Parking status gets checked before allocating the parking space to the vehicles. Here parking request is received by the fog-nodes. After receiving the request for the parking space, availability will be checked for the available parking area. If the space is available for the parking, then the particular request for the parking gets processed and location is assigned to the vehicle accordingly. If the parking space is not available at that particular time, then that request for parking will be uploaded to the cloud data center and processed later-on. After assigning the location to a vehicle, the total cost gets calculated for the vehicle by considering the waiting time and time duration.

Algorithm 1. Modified Greedy Algorithm

Input: Fog Nodes (FN), parking status, parking requests by vehicles PReq.
Output: Decision of parking slot allocation.
Procedure:1. IF Parking request is received by fog node DO
2. Check for available space.
3. IF AVLS[i] $>$ 0 THEN
4. Parking request is processed by assigning LOC[i].
5. ELSE
6. Parking request will be uploaded to cloud data center.
7. FOR k=0:N DO
8. IF vehicle is parked at parking location DO
9. Calculate the total cost (by considering waiting time and time duration)
10. END
end Procedure

4 Experimental Results

The initial experimental setup starts by considering the intake capacity of parking lot for parking. Once parking space capacity is mentioned, proposed system can allocate parking area to the each requesting vehicles. Proposed system also consider the time duration of parking as one of the input. This ensures in calculating the waiting time for the vehicles. A vehicle for which online reservation for the parking is done need not to wait for the allocation of the parking space. Fog-nodes helps to share the parking information among other requesting vehicles. Fog-nodes tries to process the parking requests in the order they are received by the servers. This also keeps the track of online parking requests and processes them according to the vacant space available. Total cost is calculated by considering the waiting time and time duration.

In the experimental results we have used modified greedy algorithm for parking space allocation in which cost calculation is modified by considering the different parameters. Figure 4 represents the average cost for on-spot parking for the various number of parked vehicles. Whereas, Fig. 5. represents the average cost for on-line reservation parking for the various number of parked vehicles. We have evaluated our results by calculating the total cost. The comparison of total cost for on-spot parking and on-line parking reservation is also shown in Fig. 6. Obtained results shows that the total cost of using on-line reservation for parking is less as compared to the total cost for on spot parking by using fog nodes.

From Table 1, it is clear that the average cost for the on-line reservation parking is less as compared to on-spot parking average cost. The number of

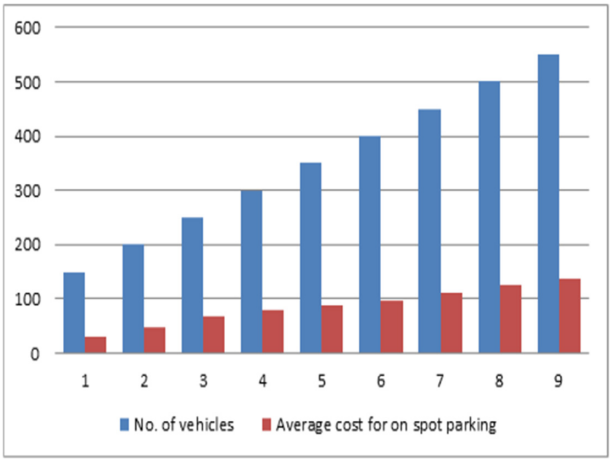

Fig. 4. Number of vehicles versus average cost for on spot parking using fog nodes.

Table 1. Average cost for on spot and online reservation parking

Number of vehicles	Average cost for on spot parking (cost per minute)	Average cost for online reservation parking (cost per minute)
150	30	14
200	48	32
250	67	51
300	79	63
350	87	71
400	98	81
450	110	93
500	125	106
550	138	118

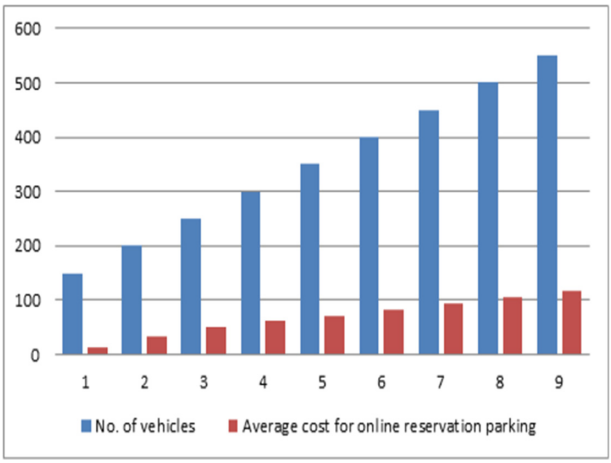

Fig. 5. Number of vehicles versus average cost for online reservation parking using fog nodes.

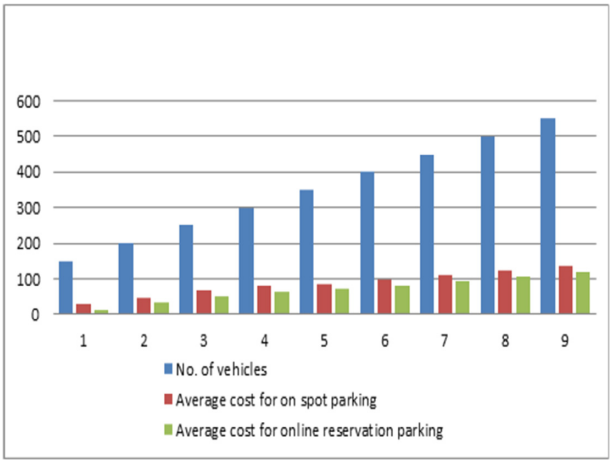

Fig. 6. Comparison between average cost for on spot parking and online reservation parking using fog nodes.

vehicles whose parking request has been processed by the fog-nodes according to the availability of the parking space, proposed algorithm will calculate the total cost for that particular vehicle. In case of on-spot parking, the parking request will be processed in the order as the vehicle arrives in the parking area. In on-line reservation of parking, the parking request of user will be processed on-line and the information regarding availability of the parking space in the parking area gets updated on-line. One need not to wait in the parking queue to know the parking status of the vehicles in case of on-line reservation parking is done

successfully. Therefore, there is difference between total cost of parking a vehicle using on-line reservation as compared to on-spot reservation. Proposed algorithm calculate the cost for different vehicles and the results for both the on-spot and on-line reservation parking is displayed in the Table 1. Also the comparison between average cost for on spot and on-line reservation parking is shown in Fig. 6 which clearly indicates that the average cost for on-line reservation parking is less as compared to the on spot parking.

5 Conclusion

Nowadays, parking problem is becoming an important research issue due to the increase in the number of vehicles. In this work, we have proposed an online reservation facility for parking area that helps to reduce the waiting time and cost of parking on per vehicle basis. We have proposed a modified greedy algorithm to calculate the total cost of the vehicles. The results have shown that the total cost for parking using online reservation is less as compared to on-spot parking by using fog nodes. Online reservation for parking is more efficient and reliable. Obtained results also shows the significant improvement to resolve the parking problems in more efficient manner by allocating the parking space to more number of vehicles. In future work, we will try to use enhanced algorithms for parking strategies.

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About this book

This book gathers high-quality papers presented at the First International Conference on Sustainable Technologies for Computational Intelligence (ICTSCI 2019), which was organized by Sri Balaji College of Engineering and Technology, Jaipur, Rajasthan, India, on March 29–30, 2019. It covers emerging topics in computational intelligence and effective strategies for its implementation in engineering applications.

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A Hybrid Cryptographic Technique for File Storage Mechanism Over Cloud



Shivam Sharma, Kanav Singla, Geetanjali Rathee and Hemraj Saini

Abstract The cloud is a radical platform that conveys dynamic, virtualization asset pools and high convenience. Since distributed computing lays on web, security issues like information security, protection, secrecy, and verification are experienced. In order to get rid of these, an assortment of mechanisms and encryption algorithms are utilized in various blends. On the comparable terms, we made utilization of hybrid encryption with the utilization of crossbreed cryptographic calculations to upgrade the security of information or data file on cloud. We plan at scrutinizing different incorporation of encryption algorithms, in view of various execution constraints to reason a hybrid calculation which can anchor information more effectively on cloud.

Keywords Cloud · Hybrid cryptography · Security · Encryption techniques · Decryption techniques · File security

1 Introduction

Cloud computing was engineered to deliver computing services over the internet. Both the fully developed, ready-to-use applications, hardware resources like network, storage are provided according to user's needs. These resources are hosted at the data centers spread globally. The resources are utilized from a configurable pool of similar resources which can be relaxed and provisioned depending on their requirement [1]. According to the definition of NIST, Cloud computing is a sculpt for

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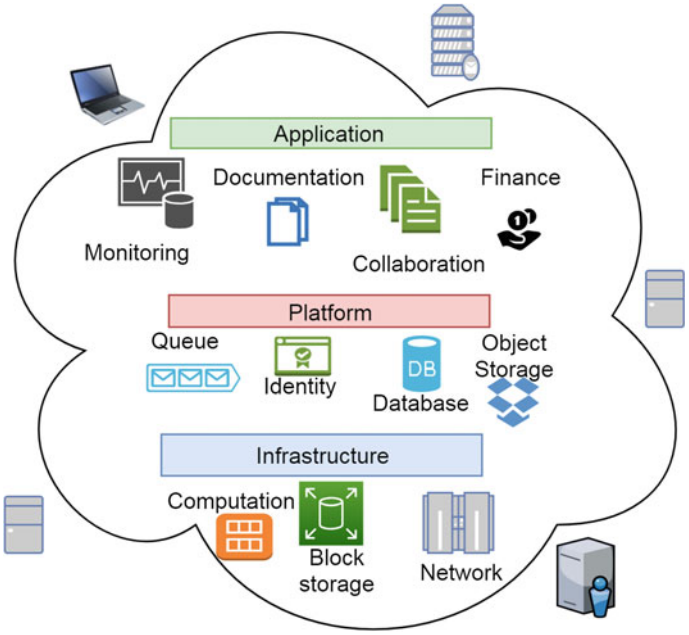

Fig. 1 Wireless mesh network

enabling suitable, on-demand system access to a mutual pool of configurable evaluating resources (e.g., storage, applications, servers, networks, and services) that can be quickly released and provisioned with minimal supervision service provider or effort interaction as depicted in Fig. 1.

- **Need for Security in Cloud Computing**

Although, Cloud computing has grown to be a popular and successful business model due to its attractive characteristics and features. In addition to the reimbursements, its features may result in severe problems specific to cloud security issues [2–4]. The entities whose concern is the security of cloud still hesitate to transfer their business to cloud. The security issues that have been governed barricade of the growth and worldwide use of cloud computing are defined as follows:

– Outsourcing: It refers to providing data to a third-party cloud hosting provider in order to support and deliver IT services that could be handed over in-house. Outsourcing means that the clients physically lose control of their tasks and data. The problem that user's data is with someone else and no longer in proximity of user is a prime security concern.
– Multi-tenancy: It implies that the cloud platform is distributed and shared, exploited by multiple clients. Furthermore, in an environment that is virtual, Different cloud user's data may reside on same physical servers in virtual environment.

A series of security problems and issues such as computation breach, data breach, and flooding attack are experienced.

- **Cryptography**

Converting useful data into unreadable text so that no one else can read it except the pre-determined user is encryption and the techniques used are called cryptographic techniques. It may be accomplished through scrambling words, using code words or using highly efficient mathematical techniques. There are different algorithms classified in two classes [5–8].

a. Symmetric Algorithms—This algorithm uses same key to decrypt and encrypt the message. For instance, if some user desires to convey a message to another and wants nobody else should read it. So, she/he can encrypt the data using a secret key that can be shared with the receiver who will decipher the data using the same key. As can be judged the key can be shared with all the users who ought to retrieve data.
b. Asymmetric Algorithms—These types of algorithms make use of two separate keys in process of decryption and encryption, respectively. Like a user ciphers, the data using one key (known as public key) and receiver decrypts the message using separate key (known as private key). Public Key—This key is nearby to all over the internet and used to cipher the secret text. Private Key—As clear form, the name it is a receiver's private key and only the receiver will be able to use this key to decrypt the required message.

We know that classic encryption schemes have long been used for security purposes and they have been successful to some extent. So why is there a need to use hybrid system? The basic answer is security. Basically, what hybrid cryptography does is that it mixes the effectiveness of symmetric encryption with easiness of public-key encryption. It enhances security level and both types of encryption efficiency. It has several advantages. The new technology was fast, dependable, and data sharing was efficient. There were certainly many benefits to it and had its limitations that were harmful to data owner. As the data was stored on outside system not within the physical reach of user there are the concerns for security of data. Data sharing may also lead to breach of sensitive data and privacy of user. There have cryptographic techniques to cipher the data and code it so that the attacker cannot understand it.

Techniques like DES, 3DES, AES, RSA, RC4 and many others have proven to be a success in hiding the data and securing it. However, everything is prone to attack and every individual encryption technique is known to be attack prone due to an increase in computational power days. Any new technique which will be developed will be known to attacks but to increase the security and efficiency hybrid encryption is used. Hybrid encryption provides effectiveness of public-key cryptography and easiness of private key cryptography. In this paper, a hybrid cryptographic mechanism is proposed by incorporating AES, DES, and RC4 techniques to implement hybrid cryptography. The remaining structure of the paper is structured as follows. Section 2 described the previous security issues proposed by different researchers. The hybrid secure mechanism is portrayed in Sect. 3. The test plan of proposed phenomenon

is elaborated in Sect. 4. Further, Sect. 5 represented the performance analysis of encryption and decryption time. Finally, Sect. 6 concludes the paper.

2 Comparative Analysis of Previous Approaches

This research paper introduces cloud architecture and characteristics of cloud. Through the paper, authors have identified present security and privacy issues and discuss their proneness to attack and provide currently used defence mechanisms by analyzing their efficiency in doing the required work [9, 10]. The authors have used current strategies including Virtualization, Data centre Techniques, and MapReduce centre that helps the cloud vendor in overcoming those challenges, but each has its shortcomings and not useful. Author gives a cloud security ecosystem to model different attacks and use different mechanisms against them. Further, the paper provided the security challenges that are a big hindrance in the customer trusting the cloud technology for commercial and personal operations. The issues regarding current defence strategies have not been ratified and left open for future resolve of these issues and enhance the user trust on cloud. Various authors have proposed several cryptographic techniques in order to ensure the security overcloud. The below text describes number of security algorithms and techniques proposed by various author's.

- **Secure Data Sharing in Clouds**

In order of preserving the thoughts of challenges in cloud the researcher has designed a new SeDaSC methodology for securing the facts storage and transfer. The authors have analysed that like cl-pre-scheme, certificates-much-less encryption and el-ghamal cryptography schemes with their blessings and cons. Like the cl-pre-scheme generates a public-non-public key pair and uses bilinear method for encryption which growth the cost of encryption. The certificates much less encryption even though tries to enhance upon the cost issue, however, falls short are in trusted facts garage. On the other hand, the el-ghamal scheme uses bilinear and incremental encryption. However, complexities nonetheless exist [11]. Although, it is clear from the picture that key evaluation time changes merely with augment in file size and the encryption time too is commendable with this methodology. However, the time needs to check with file sizes of greater than 1 GB to really test [12, 13]. Additionally, the important element is that it stores key on outside server that can be underneath outside threats, so measures should be taken to make it extra comfy or limit the level of trust in the server.

- **Brief Study of Encryption Algorithms (RC4, DES, 3DES, and AES) for Information Security**

This paper gives a comparative view of different encryption algorithms on parameters like CPU usage, encryption time, ROM utilization, throughput with different file sizes, length of packet and data type [14–16].

Further, in order to ensure the privacy for cloud providers that provide the services to the clients upon request, plenty of security techniques have been proposed. Ahmad el at. [17] have proposed a game-theoretical model that assists the brokers by identifying the malicious providers that manage and create the federations. The proposed mechanism has been analyzed and simulated over a dataset through CloudSim simulator. In order to ensure security over cloud environment, Akshay et al. [18] have proposed a hybrid cryptographic mechanism that includes both asymmetric and symmetric encryption techniques. Author's have provided multilevel encryption for authenticating the clients using hash technique. The proposed technique is validated by computing the results in CloudSim simulator. From service requested clients to cloud providers, the security has been provided through various cryptographic algorithms including AES, DES, hybrid, hash or MAC algorithms. The scope of this paper is to discuss various cryptographic approaches and propose a hybrid encryption algorithm in order to ensure the security during transmission of file from one place to another. Further, author Shefali et al. [19] have used MD5 and AES encryption techniques for ensuring the security during the login and data access by the user over the cloud. The proposed mechanism need not authenticate the user upon login while during the data accessing, the AES and MD5 algorithms require user authentication.

- **Rivest–Shamir–Adleman (RSA)**

It is a public cryptosystem technique that incorporates block size encryption and variable key size. The steps involved are: Generate two distinct prime numbers, Calculate t as product of two, Now compute phi(t), Find d such that $d * e = 1$, Public Key is $(1, e)$ and Private key is $(1, d)$. It is the most apparent disadvantage is that if two numbers are of massive length then it takes more time and should be of comparable size. The below text elaborated a brief introduction of the standard algorithms.

- **Data Encryption Standard (DES)**

This encrypt algorithm is the most widely used because it works on bits. Length of message at one time to be encrypted is 64 bits and the key size of 64-bits but every $7x$ bit is a check bit which is removed in making of sub-keys. As known, it is one of the best algorithms because no such possible attack is known to crack it other than brute-force which is costly and time-consuming.

- **Triple DES**

Alias 3 DES, it is an extension of DES because it has greater key length. DES was more prone to brute attacks due to increasing computational power. Although it is better version of standard DES, but it can be breached using MITM attacks. So, to defend better against them it can be implemented using secret-key size of 112-bits.

- **Advanced Encryption Standard (AES)**

AES also recognized as Rijndael structure is an iterative algorithm rather being called a fiestel structure. It is iterative because it uses rounds to convert data to ciphertext depending on key sizes.

- **RC4**

RC4 is produced by Bokkos Rivest also called Rivest Cipher four. In this the stream figure is utilized for secret composing of the plain content. On the off chance that the basic square figures don't appear to utilize mackintosh effectively, bit-fluttering assault is doable and furthermore the stream figure assault is moreover powerless on the off chance that they're not legitimately authorized.

- **Blowfish**

Also, a symmetric cipher built as an alternate for more commercial AES and DES with varying key sizes of length from 32 to 448 bits with a block size of 64 bits. It's a 16-round cipher. It is efficient cipher and can be used commercially as alternative to AES. Most possible obvious attacks on this encryption are birthday attacks and should not be used for files of size more than 4 GB.

3 Proposed Solution

The flow graph of proposed approach where the source file is encrypted using the hybrid encryption is shown in Fig. 2. The file is selected and divided into three equal parts using the file system module. Then, each part is encrypted using the AES, DES and RC4 encryption techniques. The encrypted parts are then merged and saved into a single file which, then, can be uploaded on the cloud servers.

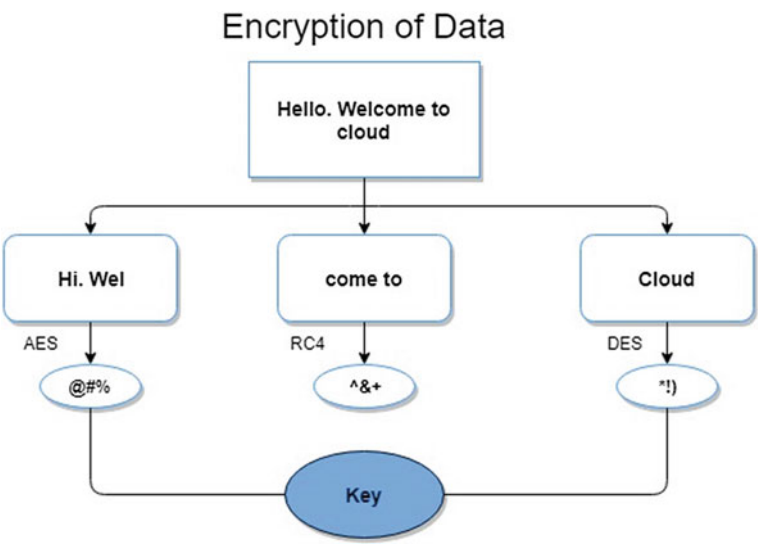

Fig. 2 Process of file encryption

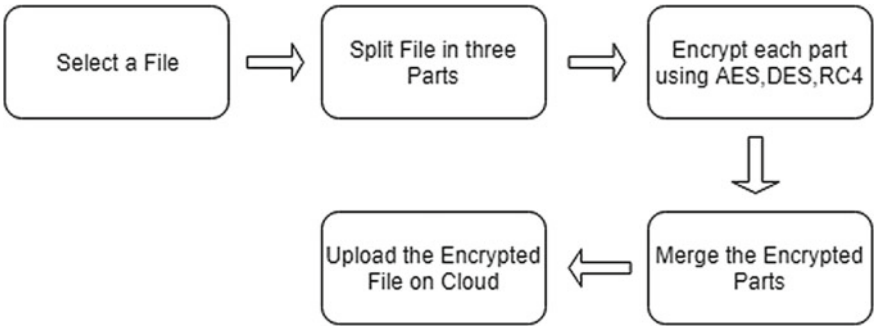

Fig. 3 Flow diagram of file encryption

File Splitting

The input file is split into three parts so that different encryption algorithms can be applied to each. Split-file module provides an efficient way to split and merge file into multiple parts.

Crypto JS

Crypto-js is a JavaScript library of crypto standards with a growing cluster of secure cryptographic algorithms implemented in JavaScript utilizing best practices and patterns. These algorithms are fast and have a simple and consistent interface. The following algorithms from module Crypto-js are used in this project. AES (Advanced Encryption Standard), DES (Data Encryption Standard), RC4 (Rivest Cipher 4), PBKDF2 (Password-Based Key Derivation Function), PKCS7 (Public Key Cryptography Standards).

File Encryption

The file is encrypted using three encryption algorithms. The steps of file encryption are shown in the given Fig. 3.

File Decryption

Further, for decryption at the receiver side as depicted in Fig. 4, the encrypted file is downloaded from the cloud servers and then split into three parts using a certain special character into three parts whereupon each part is then decrypted using the same techniques which were used for encryption, i.e., AES, DES, and RC4. The decrypted parts are merged into one and the retrieved file can then be used.

4 Test Plan

Testing will be done on different files varying from 1 MB till 30 MB.

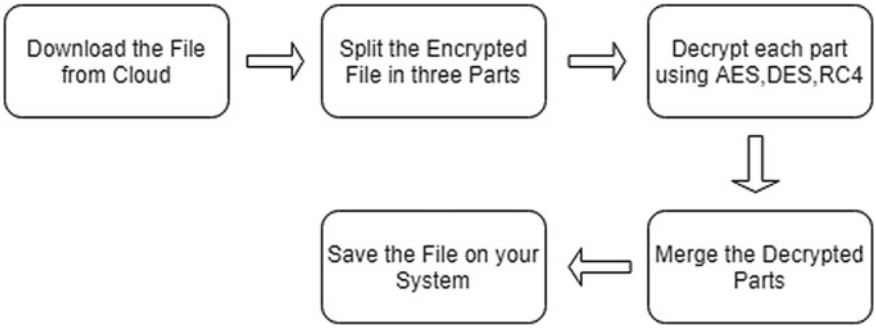

Fig. 4 Flow diagram of file decryption

Timing for encryption as well as decryption of such files using hybrid algorithm will be noted and compared with the respective encryption and decryption timings of same files using AES encryption alone. Section 5.2 offers a clear view of the time difference among the standard algorithm and the proposed algorithm. This section provides a rough idea of the comparison between the usual algorithm and the proposed algorithm. A file of size 10 MB is taken and is encrypted, firstly, AES and then using the hybrid algorithm. Also, decryption is done of the encrypted file using both, above mentioned, algorithms. The snippet of each algorithm outlines the time required to process the algorithm.

4.1 Encryption and Decryption Time for AES

A file named file.txt of size 10 MB is encrypted using the AES algorithm. Figure 5 shows how much time is required to encrypt the file while Fig. 6 depicts the decryption time.

4.2 Encryption and Decryption Time for Hybrid Algorithm

Now the file is encrypted using the hybrid algorithm (AES, DES, RC4). Figure 7 shows the time taken to encrypt the file.

Figure 8 depicts the decryption time of hybrid algorithm. The file of size 10 MB was encrypted and decrypted using the standard algorithm as well as the proposed algorithm. The timings from snippets in section show that the proposed algorithm is both comparatively faster in encryption of the file as well as decryption.

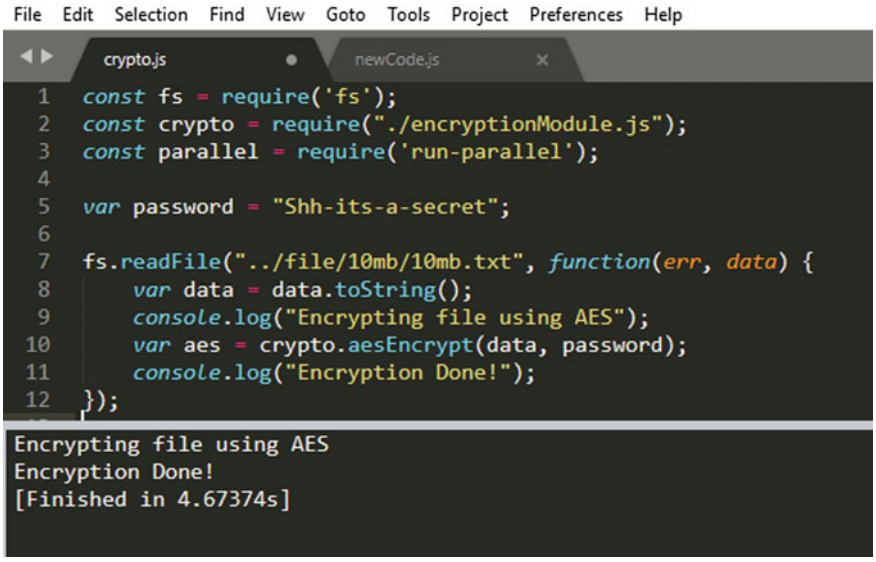

Fig. 5 AES encryption time

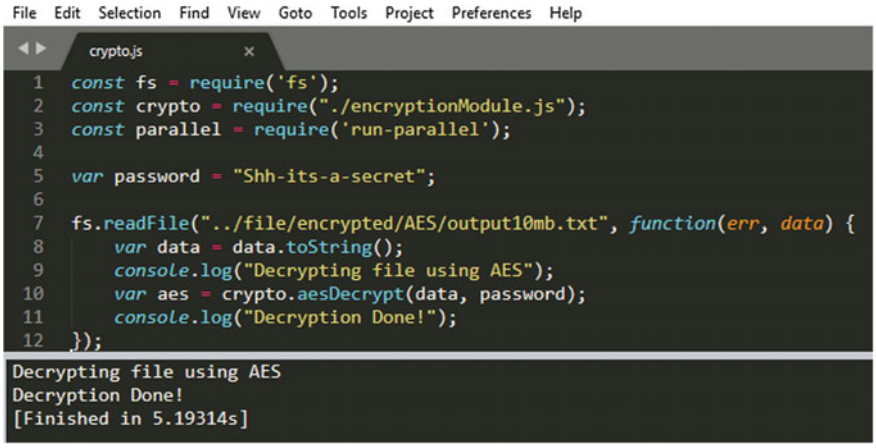

Fig. 6 AES decryption time

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newCode.js

```
const fs = require('fs');
const crypto = require("./encryptionModule.js");
const parallel = require('run-parallel');

var output;
var password = "Shh-its-a-secret";

var one = fs.readFileSync("../file/10mb/one.txt").toString();
var two = fs.readFileSync("../file/10mb/two.txt").toString();
var three = fs.readFileSync("../file/10mb/three.txt").toString();
console.log("Encrypting using Hybrid Algorithm");

parallel([
    function(callback) {
        let aes = crypto.aesEncrypt(one, password);
        callback(null, aes);
```

```
Encrypting using Hybrid Algorithm
Encryption Done!
[Finished in 4.78443s]
```

Fig. 7 Hybrid encryption time

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decryption.js

```
const fs = require('fs');
const crypto = require("./encryptionModule.js");
const parallel = require('run-parallel');

var output;
var password = "Shh-its-a-secret";

var file = fs.readFileSync("../file/encrypted/Hybrid/output10mb.txt").toString();
var files = file.split(".");
console.log("Decrypting using Hybrid Algorithm");

parallel([
    function(callback) {
        let aes = crypto.aesDecrypt(files[0], password);
        callback(null, aes);
```

```
Decrypting using Hybrid Algorithm
Decryption Done!
[Finished in 4.63709s]
```

Fig. 8 Hybrid decryption time

Table 1 Comparision of different encryption algorithms

Factors	DES	AES	RC4
Created by	IBM in 1975	Vincent Rijmen, Joan Daemen in 2001	Ron Rivest in 1987
Key length	56 bits	128, 192 or 256 bits	40–2048 bits
Round(s)	16	10, 12 or 14	1
Block size	64 bits	128 bits	2064 bits (1684 effective)
Speed	Slow	Fast	Fast
Security	Not secure enough	Excellent security	Adequate security

5 Result and Performance

In this section, various cryptographic algorithms are compared based on their key lengths, number of rounds, block sizes and other assets.

5.1 Algorithms Testing

Testing on various files will be done using AES (Standard Algorithm) and proposed algorithm (Hybrid Algorithm—AES, DES and RC4) so that the performance of the algorithm can be recorded in relation to the increasing size of the file. The files used in the tests vary from 1 MB till 30 MB. Graphs of both the algorithms along with their tables are shown below. Table 1 depicts the comparison of different encryption techniques over various parameters.

5.2 AES Testing

Encryption of file sizes ranging 1, 5, 10, 20 and 30 MB is done using AES Encryption. Encryption time of these files is calculated and plotted on a graph depicted in Fig. 9. Similarly, decryption of file sizes ranging 1, 5, 10, 20 and 30 MB is done using AES decryption algorithm. Decryption time of these files is calculated and plotted on a graph depicted Fig. 10.

5.3 Hybrid Encryption (AES, DES, RC4) Testing

Again, encryption of file sizes ranging 1, 5, 10, 20, and 30 MB is done using Hybrid Encryption. As already done on the above process, encryption time of these files is calculated and plotted on a graph depicted in Fig. 11.

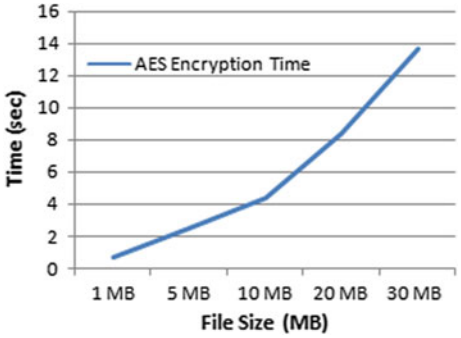

Fig. 9 AES encryption time

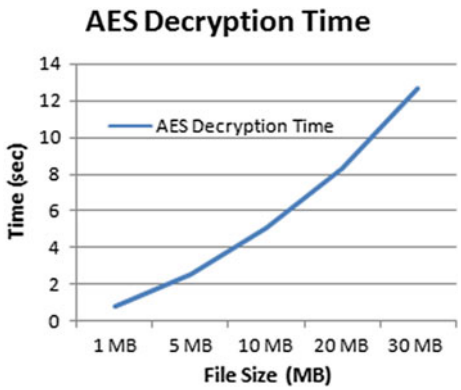

Fig. 10 AES decryption time

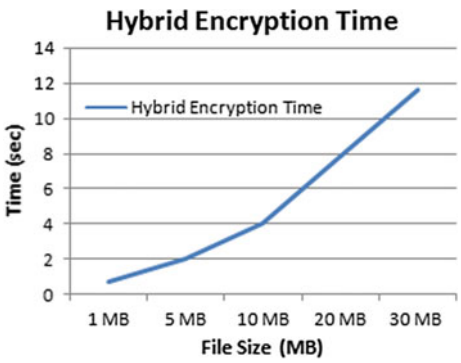

Fig. 11 Hybrid encryption time

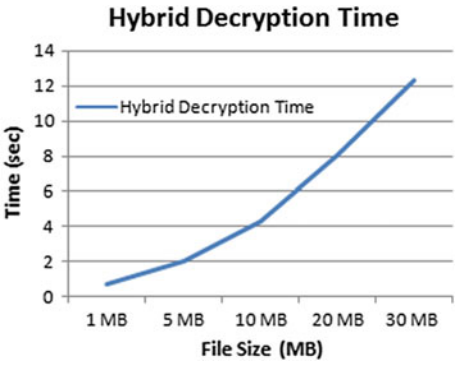

Fig. 12 Hybrid decryption time

Similarly, decryption of file sizes ranging 1, 5, 10, 20, and 30 MB is done using hybrid decryption algorithm. Decryption time of these files is calculated and plotted on a graph depicted in Fig. 12.

5.4 Comparison of Encryption Algorithms Testing Data

Bih-Hwang et al. [20] have ensured the cloud data security from third-party data models. Here, the author has used cloud platform know as Heroku that is responsible for managing and integrating the services using cryptographic algorithms. Lee et al. have used AES encryption technique to provide Heroku as cloud platform and provide data security from third parties. The authors have analyzed and validated the proposed mechanism by analyzing the encryption time over various file sizes. In this paper we have used this as over base paper and compared the proposed hybrid encryption over AES with different file sizes. Comparisons of the encryption time as well as decryption time of the files ranging 1–30 MB is shown in Table 2. Hybrid algorithm needs 10–15% less time for file to be encrypted in comparison to other encryption techniques. With single encryption algorithm such kind of data security cannot be provided.

The Graphs presented in Figs. 13 and 14 depicts the encryption time and decryption time of files with various files. As depicted in Fig. 13, AES approach ensures the

Table 2 Comparision of different algorithms

File size (MB)	AES encryption	Hybrid encryption	AES decryption	Hybrid decryption
1	0.717	0.732	0.789	0.685
5	2.544	2.076	2.499	2.034
10	4.457	4.021	5.043	4.232
20	8.429	7.875	8.325	8.063
30	13.710	11.618	12.645	12.328

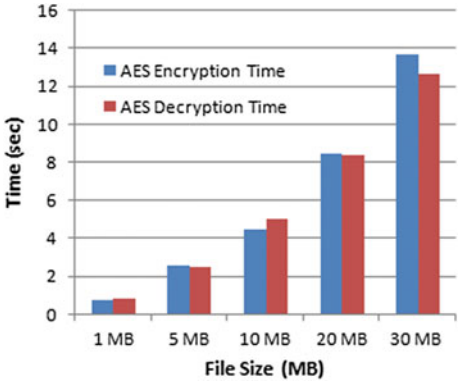

Fig. 13 Time comparison between AES and hybrid encryption algorithm

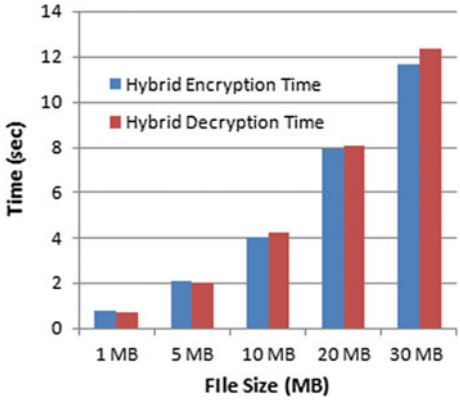

Fig. 14 Time comparison between AES and hybrid decryption algorithm

file security with the increase of file size, however, proposed approach gives better results as compare to AES because of hybrid encryption process. As the file size increases, proposed mechanism performs better. Similarly, the proposed algorithm performs better for the decryption process as presented in Fig. 14 with increasing file size, the decryption time taken for the hybrid algorithm gradually decreases in contrast to the AES algorithm.

6 Conclusion

By the investigation of the accompanying outcomes, we could reason that the hybrid algorithms of AES, DES, and RC4 gave us better execution time in contrast with that of AES algorithm alone. We saw that for moderately little document sizes AES individually produced better throughput in bytes per millisecond when contrasted with that of hybrid algorithm including AES, DES, and RC4. However, as the measure of

record augmented, proposed algorithm indicated better outcomes. Mulling over, the substantial measure of information that business applications will in general store on the cloud, record sizes can fluctuate to extensive numbers, thus the utilization of hybrid algorithm calculation is proposed to actualize staggered security on cloud information storage. Based on the examination of execution of single encryption calculations and multiple encryption calculations, it is concluded that hybrid encryption involving multiple encryption algorithms (AES, DES, and RC4) provided much better results than single algorithm (AES) implemented alone. In the future, we plan to use certain other encryption algorithms such as Blowfish and other public-key encryption techniques like RSA to be implemented in the project.

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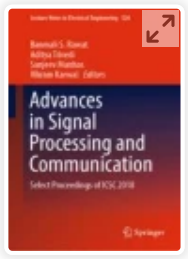

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About this book

This book is a collection of selected peer-reviewed papers presented at the International Conference on Signal Processing and Communication (ICSC 2018). It covers current research and developments in the fields of communications, signal processing, VLSI circuits and systems, and embedded systems. The book offers in-depth discussions and analyses of latest problems across different sub-fields of signal processing and communications. The contents of this

book will prove to be useful for students, researchers, and professionals working in electronics and electrical engineering, as well as other allied fields.

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Mathematical Analysis of Commonly Used Feeding Techniques in Rectangular Microstrip Patch Antenna



Ekta Thakur, Dinesh Kumar, Naveen Jaglan, Samir Dev Gupta and Shweta Srivastava

Abstract In the presented work, different feeding techniques are employed to design microstrip patch antenna for wireless applications. These feeding techniques are as follows: microstrip inset feed, quarter wavelength feed, and coaxial probe feed. Parameters valuated for comparing these feeding techniques are: return loss, directivity, gain, and radiation efficiency. In the presented work, it is observed that by using coaxial probe feed, the values achieved for maximum directivity and gain are 5.43 dBi and 5.33 dB, respectively.

Keywords Microstrip patch antenna · Feeding techniques · Directivity · Gain Bandwidth

1 Introduction

The Microstrip Patch Antenna (MPA) antennas are popularly engaged for improving the performance of wireless application. This is due to their conformal structure, small

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size, moderate efficiency, lightweight, and ease of integration with active devices. The MPA consists of metallic ground plane, dielectric substrate, and radiating patch. The ground plane and patch are made up of conducting material like gold and aluminum whereas substrate is made up of dielectric material like RT/duroid, FR4, etc. There are multiple approaches to feed the microstrip antennas which are generally divided into two varieties namely, the contacting and the non-contacting approach [1]. In the former, the microstrip line is used to feed patch however, in the latter, the coupling is exploited to transfer the power among the patch and the microstrip line. In this microstrip feed line method, the radiating patch is connected to a straight feed using conducting copper strip line. The width of the microstrip line is less as compared to width of the patch. There are various substrates that are used to design and fabricate the antenna with dielectric constant ranging between $2.2 \leq \varepsilon_r \leq 12$ [1]. The coaxial feed or probe feed is mostly used to feed the MPA. Due to the easy implementation of the coaxial feed, it is one of the popular feeding techniques used. The internal and external conductors are separated by dielectric in the coaxial feed. The internal conductor of the coaxial feed is attached to the patch, while the external conductor is attached to the ground plane [2]. The MPA can also be designed using inset feed, which is the simplest method due to easy impedance matching.

Among the various non-contacting feeding techniques, proximity coupling [3] and aperture coupling are studied by the researchers [4]. In the former technique, the strip line is amid two dielectric substrates and the patch is on the top of upper substrate. In the latter technique, the ground plane is in between the patch and feed line. Among the four feeds discussed, the proximity coupling consumes the largest bandwidth despite its difficulty.

2 Antenna Design

For the better antenna performance, the thick dielectric substrate is used because it provides larger bandwidth and better radiation however, the thick dielectric substrate results in the large antenna dimension [4]. Moreover, the thick dielectric substrate has low dielectric constant value. The three antennas are simulated using high-frequency structure simulator (HFSS) software.

2.1 Coaxial Feed MPA Design

The MPA is designed at the frequency of 2.4 GHz, where the FR4 substrate is used with dielectric constant 4.7 and loss tangent 0.002. The parameters of the patch are calculated by using the given formulas.

The patch length is calculated by

$$L = L_{eff} - 2\Delta L \tag{1}$$

$$L_{eff} = \frac{c}{f\sqrt{\in_{eff}}} \tag{2}$$

where L, L_{eff} represents the length of the patch, effective length. The width and the effective dielectric constant of the patch is obtained by

$$W = \frac{c}{2f\sqrt{\in_r + 1}} \tag{3}$$

$$\in_{eff} = \frac{\in_r + 1}{2} + \frac{\in_r - 1}{2}\left(1 + 12\frac{h}{W}\right)^{-1/2} \tag{4}$$

where f, c, W, ε_r, h and ε_{eff} represents the resonant frequency, speed of light, width of the patch, dielectric constant, height of substrate, and effective dielectric constant, respectively. The effective length of the patch is $\mathrm{L} = \frac{\lambda}{2}$ for TM_{010} mode with no fringing [5].

$$\Delta L = 0.412h\frac{\left(\in_{eff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\in_{eff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \tag{5}$$

Characteristic impedance is given by [6]

$$Z_C = \begin{pmatrix} \frac{60}{\sqrt{\in_{eff}}}\ln\left(\frac{8h}{w_0} + \frac{w_0}{4h}\right) & \frac{w_0}{h} \le 1 \\ \frac{120\pi}{\sqrt{\in_{eff}}\left[\frac{w_0}{h} + 1.393 + 0.667\left(\frac{w_0}{h} + 1.444\right)\right]} & \frac{w_0}{h} \ge 1 \end{pmatrix} \tag{6}$$

where w_0 is the width of the microstrip line. The calculated effective dielectric $\left(\varepsilon_{eff}\right)$ is equal to 4.04.

Therefore, the length due to fringing effect (ΔL) is equal to 1.116 mm. Further, the calculated dimensions like width and length of patch of coaxial feed MPA are presented in Table 1. The calculated effective dielectric $\left(\varepsilon_{eff}\right)$ is equal to 4.04. The length and width of ground plane is the same as the substrate dimensions.

Table 1 Dimensions of coaxial feed MPA Design

Parameters	Values (mm)
Width of patch (W_{P1})	30
Length of patch ($\mathrm{L_{P1}}$)	39.5
Width of substrate ($\mathrm{W_{S1}}$)	90
Length of substrate ($\mathrm{L_{S1}}$)	100
Feeding point (Y_O)	4.3
Radius of internal conductor	0.7
Radius of external conductor	1.7

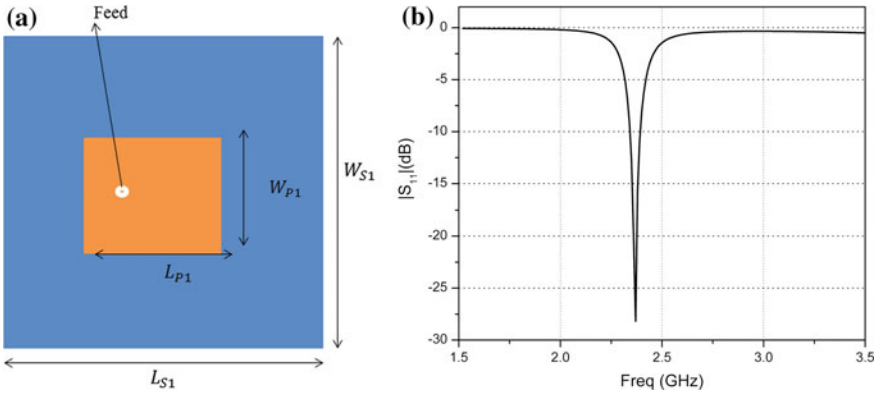

Fig. 1 **a** Antenna designed using coaxial probe feed. **b** Return loss of coaxial feed MPA

2.2 Results of Coaxial Probe Feed MPA

Return loss of the coaxial probe feed MPA at 2.4 GHz is −26 dB as shown in Fig. 1b. If the dip is below −10 dB, this means that 1/10th of incident power is reflected back at the interferences of the transmissions lines and the antenna [6]. Bandwidth achieved for 50 MHz is calculated by the formula given in Eq. (8). The return loss and bandwidth are given as [7]

$$RL = -20\log(\Gamma) \tag{7}$$

$$BW = \frac{(f_h - f_l)}{f_c} \times 100 \tag{8}$$

where the RL, Γ, BW, f_l, f_h, and f_c signify the return loss, reflection coefficient, bandwidth, lower frequency, upper frequency, and center frequency, respectively. The ideal matching between the transmitter and antenna is achieved when the reflection coefficient and RL is zero and 0 dB, respectively. This signifies that there is zero power reflected back however, when the reflection coefficient and RL is one and infinity, respectively, indicates the total reflection of incident power. The field pattern of the MPA with coaxial feed is obtained as Fig. 3a.

2.3 Inset Feed MPA Design

The impedance of feedline should match to the patch to obtain good antenna efficiency which can be achieved using inset feed. The input impedance can be altered by using an inset feed. The input resistance for the inset feed is calculated as [8]

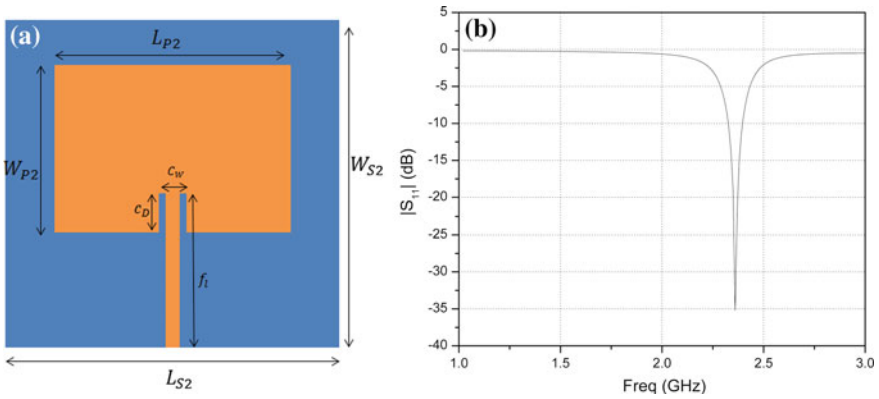

Fig. 2 **a** Antenna designed using inset feed. **b** Return loss of inset feed MPA

$$R_{in}(C_D) = \frac{1}{2(G_1 + G_{12})} \cos^2\left(\frac{\pi}{L} C_D\right) \tag{9}$$

$$G_1 = \begin{pmatrix} \frac{1}{90}\left(\frac{W}{\lambda}\right)^2 & W \ll \lambda \\ \frac{1}{120}\left(\frac{W}{\lambda}\right) & W \gg \lambda \end{pmatrix} \tag{10}$$

$$G_{12} = \frac{1}{120\pi^2} \int_0^{\pi} \left[\frac{\sin^2\left(\frac{k_0 W}{2}\right)^2}{\cos\theta}\right] J_0(k_0 \sin\theta) \sin^3\theta d\theta \tag{11}$$

where $R_{in}\ (C_D)$ is the input impedance at point C_D.

2.4 Results of Inset Feed MPA

Figure 2b illustrates the return loss of the inset feed. The calculated dimensions of inset MPA are shown in Table 2. The electric field plane and magnetic field plane pattern of a rectangular microstrip antenna with inset feed at 2.4 GHz center frequency shown in Fig. 3b [9] (Fig. 4).

2.5 Quarter Wavelength Feed MPA Design

The characteristic impedance of quarter wavelength transmission line [10–15]

$$Z_{in} = \frac{Z_0^2}{Z_A} \tag{12}$$

Table 2 Dimensions of inset feed MPA Design

Parameters	Values (mm)
Width of patch (W_{P2})	29.44
Length of patch (L_{P2})	38.04
Width of substrate (W_{S2})	49.75
Length of substrate (L_{S2})	50
Slot width (C_W)	2.4
Slot Depth (C_D)	5
Feed Length (f_l)	20
Feed width (f_w)	1.6

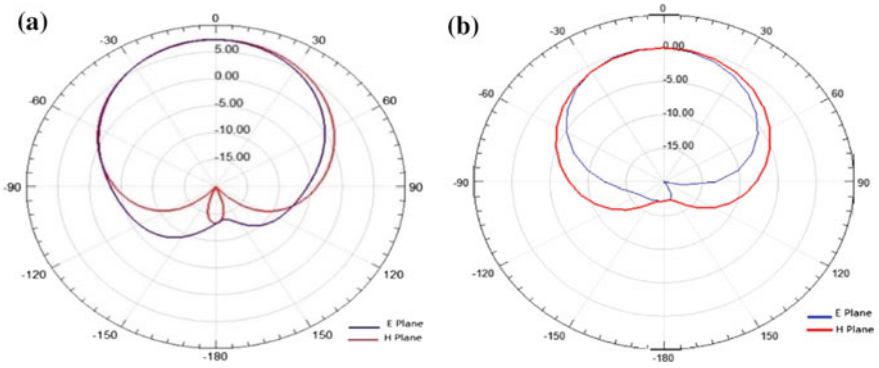

Fig. 3 **a** E plane and H plane of coaxial feed MPA. **b** E plane and H plane of inset feed MPA

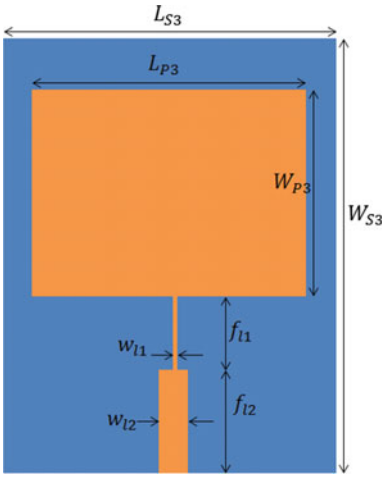

Fig. 4 Antenna designed using quarter wavelength feed

Table 3 Dimensions of quarter wavelength MPA

Parameters	Values (mm)
Width of patch (W_{P3})	29.26
Length of patch (L_{P3})	36.26
Width of substrate (W_{S3})	45
Length of substrate (L_{S2})	60.94
Feed length (f_{l1})	5
Feed length (f_{l2})	15
Feed width (w_{l1})	0.62
Feed width (w_{l2})	3.05

$$Z_0 = \sqrt{Z_A Z_{in}} \tag{13}$$

where Z_0 is characteristic impedance, Z_{in} is input impedance, and Z_A is load impedance. The calculated dimensions of quarter wavelength feed microstrip patch antenna is shown in Table 3.

2.6 Results of Quarter MPA Feed

The return loss of the quarter wavelength feed antenna at 2.4 GHz is −27 dB shown in Fig. 5b. The bandwidth achieved 80 MHz that is calculated by using Eq. (8). The radiation pattern of a rectangular microstrip antenna with quarter wavelength feed at 2.4 GHz center frequency shown in Fig. 5a.

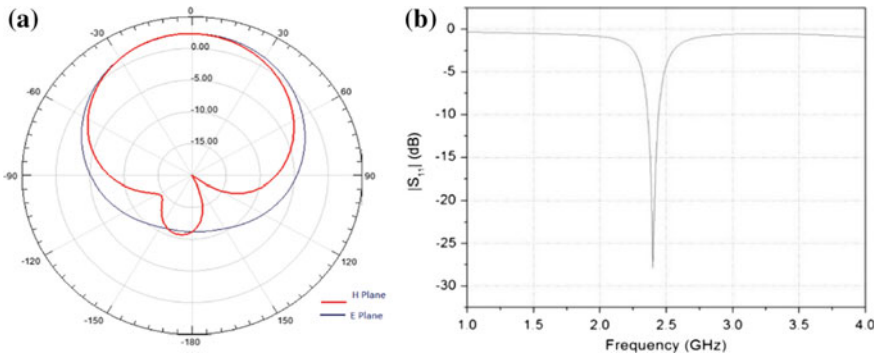

Fig. 5 **a** Radiation pattern of quarter wavelength feed MPA. **b** Return loss of quarter wavelength feed MPA

Table 4 Comparison of various feeding techniques of MPA

Parameters	Coaxial feed	Inset feed	Quarter wavelength feed
Return loss (dB)	−26	−35	−27
Frequency (GHz)	2.4	2.4	2.4
Max U(W/sr)	0.0036528	0.070014	0.13607
Bandwidth(MHz)	50	10	80
Peak Gain(dB)	5.3308	1.2	1.7167
Radiated Power (W)	0.0084524	0.047574	0.54238
Peak Directivity(dBi)	5.4309	1.8494	3.152
Accepted power(W)	0.008611	0.86261	0.99607
Incident Power (W)	0.010122	0.0094294	1
Radiation Efficiency	0.98157	0.5515	0.5452
Front to Back Ratio	113.48	56.188	25.795

3 Comparison

The simulated result of all feeding techniques is shown in Table 4. Those feeding methods are microstrip inset feed, quarter wavelength, and co-axial probe feed. Table 4 also gives the variation in different parameters like directivity, gain, etc.

4 Conclusion

It is observed that all considered feeding techniques of the microstrip patch antenna provide different results. Selection of feed is a significant decision because it varies almost all the parameters of the antenna (Fig. 4).

The variations in bandwidth, directivity, gain, and efficiency of MPA under different feeding techniques are considered. It can be seen that coaxial feed achieves better gain and directivity of 5.43 dBi and 5.33 dB, respectively. These values are better as compared to other feeding methods.

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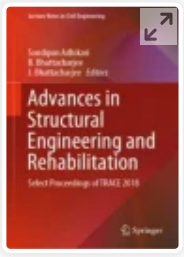

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About this book

This book comprises select papers presented at the International Conference on Trends and Recent Advances in Civil Engineering (TRACE 2018). The book covers a wide range of topics related to recent advancements in structural engineering, structural health monitoring, rehabilitation and retrofitting of

structures, and earthquake-resistant structures. Based on case studies and laboratory investigations, the book highlights latest techniques and innovative methods for building repair and maintenance. Recent development in materials being used in structural rehabilitation and retrofitting is also discussed. The contents of this book can be useful for researchers and professionals working in structural engineering and allied areas.

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Keywords

Structural health monitoring

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Rehabilitation **TRACE 2018**

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Mix Design and Factors Affecting Strength of Pervious Concrete



Bishnu Kant Shukla and Aakash Gupta

Abstract Pervious concrete is a sure sort of concrete with a high porosity utilized for concrete flatwork applications that will permit the water from precipitation and different sources to go straightforwardly through, along these lines diminishes the overflow from a site and permitting groundwater to revive. The concrete glue at that point coats the totals and enables water to go through the concrete piece. With interconnected void content, we can achieve high porosity. Water-to-cementitious material ratio is 0.40–0.50. Designs were made at different water–cement ratios, and these ratios show the different exposure conditions. In this paper, specific gravity of cement, coarse aggregate and fine aggregate were selected as 3.15, 2.68, 2.65 respectively. Cement used in this project was OPC-43. Coarse aggregate were used at different proportions. The present examination tended to the strength and seepage parts of pervious concrete mix and furthermore the impact of CS as FA. A point-by-point contemplate is required to know the impacts of total degree with different kinds of total. In this undertaking, the mechanical properties of pervious concrete have been used to plan road pavements. The properties of PCC blend to be examined are compressive strenth and flexural strength. An optimum percentage has been determined which shows the concrete is permeable and having good compressive and flexural strength. In this research paper, the mechanical properties of pervious concrete have been used to design road pavements. Main focus of the paper is to determine and improve compressive strength, and flexural strength.

Keywords Pervious concrete · OPC · NFC · FA · CA · River sand · Crushed stone

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1 Introduction

Porous concrete is a blend of shake or stone, bond, water and alongside zero FA which influences an open cell for structure which further then empowers water and air to experience it. According to the environmental protection agency (EPA), storm water flood can send as much of 90% toxic substance, for instance, oil and other hydrocarbons. The limit of porous concrete to empower water to travel through itself resuscitates and after that groundwater restricts the level of defilement and whirlwind water overflow. Porous cement is used to allow storm water to attack through the black-top and diminish or shed the necessity for the additional control structures, for instance, support lakes.

The pervious solid black-top has various ideal conditions that can improve the city condition as takes after:

1. The water can quickly channel into the ground, so the groundwater resources can re-establish in time as the black-top is air permeable, water vulnerable and the soil underneath can be kept wet.
2. The porous solid black-top can hold the commotion of vehicles, which influences peaceful and pleasant to condition.
3. In tempestuous days, the pervious solid black-top has no plash at first look and does not flash around night time. This will improve the comfort and prosperity of the drivers.
4. The pervious solid black-top materials have openings that can cumulate warm.

Such black-top can change the temperature and suddenness' of the earth's surface and gets rid of the wonder of hot island in urban zones. An achieved installer is irreplaceable to the accomplishment of pervious solid black-tops as with any solid black-top, fitting subgrade status is crucial [1]. The subgrade should be properly compacted for reason that it will give a uniform and stable surface. Right when pervious black-top is set direct on the sandy soil, then it is recommended to moderate the subgrade from 92 to 96% of the most extraordinary thickness. With the silty or clayey soils, the level of compaction will tons of black-top arrangement and a layer open assessed stone may must be put over soil. The voids can go from 18 to 35% with compressive strength of 10–30 MPa. The invasion rate of pervious cementitious materials, coarse totals, water with practically no fine aggregates and admixtures. The expansion of little measures of fine totals will continuously lessen the void space and increment the strength, which might be attractive in specific circumstances. This material is touchy to change in water content, so field modification of crisp blend is typically important. The right amount of water in the solid is basic. An excess of water will cause isolation, and too little water will prompt balling in the blender and moderate blender emptying. The W/C and C/A proportions are regularly varied from 0.25 to 0.45 and 1:3.5 to 1:6. To make a porous solid structure with ideal porousness and compressive strength, the measure of water, measure of bond, sort and size of aggregate, and compaction should all be considered. A colossal number of examinations have been now driven all through the past couple of

decades by an assortment of specialists contrasting a few or these components. In his paper [2], V. M. Malhotra discussed pervious concrete as it relates to applications and properties. He gave purposes of enthusiasm on the properties such as consistency, extents of materials, unit weight, comparability and curing endeavouring to open up penetrability in the porous cement. Malhotra also drove various investigations on different test chambers endeavouring to find a connection between strength like compressive strength and any of the material's properties. He gathered for the compressive nature of pervious cement was reliant on the water bond proportion and the total concrete ratio. Attractive vibration is essential for nature of customary cement. The use of porous cement is one of a kind and is a self-pressing item. It was recommended by several researchers [2–6] that the use of mechanical vibrators and smashing is not proposed with porous cement. A light rodding should be attractive and used to ensure that the solid accomplishes all regions of the formwork. This is not an issue with customary cement, since it has more prominent stream capacity than penetrable cement. The light rodding ensures that the solid entered every region obstructed by fortifying steel. Malhotra [2] stressed that in circumstances where common conditions are not refined amid arrangement and curing, the formwork ought not to be expelled following 24 h as with normal cement. Permeable cement has low cohesiveness and formwork ought to stay until the point that the bond glue has solidified adequately to hold the total particles together. Be that as it may, this is to a greater degree a thought in low temperature conditions and when utilized as a part of non-asphalt applications where the concrete is not adequately upheld by the ground or different means.

Another recent work on Portland cement concrete pavement permeability execution [7] expresses test ponders on transport properties of concrete are controlled by the attributes of its pore arrange. Add up to porosity, pore size, pore connectivity, and pore saturation, all impact the deliberate transport coefficients [7]. Water-absorbing concrete was first utilized as a part of the 1800s in Europe as pavement surfacing and load-bearing walls. Cost-effectiveness was the principle thought process because of a diminished measure of cement. It ended up prominent again in the 1920s for two story homes in Scotland and England. It turned out to be progressively suitable in Europe after WWII because of the shortage of cement. It did not move towards becoming as well known in the USA until the 1970s. In India, it ended up well known in 2000. The first water-absorbing placement in the Indian metro area was in Sugar Creek, MO in November 2005. Since that time, around 30+ pavements have been put and numerous lessons found out about what makes water-absorbing concrete 'great'. Here in, are the present rules that have been educated and adjusted. Shah et al. [8], in his work on water-absorbing concrete examined on utilizing pervious concrete as street development material generally new idea for provincial street pavement, with expanding issue in country zones identified with low groundwater level, farming issue. His report centres around pavement utilization of concrete which additionally has been referred on pervious concrete, penetrable concrete, no fine concrete, hole-reviewed concrete and upgraded porosity concrete.

As a result of work on water-absorbing concrete, Eathakoti et al. [1] developed an innovative model that can transport water go into the pavement has been proposed

towards this path. Diverse mixes of cement, water and coarse aggregate with various greatest size and gradation were adopted for mixing procedure to make roughly at M20 grade concrete. M20 grade concrete is accomplished with a w/c proportion of 0.4–0.45, coarse aggregate of nominal size 20 mm and with cement to coarse aggregate proportion of 1:4. Its density and flexural strength quality were seen to be 21 kN/m^3 and 35 kg/cm^2 individually. A pavement piece appropriate for low activity volume streets is planned according to IRC SP62: 2004 which permits stockpiling of water up to 125 L/m^3 of concrete pavement giving time for invasion in this way diminishing the runoff and reviving the groundwater or adequate time for transport of it. A perforated pipe can be given at focus of the pavement above sub-base with the end goal that it gathers the water put away in concrete and depletes it to the required treatment plant or a fill pit [9, 10]. This, however, needs to encourage examination and trials before practical implementation [11]. Aims and objectives of the present work are:

1. The principle target of this examination is to build up a solid and tough pervious bond concrete (PCC) blend utilizing distinctive kinds of FA with changing the amount of FA. Moreover, it is likewise expected to think about the properties of these PCC blends.
2. The level of fine aggregates to be utilized as a part of PCC blend is set to 30% max.
3. The properties of PCC mixes to be looked into are compressive quality and flexural quality.

2 Methodology

After distinguishing proof of issue and setting the targets of the research, the research methodology has been carefully designed to accomplish these destinations.

1. Accumulation and investigation of writing relating to the exposition work.
2. Decide the building properties of porous concrete and compare them with ordinary concrete. Cast different trial blends with changing rates of porous concrete and analyse for the compressive strength.
3. Get-ready test tests with the rate esteem and tests the examples for the different properties.
4. To remark on the reasonableness and confinements of porous concrete with traditional concrete.

2.1 Planning Schedule

Collections of material were carried out as per the following schedule:

1. Collection of OPC Cement
2. Preparation of mould for casting of cubes and beams

3. Collection of CA and FA.

Commercially available CA and FA were collected, and suitable percentages of both the aggregates were fixed. For example, NFA, 4:1, 3:2. Mixes were created by varying cement content from 350 to 480 kg/m^3. Sets of three cubes were casted having different mix proportions. After 24 h of casting, cubes were demoulded and water cured for several days. Each set of cubes were tested for mechanical properties at the end of 3, 7 and 28 days.

2.2 Casting and Testing

After making the mix design at three different cement contents, i.e. 479, 446, 384 kg/m^3 and without taking fine aggregates, with coarse aggregate to fine aggregate ratio as 5:0, the mix design with lowest concrete density has been selected. The cement content of 384 kg/m^3 has the lowest concrete density; therefore, further two more mix proportions prepared using ratio 4:1 and 3:2 of coarse aggregate and fine aggregate. Mix proportions for casting of cubes and beams have been shown in Tables 1, 2, 3, 4, 5 and 6.

Table 1 Mix proportion for cube using no fine aggregate at cement content 384 kg/m^3 (w/c = 0.50) (CA:FA = 5:0)

S. No.	Material	Quantity per m^3 (kg)	Quantity for casting one cube (150 * 150 * 150 mm) (kg/mm^3)
1	Cement	384	1.296
2	Water	191.6	0.6466
3	CA	1839.82	6.2093
4	FA	Nil	Nil
5	Yield	2415.42	8.1519

Table 2 Mix proportion for cube using fine aggregate at cement content 384 kg/m^3 (w/c = 0.50) (CA:FA = 4:1)

S. No.	Material	Quantity per m^3 (kg)	Quantity for casting one cube (150 * 150 * 150 mm) (kg/mm^3)
1	Cement	384	1.296
2	Water	191.6	0.6466
3	CA	1471.856	4.967
4	FA	363.845	1.2279
5	Yield	2411.3	8.1375

Table 3 Mix proportion for cube using fine aggregate at cement content 384 kg/m^3 (w/c = 0.50) (CA:FA = 3:2)

S. No.	Material	Quantity per m^3 (kg)	Quantity for casting one cube (150 * 150 * 150 mm) (kg/mm^3)
1	Cement	384	1.296
2	Water	191.6	0.6466
3	CA	1103.89	3.7256
4	FA	727.69	2.4559
5	Yield	2407.18	8.1241

Table 4 Mix proportion for beam using no fine aggregate at cement content 384 kg/m^3 (w/c = 0.50) (CA:FA = 5:0)

S. No.	Material	Quantity per m^3 (kg)	Quantity for casting one beam (100 * 100 * 500 mm) (kg/mm^3)
1	Cement	384	1.92
2	Water	191.6	0.958
3	CA	1839.82	9.1991
4	FA	Nil	Nil
5	Yield	2415.42	12.077

Table 5 Mix proportion for beam using fine aggregate at cement content 384 kg/m^3 (w/c = 0.50) (CA:FA = 4:1)

S. No.	Material	Quantity per m^3 (kg)	Quantity for casting one beam (100 * 100 * 500 mm) (kg/mm^3)
1	Cement	384	1.92
2	Water	191.6	0.958
3	CA	1471.856	7.359
4	FA	363.845	1.8192
5	Yield	2411.3	12.056

Table 6 Mix proportion for beam using fine aggregate at cement content 384 kg/m^3 (w/c = 0.50) (CA:FA = 3:2)

S. No.	Material	Quantity per m^3 (kg)	Quantity for casting one beam (100 * 100 * 500 mm) (kg/mm^3)
1	Cement	384	1.92
2	Water	191.6	0.958
3	CA	1103.89	5.519
4	FA	727.69	3.638
5	Yield	2407.18	12.035



Fig. 1 Surface cleaned and oiled moulds

2.3 Size of Test Specimens

Test specimens cubical in shape was 15 cm × 15 cm × 15 cm. If the largest nominal size of the aggregate does not exceed 2 cm, 10-cm cubes may be used as an alternative. Similarly for beams, the size of moulds used was 50 cm × 10 cm × 10 cm. Cubes were casted to perform check on compressive strength of pervious concrete while beams were casted to check the flexural strength of pervious concrete.

2.4 Preparation of Moulds

Prior to mixing and casting of specimen, one of the most important and time-consuming works is the preparation of moulds [12]. Moulds were prepared such that all surfaces of moulds were cleaned and oiled properly, and all the bolts were tightened so that it did not allow any leakage of mortar (Fig. 1).

Special care was taken while applying oil. Excessive amount of oil can lead to the presence of bug holes on the surface of concrete after demoulding. A suitable brush or cloth was used while applying oil on the surface of moulds. Also, type of oil used is very important as the purpose of oil is to provide necessary lubrication so that concrete may not stick to the surface of moulds and it should be easy to demould the specimen. If suitable oil is not used, then it may break your specimens and whole procedure is to be repeated again. The oil used in this study was waste black oil easily available at any workshop at no cost or very minimal charges.



Fig. 2 Homogeneous dry mix



Fig. 3 Homogeneous wet mix after adding water

2.5 Mixing

All of the mixing of concrete was done by hand mixing only. All of the ingredients of pervious concrete like cement, coarse aggregate and fine aggregate were first weighed as per mix design proportion and then mixed on floor which was prepared for saturated surface dry condition so that floor shall not absorb any water from the mix neither shall it release more water into the mix. All three ingredients of pervious concrete were first mixed in dry condition (Fig. 2) so that all aggregates were properly mixed with cement in order to have homogeneous mixture (Fig. 3).

After the mixing of concrete, well-cleaned and oiled moulds were filled with concrete and hand compacted. Here, table vibrator is not recommended as it was noted that under effect of vibration cement slurry settles down and makes the concrete impervious. Each mould was filled in three layers and hand compacted after each layer with the help of tamping road.



Fig. 4 Specimen kept for 24 h prior to demoulding

Again, after the moulds were filled with concrete and leveled, the specimens were left for 24 h before demoulding (Fig. 4) so that concrete achieves its hardening. After 24 h of casting, the cubes were demoulded on very next day without any delay.

2.6 Testing of Specimens

The entire specimens were tested as per directions given in IS 516 (1959). To check compressive strength of concrete using pervious concrete cubes, compression testing machine was used, whereas to perform check on flexural strength of beams, flexural testing machine was used. The load for compression testing machine was set as specified in IS 516, i.e. 140 kg/cm^2/min. The load shall be applied slowly without shock and increased continuously until the resistance of specimen (concrete cube) to increasing load breaks.

Calculation of Load:

Load as per IS Code = 140 kg/cm^2/min
1 kg = 9.81 N
1000 N = 1 kN
1 min = 60 s

But load specified in IS 516 is in kg/cm^2/min
= (1.373 × 15 × 15)/60
= **5.148 kN/s**

Similarly, for flexural strength test, load specified in IS 516 = 180 kg/min for 10-cm beams that comes out to be 29.42 N/s.

3 Results and Discussion

The results of the study have been presented under the following heads.

3.1 Compressive Strength Results

Compressive strength results were determined after 3, 7 and 28 days of curing and presented in Tables 7, 8 and 9.

Table 7 Compressive strength of cubes using no fine aggregates (CA:FA = 5:0)

S. No.	Age of cube (days)	Compressive strength of cube (MPa)
1	3	6.9
2	3	7.6
3	3	7.4
4	7	8.2
5	7	8.8
6	7	9.4
7	28	10.55
8	28	11.3
9	28	11.9

Table 8 Compressive strength of cube using fine aggregates (CA:FA = 4:1)

S. No.	Age of cube (days)	Compressive strength of cube (MPa)
1	3	8.53
2	3	8.88
3	3	8.1
4	7	11.87
5	7	11.82
6	7	12.88
7	28	13.55
8	28	15.7
9	28	16.66

Table 9 Compressive strength of cube using fine aggregates (CA:FA = 3:2)

S. No.	Age of cube (days)	Compressive strength of cube (MPa)
1	3	18
2	3	17.82
3	3	18.1
4	7	33.64
5	7	32.26
6	7	33.82
7	28	42.04
8	28	41.91
9	28	41.56

Table 10 Flexural strength of beams using no fine aggregates (CA:FA = 5:0)

S. No.	Age of beam (days)	Compressive strength of beam (MPa)
1	7	2.76
2	7	2.73
3	7	3
4	28	2.99
5	28	3.26
6	28	3.5

Table 11 Flexural strength of beams using fine aggregates (CA:FA = 4:1)

S. No.	Age of beam (days)	Compressive strength of beam (MPa)
1	7	4
2	7	3.25
3	7	3
4	28	4.2
5	28	4.3
6	28	3.9

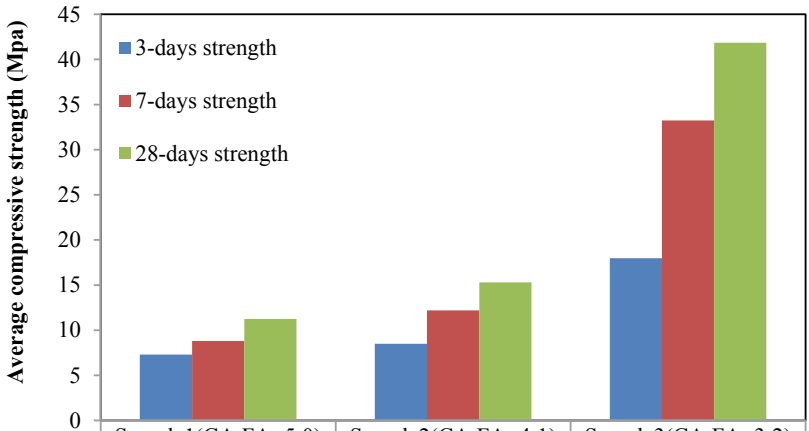
3.2 Flexural Strength Results

Flexural strength results were determined after 7 and 28 days of curing and presented in Tables 10, 11 and 12.

Figure 5 shows a comparative study of compressive strengths after 3, 7 and 28 days for sample 1, sample 2 and sample 3. It was noticed that compressive strength increases from sample 1 to sample 3 with sample 3 showing highest compressive strength and sample 1 showing lowest compressive strength as compared to other

Table 12 Flexural strength of beams using fine aggregates (CA:FA = 3:2)

S. No.	Age of beam (days)	Compressive strength of beam (MPa)
1	7	4.6
2	7	4.5
3	7	4
4	28	6
5	28	5.75
6	28	5

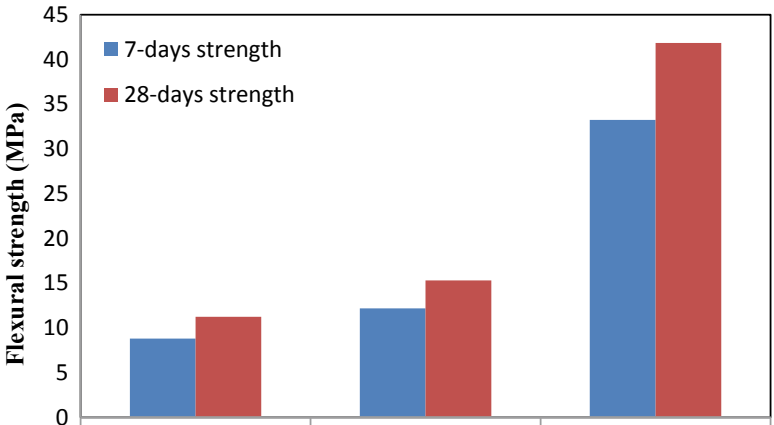


	Sample1(CA:FA=5:0)	Sample2(CA:FA=4:1)	Sample3(CA:FA=3:2)
3-days strength	7.3	8.5	17.97
7-days strength	8.8	12.19	33.24
28-days strength	11.25	15.3	41.84

Fig. 5 Comparison of average compressive strength of cubes with different CA:FA ratios

two samples, but sample 2 having higher compressive strength than sample 1 and lower compressive strength than sample 3.

Figure 6 shows a comparative study of flexural strengths after 7 and 28 days for sample 1, sample 2 and sample 3 which shows that flexural strength increases from sample 1 to sample 3. Sample 3 demonstrated higher flexural strength as compared to the other two samples while sample 1 showing the lowest flexural strength .



	Sample1(CA:FA=5:0)	Sample2(CA:FA=4:1)	Sample3(CA:FA=3:2)
7-days strength	8.8	12.19	33.24
28-days strength	11.25	15.3	41.84

Fig. 6 Comparison of average flexural strengths of beams with different CA:FA ratios

3.3 Discussion of Results

Compressive Strength:

It was established as a result of experimental observations that the 3-day strength of specimen increases in the compressive strength of M20 grade (from ratio 5:0 to 3:2 of CA:FA) of pervious concrete by 13.8%, whereas an increase in the compressive strength of M20 grade (from ratio 5:0 to 3:2 of CA:FA) of pervious concrete was seen by 25.9% in case of 7-day strength. On the other hand, the rise in 28-day compressive strength was observed to be 54.8% From the results, it was concluded that compressive strength increases from ratio 5:0 to 3:2 of coarse aggregate and fine aggregate. Compressive strength of pervious concrete is lower than of conventional concrete. At the CA:FA ratio 4:1, sample shows very good porosity and good compressive strength. Strength also increases from 3 days to 28 days. It means strength is directly proportional to time.

Flexural Strength:

As a result of experimental observations, an increase of 10.7% was observed in the 7-day flexural strength of M20 grade (from ratio 5:0 to 3:2 of CA:FA), whereas the increase in 28-day flexural strength of the sample was found to be 21.4%. From the flexural strength results, it was concluded that flexural strength increases from ratio 5:0 to 3:2 of coarse aggregate and fine aggregate. Flexural strength of pervious concrete is lower than of conventional concrete. At ratio 4:1, sample shows the porosity and good flexural strength. Strength also increases from 3 days to 28 days, which means that flexural strength increases with time.

4 Conclusions

From this study, several conclusions were made to successfully develop pervious concrete of desired physical and mechanical properties

- Content of cement is a very important aspect to be considered while designing pervious concrete. Excessive amount of cement will form cement slurry when mixed with water and will settle down after the concrete has been placed into the moulds, thereby making the base of concrete impervious.
- It was also found that as the mixture is unable to retain/hold water while mixing therefore concrete mixer is recommended for heavy concreting. However for small scale work in laboratory, steel or iron mixing tray can be used in order to avoid loss of water.
- Table vibrator or any other vibratory compaction method shall not be used while compacting pervious concrete as vibration leads to gravitational settlement of cement slurry again making the base of specimen impervious. Only hand compaction is recommended as per this study.
- While oiling the cubes, excessive oil should be prevented on the surface of moulds as it leads to the formation of bug holes on the surface of concrete cubes. Type of oil used should be checked for its lubricating properties. Oil should not be sticky rather it should be oily. Motor vehicle black oil is recommended in this study.
- Out of three different mixes on different proportions of cement, i.e. 479, 446 and 384 kg/m^3 it was found that specimens having cement quantity as 384 kg/m^3 had greater permeability.
- Three different mixes were prepared having cement content as 384 kg/m^3 of cement—Mix 1 having 0% sand, Mix 2 having 15.02% sand and Mix 3 having 30.22% sand. It was found that the first two mixes had good permeability, while the third mix was impermeable. Out of the first two mixes, second mix is recommended as it had considerable permeability and good compressive strength as compared to Mix 1 specimens.
- Lastly, it was concluded that the proportion of fine aggregate can be used in development of pervious concrete not exceeding 15% in proportion of mix by weight.

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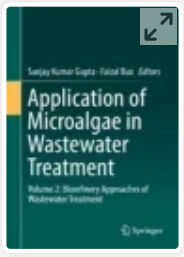

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Application of Microalgae in Wastewater Treatment

Volume 2: Biorefinery Approaches of Wastewater Treatment

Editors: Sanjay Kumar Gupta, Faizal Bux

Discusses the biorefinery aspects of algal-based wastewater treatment

Addresses the potential of microalgae for biomass production with various applications in treating industrial and municipal wastewaters

Evaluates the techno-economical aspects and commercialization potential of pilot scale phycoremediation projects

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About this book

This two-volume work presents comprehensive, accurate information on the present status and contemporary development in phycoremediation of various types of domestic and industrial wastewaters. The volume covers a mechanistic understanding of microalgae based treatment of wastewaters, including current challenges in the treatment of various organic and inorganic pollutants, and future opportunities of bioremediation of wastewater and

industrial effluents on an algal platform. The editors compile the work of authors from around the globe, providing insight on key issues and state-of-the-art developments in algal bioremediation that is missing from the currently available body of literature. The volume hopes to serve as a much needed resource for professors, researchers and scientists interested in microalgae applications for wastewater treatment.

Volume 2 addresses the various biorefinery aspects and applications of algal-based wastewater treatment in industrial and domestic contexts. The analyses are approached from multiple perspectives, including biotechnology, commercial, economic, and sustainability. The authors discuss the potential of microalgae for integrated biomass production utilizing various resources to treat wastewaters, and include evaluations of the economical and commercialization potential for such processes.

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Microalgal Biotechnology Application Towards Environmental Sustainability



Hesam Kamyab, Shreeshivadasan Chelliapan, Ashok Kumar, Shahabaldin Rezania, Amirreza Talaiekhozani, Tayebeh Khademi, Parveen Fatemeh Rupani, and Swati Sharma

1 Introduction

Algae are one among the foremost photosynthetic living groups beside plants and bacteria. Algae are composed of eukaryote cell. They are usually found in marine and fresh water with the size extending from a couple of micrometers to a couple of

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many micrometers. Green growth called algae have an excellent part in nourishment and agribusiness and in misusing microbial exercises for creating significant human items, producing vitality, and tidying up the earth. Green growth can be additionally separated into microalgae and macroalgae in light of their size. Those with diameters below 50 μm are called microalgae and are usually monocellular organisms, while algae with larger sizes are macroalgae. Macroalgae or "seaweeds" are multicellular plants growing in salt or fresh water. They are often fast growing and can reach sizes of up to 60 m in length (McHugh 2003).

Microalgae are minute unicellular species, prokaryotic or eukaryotic, photosynthetic microorganisms that exist in both aquatic and fresh water. Microalgae are among the quickest developing photosynthetic creatures on earth. Their photosynthetic system is like land-based plants; however because of a straightforward cell structure, and submerged in a watery situation where they have proficient access to water, CO_2, and different supplements, they are for the most part more productive in changing over sun-based vitality into biomass. They can be totally presented to light, so every cell can lead photosynthesis at full speed and twofold inside a few hours. The photosynthetic productivity of microalgae is normally more than ten times that of the higher plants and macroalgae (Hemschemeier et al. 2009; Kamyab et al. 2016a).

The most frequently used microalgae are *Cyanophyceae* (blue-green algae), *Chlorophyceae* (green algae), *Bacillariophyceae* (including the diatoms), and *Chrysophyceae* (including golden algae). All cells require wellsprings of carbon and energy for growth. Chemoorganotrophs, chemolithotrophs, and phototrophs utilize natural chemicals, inorganic chemicals, or light, respectively, as their wellspring of energy. Autotrophs utilize CO_2 as their carbon source, while heterotrophs utilize natural compounds (Xu et al. 2006). Numerous microalgae species could change from phototrophic to heterotrophic growth. As heterotrophs, the green algae growth depends on glucose or other utilizable carbon sources for carbon digestion and energy. Limited algae can also grow mixotrophically.

Microalgae have been the focus and interest of researchers, government, and industries because of (i) their growth rate and simple structure; (ii) cellular components such as carbohydrate, proteins, and lipids which can be utilized for biotechnological applications like creating biofuel and product of nutritional, pharmaceutical, and cosmetic value; and (iii) the shift toward the development of green processes. Microalgae represent very interesting natural sources of bioactive compounds such as carotenoids, fatty acids, vitamins, and sterols (Plaza et al. 2009; Chacón-Lee and González-Mariño 2010). They have been generally utilized for different applications such as biofuels, animal feed, food supplements, cosmetics, pharmaceuticals, nutraceuticals, CO_2 capture, etc. (Nesamma et al. 2015; Kamyab et al. 2017). In addition, microalgae are additionally utilized as a part of wastewater treatment for toxin and supplement expulsion. That is on the grounds that microalgae developments are subject to supplement focus and in addition light, temperature, saltiness, and pH (Venkatesan et al. 2015). Microalgae-construct wastewater treatment depends with respect to the capacity of phototrophic microorganisms to supply oxygen to vigorous natural toxin degraders and upgrade the evacuation of supplements

and pathogens. It is generally known that microalgae plays an important role in self-purification of natural waters and therefore offers an alternative means as a tertiary treatment of organic wastewater (Venkatesan et al. 2015).

Microalgae are recognized as one of the oldest living microorganisms in earth (Lam and Lee 2011). They are prokaryotic or eukaryotic photosynthetic microorganisms that can develop quickly and live in brutal conditions (Mata et al. 2010; Resdi et al. 2016). Biologists have categorized microalgae in a variety of classes, mainly distinguished by their pigmentation, life cycle, and basic cellular structure (Khan et al. 2009). Microalgae are available in all current earth biological systems, not just aquatic but also terrestrial, instead of a major assortment of groups living in an extensive variety of ecological conditions, such as lakes, rivers, ponds, wetlands, and deserts, and even living in the North and South Poles (Mata et al. 2010). It is estimated that more than 50,000 species exist, but only a limited number of around 30,000 have been studied and analyzed (Mata et al. 2010). Like plants, microalgae require basically three parts to develop: daylight, carbon dioxide, and water. Photosynthesis is an imperative bio-compound process in which plants, microalgae, and a few microorganisms change over the vitality of daylight to synthetic energy. Among others, microalgae consist of lipids and unsaturated fats as membrane segments, stockpiling items, metabolites, and wellsprings of energy. Lipids are characterized as any of a gathering of natural compounds that are insoluble in water but dissolvable in natural solvents. The synthetic highlights are introduced in an expansive scope of molecules, for example, unsaturated fats, phospholipids, sterols, sphingolipids, terpenes, and others (Fogg 1959; Fahy et al. 2011).

2 Classification of Microalgae

According to Fogg (1959), microorganisms are classified according to their morphological properties, the nature of their life cycle, the chemical nature reserve photosynthetic products (intracellular accumulation product), and pigmentation. Various algae species can be found growing in lakes, oceans, rocks, and soil. There are basically two groups of microalgae, prokaryotic and eukaryotic. Prokaryotes microalgae are unicellular organisms that lack a membrane-bound nucleus (karyon), mitochondria, or any other membrane-bound organelles and rarely have cellular organelles. Under its categories is *Cyanophyceae*. *Cyanophyceae* is also called *cyanobacteria*. It is photosynthetic bacteria that are found in fresh and salt water and have chlorophyll a and phycobilins. *Cyanophyceae* are thought to be blue-green microalgae which have a high tolerance to extreme temperatures (Pulz and Gross 2004). The best known species are *Spirulina* (*Arthrospira*) *platensis*, *Nostoc commune*, and *Aphanizomenon flos-aquae*. Eukaryotes are uni- or multicellular organisms which have a complex structure comprising a core surrounded by a membrane and many intracellular organelles. These microorganisms are additionally inexhaustible in fresh water. A few types can likewise live in terrestrial area, developing on wet soils, wet rocks, and soggy wood. They can show up as single cells or as

colonies. Eukaryotes are ordered into an assortment of classes for the most part characterized by their pigmentation, life cycle, and fundamental cell structure (Khan et al. 2009). The most vital classes are green growth algae (*Chlorophyta*), red algae (*Rhodophyta*), and diatoms (*Bacillariophyta*). These microalgae usually contain three main types of pigments which are chlorophylls, carotenoids, and phycobiliproteins. Microalgae signify to an exceptionally intriguing asset as normal wellsprings of bioactive compounds, for example, carotenoids, unsaturated fats, vitamins, and sterols (Plaza et al. 2009; Chacón-Lee and González-Mariño 2010). To sum up the classes of microalgae, there are 11 different divisions of microalgae, which are *Cyanophyta*, *Prochlorophyta*, *Glaucophyta*, *Rhodophyta*, *Heterokonta*, *Haptophyta*, *Cryptophyta*, *Chlorarachniophyta*, *Dinophyta*, *Euglenophyta*, and *Chlorophyta*. The largest groups are *Chlorophyceae* (green algae), *Bacillariophyceae* (diatoms), *Phaeophyceae* (brown algae), *Chrysophyceae* (golden-grown algae), *Pyrrophyceae* (dinoflagellates), and *Rhodophyceae* (red algae) (Milano et al. 2016). Green growth algae are the transformative progenitors of current plants, yet dissimilar to plants, they are basically aquatic. These microorganisms have the filamentous forms. The best known species are *Chlorella*, *Chlamydomonas*, *Dunaliella*, and *Haematococcus* (Pulz and Gross 2004). The main storage compound of these algae is starch, although oils can also be produced.

3 Culture Parameters

3.1 Temperature

Most of the microalgae are able to survive at a temperature range between 16 and 27 °C. *Chlorella sorokiniana* had an upper growth limit at 38–42 °C (Kessler 1985). For a multi-specific microalgal biomass, as studied by Golueke et al. (1957), the rate of microalgae biodegradability from 5% to 10% can be enhanced by a temperature increase from 35 to 50 °C. However, maximal methane productivity at 40 °C that was found by Chen et al. (1996), confirms most mesophilic temperatures considered as optimal conditions for methane production.

3.2 Nitrogen Concentration

Nitrogen-limiting conditions were in fact reported to significantly increase the lipid fraction of many microalgae (Illman et al. 2000). Nitrogen is vital for peptides, proteins, enzymes, chlorophylls, ATP, DNA, and other cellular constituents' synthesis. The increment of lipid fraction occurred due to the reduction of nitrate in growth medium, although of an almost constant growth rate, thus doubling the productivity of the oil (Converti et al. 2009).

3.3 Light Intensity

The limiting factor for microalgal growth is light intensity. Consequently, a suitable light intensity for microalgal cultivation needs about 1/10 of amount of light from direct sunlight. This photosynthetic microorganism produces microalgal biomass by utilizing the sunlight, water, and carbon dioxide. Twenty-five percent consumption of the biomass produced during daylight might be consumed during the night to sustain the cells until sunrise (Chisti 2007). Some microalgae are fit for heterotrophic development on monosaccharide or natural acids. This method of development offers the likelihood of extraordinarily enhancing the profitability of microalgal culture using fed-batch and high cell-density strategies, which can't be connected to photosynthetic frameworks. These strategies are routinely connected to bacterial and yeast cultures to product cell densities in the request of 150–200 g 1 dry weight (Suzuki et al. 1985).

3.4 pH

Acid or basic condition is the suitable pH for microalgal growth. Carbon dioxide consumption may lead to the increasing of pH in the medium. Therefore, CO_2 sparging maintains the pH of the medium. Culture pH was not affecting *Chlorella sorokiniana* when the value was higher than pH 4.0, and the growth rate was inhibited drastically at pH 3.0 (Morita et al. 2001).

3.5 Culture Parameters

The most critical parameters controlling algal growth by methods for photosynthesis are ecological conditions, for example, light power, pH, temperature, turbulence, saltiness, and supplements (Kayombo et al. 2003). The ideal range and the tolerable scope of working conditions depends on different species, which could associate with different components.

3.6 Nutrients

Microalgae production requires high concentrations of essential nutrients (C, N, P, S, K, Fe, etc.). The main focus is on the three most significant nutrients, i.e., carbon, nitrogen, and phosphorus; supplements are normally taken up in the inorganic shape; however a few natural types of them are additionally assimilable. A few supplements don't show any restraint impacts on microalgal development, while

others, for example, NO_2 or NH_3, have inconvenient impacts when exhibited in high focuses. Supplements in the vaporous frame, for example, CO_2 and NO, face a noteworthy impediment which is connected basically to their mass exchange from the vaporous to the fluid state (Markou et al. 2014).

3.7 Carbon Sources

According to the mode of cell growth (heterotrophic, autotrophic, or mixotrophic), microalgae can utilize organic and/or inorganic carbon sources for cell growth (Feng et al. 2011). From the perspective of microalgae cultivation, the most common organic carbon sources for heterotrophic and mixotrophic cultivation of microalgae are glucose, sucrose, lactase, lactose, acetate, glycerol, ethanol (Liang et al. 2009; Perez-Garcia et al. 2011), and other sugars derived from starch, sugar cane, lignocellulosic biomass, and other sugar sources (Perez-Garcia et al. 2011).

3.8 Phosphorus

Phosphorus is another component that has huge pertinence to the cell development and metabolism of microalgae. It is one of the basic components containing DNA, RNA, ATP and cell layer materials, and so on. It is significant that, as a constituent component of ATP, phosphorus is fundamental to the cell forms identified with vitality exchange (e.g., photophosphorylation). On another pertinent idea, photosynthesis requires a lot of proteins, and the proteins are orchestrated by phosphorus-rich ribosomes (Ågren 2004). Phosphorus-containing ATP/ADP are fundamental for photophosphorylation. As a result, confinement of development by phosphate starvation may severely affect different parts of microalgal digestion, including photosynthesis and lipid aggregation. Phosphorus is especially absorbed as inorganic phosphates as H_2PO_4 - and HPO_4^{2-} (Martinez et al. 1999).

3.9 Other Elements

Magnesium, sulfur, iron, and different components are additionally key for the development of microalgae (Zhang et al. 2000). Magnesium is required for nitrogenase movement utilizing a creatine phosphate−/kinase-/ATP-producing framework as one of its parts in cell digestion (Roden et al. 1996). Sulfur is a fundamental part of cysteine and methionine. Without sulfur, protein biosynthesis is hindered, and the photosynthetic framework PSII repair cycle is blocked (Zhang et al. 2000). Iron is associated with electron spill out of H_2O to $NADP^+$ (Roden et al. 1996). According

to Raven et al (1999), some metals could enter in (noncyclic) photosynthetic electron transport systems.

3.10 Factors Limiting Microalgae Growth

A few natural parameters, for example, light's source and intensity, photoperiod, temperature, saltiness, pH, blending, and so forth, impact the development of microalgae (Atta et al. 2013; Singh and Singh 2015). Therefore, it is suggested to adjust and keep up these parameters amid the cultivation time frame. Table 1 indicates parameters and their ideal ranges.

4 Culture of Microalgae

The growth qualities and arrangement of microalgae are known to essentially rely upon the cultivation conditions (Chen et al. 1996). There are four noteworthy sorts of development conditions for microalgae: photoautotrophic, heterotrophic, mixotrophic, and photoheterotrophic cultivation (Chen et al. 1996). Microalgae, however, developed under pressure conditions, for example, supplement starvation, high saltiness, high temperature, and so forth, aggregate extensive sums (up to 60–65% of dry weight) of lipids or sugars alongside a few auxiliary metabolites (Markou et al. 2014).

4.1 Phototrophic Cultivation

Phototrophic development happens when the microalgae utilize light, for example, daylight, as the energy source, and inorganic carbon (e.g., carbon dioxide) as the carbon source to shape of chemical energy (e.g., polysaccharides, proteins, lipids,

Table 1 A generalized set of conditions for culturing microalgae

Parameters	Range	Optimum
Temperature (°C)	16–27	18–24
Salinity (gl^{-1})	12–40	20–24
Light intensity (Lux)[a]	1000–10,000	2500–5000
Photoperiod (light/dark)	–	16:8 (minimum) 24:0 (maximum)
pH	7–9	8.2–8.7

[a]Depends on volume and density
Adapted from Singh and Singh (2015) and Kamyab et al. (2016b)

and hydrocarbons) through photosynthesis (Chen et al. 1996; Huang et al. 2010). This species is the most regularly utilized development condition for microalgae growth (Gouveia and Oliveira 2009; Yoo et al. 2010). Rather, both lipid substance and biomass generation should be considered simultaneously. Thus, lipid profitability, considering the consolidated impacts of oil substance and biomass creation, is a more reasonable execution file to show the capacity of a microalga with respect to oil generation (Chen et al. 1996). The real favorable advantage of utilizing autotrophic cultivation contrasted with different kinds of development; the defilement issue is less serious when utilizing autotrophic development. In this way, outside scale-up microalgae development systems (e.g., open ponds and raceway ponds) are normally worked under phototrophic development conditions (Mata et al. 2010).

4.2 Heterotrophic Cultivation

Heterotrophic development is the condition when microalgae utilize natural carbon as both the energy and carbon source. This sort of development offers a few points of interest over phototrophic development as far as end of light prerequisite, great control of the development procedure, and ease for collecting the biomass (Chen et al. 1996). Some microalgae species demonstrate higher lipid content amid heterotrophic development, and a 40% expansion in lipid content was gotten in *Chlorella protothecoides* by changing the development condition from phototrophic to heterotrophic (Xu et al. 2006; Chen et al. 1996). Zheng et al., (2013) studied on the biomass and lipid productivities of heterotrophic refined microalgae *Chlorella sorokiniana*. The authors investigated the impact of temperature and medium variables such as carbon source, nitrogen source, and their underlying fixations. Authors reported the most extreme lipid substance of 31.5% was accomplished in 96 h, and the lipid profitability was 2.9 g L^{-1} d^{-1}. Carbon sources are the most imperative component for heterotrophic culture of microalgae in the generation of lipids. Microalgae can absorb an assortment of natural carbon sources, for example, glucose, acetic acid derivation, glycerol, fructose, sucrose, lactose, galactose, and mannose relying upon microalgae species utilized for development (Liang et al. 2009). For example, (Chen et al. 1996) analyzed three carbon sources like acetic acid derivation, glucose, and glycerol for creating significantly higher biomass and in addition lipid content in cells by *Chlorella protothecoides* performance. A few investigations have along these lines concentrated on finding less expensive natural carbon sources, for example, corn powder hydrolysate (CPH) rather than sugars, bringing about high biomass (2 g/L/day) and lipid (932 mg/L/day) productivities (Plaza et al. 2009). Once more, heterotrophic development gives considerably higher lipid efficiency, as the most noteworthy lipid profitability from heterotrophic development is almost 20 times higher than that got under phototrophic development. In any case, the sugar-based heterotrophic framework much of the time experiences issues with tainting (Chen et al. 1996).

4.3 Mixotrophic Cultivation

Mixotrophic cultivation happens when microalgae experience photosynthesis and utilize both natural mixes and inorganic carbon (CO_2) as a carbon source for growth. This mentions that microalgae are able to live under either phototrophic or heterotrophic conditions or both (Chen et al. 1996). Natural mixes and CO_2 as a carbon source absorbed by microalgae, at that point microalgae discharge CO_2 by means of breath, will be caught and reused under phototrophic growth (Mata et al. 2010). Contrasted and phototrophic and heterotrophic cultivation, mixotrophic development is once in a while utilized as a part of microalgal oil generation (Chen et al. 1996). For instance, the development and lipid efficiency of a separated microalga *Chlorella vulgaris* ESP-31 were explored under various media and developmental conditions, including phototrophic ($NaHCO_3$ or CO_2, with light), heterotrophic (glucose, without light), photoheterotrophic (glucose, with light), and mixotrophic (glucose and CO_2, with light). The results demonstrated the higher lipid efficiency (67–144 mg/l/d) were obtained under mixotrophic growth along with the utilized media (Yeh and Chang 2012).

4.4 Photoheterotrophic Cultivation

Photoheterotrophic cultivation takes place when the microalgae require light when utilizing natural mixes as the carbon source. The principal distinction among mixotrophic and photoheterotrophic cultivation is that the last requires light as the energy source, while mixotrophic cultivation can utilize natural mixes to fill this need. Along these lines, photoheterotrophic development needs the two sugars and light in the meantime. Despite the fact that the creation of some light-directed valuable metabolites can be improved by utilizing photoheterotrophic cultivation, utilizing this way to deal with the delivery of biodiesel is exceptionally uncommon, similar to the case with mixotrophic cultivation (Chen et al. 1996). Algal–bacterial framework that productively debases thiocyanate (SCN^-), a lethal contaminant, and displays high lipid efficiency was created. A consortium of blended microscopic organisms (activated sludge) and microalgae was consecutively cultivated under photoautotrophic and photoheterotrophic modes. The development mode was changed to photoheterotrophic conditions in a consecutive way. Algal–bacterial culture containing *Chlorella protothecoides* and *Ettlia* sp. yielded essentially higher lipid efficiency under photoheterotrophic conditions contrasted with photoautotrophic conditions showing 28.7 and 17.3 higher productivity (Ryu et al. 2014).

5 Microalgae Harvesting Methods

Choice of harvesting technique is subject to attributes of microalgae, e.g., size, thickness, and e-value of the target products (Olaizola 2003). Generally, microalgae harvesting is a two-phase process, including (1) bulk gathering—aimed at detachment of biomass from the mass suspension. The focus factors for this activity are generally 100–800 times to reach 2–7% total solid matter. This will rely upon the initial biomass fixation and advances utilized, including flocculation, flotation, or gravity sedimentation. (2) Thickening—the point is to concentrate on the slurry through methods, for example, centrifugation, filtration, and ultrasonic accumulation, subsequently—is for the most part a more energy concentrated advancement than mass harvesting (Olaizola 2003).

5.1 Gravity and Centrifugal Sedimentation

Gravity and centrifugal sedimentation techniques depend on Stokes' law (Schenk et al. 2008), i.e., settling characteristics of suspended solids are determined by thickness and range of algae growth cells (Stoke's sweep) and sedimentation velocity. Gravity sedimentation is the most well-known harvesting method for algae growth biomass in wastewater treatment due to the extensive volumes treated and the low scale of the biomass produced (Nurdogan and Oswald 1996). However, the strategy is reasonable for expansive (ca. >70 mm) microalgae, for example, *Spirulina* (Munoz and Guieysse 2006). Centrifugation recovery (CR) is favored for gathering of high-value metabolites and expanded time frame of realistic usability concentrates for incubators in aquaculture (Heasman et al. 2000). The procedure is quick and energy intensive; biomass recuperation relies upon the settling qualities of the cells, slurry residence time in the centrifuge, and settling depth (Grima et al. 2003). The drawback point of the procedure incorporates high energy costs and potentially higher support requirements because of freely moving parts (Bosma et al. 2003). Harvesting productivity of>95% [50] and increment in slurry focus by up to 150 times for 15% aggregate suspended solids are actually feasible (Mohn 1980).

6 Growth Cycle of Microalgae

In the batch cultures, the growth bend of algae growth, as with most microbial frameworks, can be represented by the accompanying stages: (a) lag phase, (b) exponential growth stage, (c) deceleration growth stage, (d) stationary stage, and (e) demise stage (Shuler and Kargi 2002) as described in Fig. 1. The cellular structure and metabolic way can be differed amid each stage because of supplement levels inside the batch vessel (Shuler and Kargi 2002).

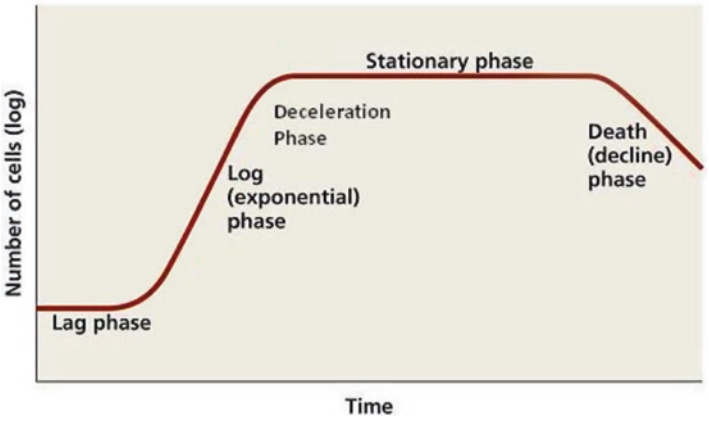

Fig. 1 Typical growth curve for microorganism population

6.1 Lag Phase

Lag stage is a time of cell adjustment in accordance with the new condition, which occurs instantly after inoculation. In this stage, cells encounter a supplement-rich condition, however altogether not the same as that of the seed culture from which the cell was exchanged. The growth occurs in the new framework; adaption happens by incorporating enzymes and co-proteins essential for cell multiplication (Shuler and Kargi 2002). Length of the lag stage depends on the measure of cells exchanged to the new growth medium, the supplement levels present, and culture age. The time duration which the inoculum has been cultured strongly affects the length of lag stage in a batch culture. Typically, the lag time frame increments with the age of the inoculums (Shuler and Kargi 2002).

6.2 Exponential Growth Phase

At this level, also called as the *logarithmic growth phase*, the cells have changed in accordance with their new environment. At the point when there is indication of growth, the development curve is moving from the lag stage into the exponential growth stage or logarithmic growth stage. After cells are adjusted to the new condition and new protein/compounds are orchestrated, cells begin to develop exponentially quickly (Shuler and Kargi 2002). Nevertheless, exponential development not just occurred after the lag stage yet additionally can occur after stationary stage (Monod 1949). This is a period-adjusted growth, in which all parts of the cells grow at a similar rate, because the normal organization of a single cell remains roughly steady during exponential period of development. During this adjusted growth, the net particular growth rate determined from either cell number or cell mass would be

the same. Since the supplement focuses are vast in this stage, the development rate is free of supplement concentration. The exponential development rate is first requested (Shuler and Kargi 2002):

$$= X\,X = X0\text{at}\,t = 0 \quad dt\,dX\,\mu\text{net} \tag{1}$$

where integration X and $X0$ are cell concentrations at time t and $t = 0$.

$$T\ \text{net}\ t\ \text{or}\ X\ X\ e\ \text{net}\ X\ X\mu\ \mu\ 00\ \ln \tag{2}$$

The time required to double the microbial mass is given by Eq. 2. The exponential growth is characterized by a straight line on a semilogarithmic plot of ln X versus time:

$$\text{net net}\,d\,\mu\ \mu\,\tau = \ln 2 = 0.693 \tag{3}$$

where τd is the doubling time of cell mass.

Similarly, a doubling time based on cell numbers and the net-specific rate of replication may be calculated:

$$Rd\,\mu\,\tau' = \ln 2 \tag{4}$$

where $\tau' d$ is the doubling time based on the replication rate. During balanced growth, τd will equal $\tau' d$, since the average cell composition and size will not change with time.

6.3 Deceleration Growth Phase

Supplements are expended, and poisons are discharged into nature, in this stage. Space or volume required for cell multiplication may wind up restricted. Assumptions in the exponential stage are never again substantial. As such, expanding lethality and diminishing supplement level decrease the growth rate of cell. Additionally the cell morphology and physiology may change (i.e., size, cell structure, and metabolic pathways) (Shuler and Kargi 2002). Additionally, this stage takes place as quickly as changing conditions results in unbalanced development, in which τd, and $\tau' d$ will not be equivalent. This stage is called deceleration development stage before the net growth rate achieves zero. The model created on the exponential growth stage cannot be utilized to foresee precise biomass fixation without redesigning the condition (Shuler and Kargi 2002).

6.4 Stationary Phase

Stationary stage resulted in light of the fact that microorganism might not grow uncertainly, in alternate words that the net growth rate achieves zero. The growth bend enters the stationary stage from deceleration growth stage. The metabolic pathway is changed from essential metabolites to auxiliary metabolites (Shuler and Kargi 2002). A few preparations can be framed in this stage, for example, aggregation of lipid (Gouveia and Oliveira 2009). In this stage, the aggregate cell fixation may remain consistent, but total practical cells may diminish. This leads the consistent decline of the net particular growth rate into the demise stage. Another exponential stage might be seen after the stationary stage with a lower net particular growth rate (in contrast with the illustration during the initial exponential growth stage). This could be because of the cell lysis, where the lysed cells could be utilized for growth (Shuler and Kargi 2002).

6.5 Death Phase

Death stage is the decay rate of the microbial populations which is higher than the growth rate. This stage occurs after the stationary stage. In any case, the outline between late stationary and early demise stage might be hard to characterize with accuracy. In the death stage, the net particular stage is negative because of reducing quantities of reasonable cells, supplement consumption, and presence of lethal pressure (Shuler and Kargi 2002).

7 Microalgae Versus Wastewater

Numerous types of microalgae can viably exist in wastewater conditions through their capacity to use copious natural carbon and inorganic N and P in the wastewater (Kamyab et al. 2014;Kamyab et al. 2015). Furthermore, the utilization of microalgae in the wastewater manufacture is still genuinely constrained. Algae growth is utilized all through the world for wastewater treatment but on a generally minor scale. This is either using regular oxidation (adjustment) ponds or the more created suspended algal lake frameworks, for example, high-rate algal lakes which are shallow raceway-type oxidation ponds with mechanical blending and have been observed to be exceedingly successful for wastewater treatment (Pittman et al. 2011). A noteworthy necessity of wastewater treatment is the need to expel high convergences of supplements specifically N and P, which generally can prompt dangers of eutrophication if these supplements aggregate in river and ponds (Pittman et al. 2011). Microalgae are proficient in evacuating N, P, and poisonous metals from wastewater (Wang et al. 2010) and in this manner can possibly assume a

critical remediation part especially during the last (tertiary) treatment period of wastewater (Pittman et al. 2011). The noteworthy preferred standpoint of algal procedures in wastewater treatment over the regular substance-based treatment strategies is the potential cost sparing and the lower-level innovation (Mallick 2002; Wang et al. 2010). An extensive variety of studies have broken down the development of microalgae under an assortment of wastewater condition (Pittman et al. 2011).

Regular municipal sewage treatment comprises of an essential treatment stage for the sedimentation of solid materials, a secondary treatment stage in which suspended and dissolved natural materials are expelled, and a tertiary treatment stage in which last treatment of the water is performed before release into condition. During tertiary treatment stage, a considerable decrease in inorganic compounds occures, for example, N and P absorbs by microalgae (Pittman et al. 2011). Some unicellular green microalgae species are especially tolerant to sewage effluent condition (Ruiz-Marin et al. 2010; Pittman et al. 2011). For instance, different types of *Chlorella* and *Scenedesmus* can expel up to >80% alkali, nitrate, and aggregate P from auxiliary-treated wastewater (Ruiz-Marin et al. 2010; Zheng et al. 2013). Moreover, microalgae additionally appeared to growth and effectively expel supplements from essential settled sewage wastewater. This showing the capability of microalgae for developing and expelling of supplement is not essentially subject to treatment level (Mallick 2002; Pittman et al. 2011).

In contrast with municipal local sewage-based wastewater, agricultural wastewater, which is frequently resulted from compost, containing high N and P (Pittman et al. 2011). In spite of high supplement fixations, previous scholar investigated that effective development of microalgae on rural waste and additionally municipal wastewater, microalgae are proficient at reducing N and P from wastewater (Pittman et al. 2011). Investigations of algal-intervened supplement recuperation from dairy manure have surveyed the capability of benthic freshwater green growth (algae) instead of planktonic (suspended) algae growth because of the potential higher supplement take-up rates in a few types of benthic algae. These species incorporate *Microspora willeana*, *Ulothrix* sp., and also *Rhizoclonium hierglyphicum*. Different studies on using a semicontinuous cultivation technique where the benthic algal growth was developed in reusing wastewater with new fertilizer has been increased by the scholars. For instance, algal cultivation rates and supplement take-up were observed to be high and identical to values from algae growth cultivation on municipal wastewater (Pittman et al. 2011).

A few investigations have analyzed microalgae cultivation and supplement expulsion characteristics utilizing artificial wastewater (Aslan and Kapdan 2006;Pittman et al. 2011). Usage of a simulated medium has advantages, for example, usability for starting research facility-based examinations. It additionally takes into account a streamlined examination of the significant segments in a wastewater medium without one expecting to consider obscure factors, for example, biotic parts. Most manufactured wastewater media are made out of inorganic constituents including high concentrations of particular supplements and will lack solid natural material and other potential poisons. Hence, there might be a few disadvantages in

utilizing manufactured wastewater to survey conditions in actual wastewater. Real examinations of artificial wastewater with municipal wastewater have discovered that albeit supplement expulsion rates are comparable, microalgae growth rates are higher in simulated wastewater (Ruiz-Marin et al. 2010; Pittman et al. 2011). This is likely because of expanded poisonous quality of the actual wastewaters, inhibitory or aggressive impacts of indigenous microorganisms and protozoa, and by the distinctive synthetic organization of the wastewaters (Pittman et al. 2011).

There is critical enthusiasm for the utilization of microalgae for remediation of mechanically determined wastewaters, principally for the evacuation of substantial metal contaminants (cadmium, chromium, zinc, etc.) and natural compound poisons (hydrocarbons, biocides, and surfactants), instead of N and P. Because of, for the most part, the low N and P focus and high poison fixations, algal development rates are brought down in numerous modern wastewaters. Therefore, there is less potential for using modern wastewaters for expansive scale age of microalgae biomass (Pittman et al. 2011). The wastewater incorporates process chemicals and shades utilized as a part of the mills, plus a range of inorganic components including low concentrations of metals and generally low concentrations of aggregates P and N. This wastewater was appeared to be sufficiently low in poisons and had enough P and N to help microalgae growth, with two freshwater microalgae *Botryococcus braunii* and *Chlorella saccharophila* and a marine alga *Pleurochrysis carterae*, ready to become especially well on the untreated wastewater (Chinnasamy et al. 2010). With the huge measure of wastewater accessible from this industry, a lot of biomass and possibly likewise biodiesel could be produced from this asset (Pittman et al. 2011).

8 Sustainable Algal Biomass Production with Wastewater

Algae grow naturally in a wide range of environments. Typical requirements for phototrophic algae include sunlight, CO_2, temperatures between 20 and 30 °C, water, and nutrients (primarily N, P, and K). Algae have been grown on an industrial scale for different purposes such as treatment of organic residues, nutrient recovery for animal feed and fertilizer, human food, and production of biofuels. In industrial algae production, the ideal conditions may be provided, such as artificial light with the appropriate photoperiod and wavelength, consistent CO_2 supply, optimal temperature, and essential nutrients like nitrogen (N) and phosphorous (P). Providing optimal conditions improves the algae growth rate and potentially improves the composition (oil, starch, protein) of the algae, although it increases the costs of the production. Table 2 presents a recent comparison between open and close cultivation system in terms of environmental impact, biological issues, process issues, and costs. Measuring the algae concentration and growth rate during cultivation is a critical parameter for evaluating the feasibility of algae production. Carbon sources are essential for microalgae growth. Photoautotrophic organisms are the organisms that derive their energy for food synthesis from light and are capable of using

Table 2 Comparison between open system and close systems for microalgae production

Parameter		Open Systems	Closed systems
Environmental impact	Land footprint	High	Low
	Water footprint	High	Low
	CO_2 losses	High	Low
Biological issues	Algae species	Restricted	Flexible
	Contamination	High risk	Low risk
	Biomass productivity	Low	High
	Biomass composition	Variable	Reproducible
Process issues	Temperature control	Yes	No
	Weather dependence	High	Low
	Energy requirement	Low	High
	Process control	Difficult	Easy
	Use of wastewater	Yes	Yes
	Reactor cleaning	Not required	Required
Costs	Investment cost	Low	High
	Operational costs	Low	High
	Harvesting costs	Low	High

Adapted from (Barros et al. 2015)

carbon dioxide as their principal source of carbon. Hence, photoautotrophic cultivation implies that inorganic types of carbon (CO_2 or bicarbonates) are provided to the cultures, while light energy is changed into compound energy through photosynthesis (Ren et al. 2014). Other microalgae strains can utilize natural carbon as both energy and carbon source (heterotrophic cultivation); this cultivation framework is however practiced for the creation of high-value items as it were. Mixotrophic nutrition mode is the mix of both autotrophic and heterotrophic. Table 3 shows a comparison between photoautotrophic, heterotrophic, mixotrophic, and photoheterotrophic cultivation conditions. The following section provides extra details on each metabolism system.

8.1 Application of Microalgae in Biomass Production and CO_2 Sequestration

Microalgae have been broadly utilized for different applications, for example, biofuels, animal feed, nourishment supplements, beautifiers, pharmaceuticals, nutraceuticals, CO_2 capture, and so on (Nesamma et al. 2015; Kamyab et al. 2016c). In addition, microalgae are likewise utilized as a part of wastewater treatment for contamination and supplement evacuation. That is due to microalgae growths which are subject to supplement focus and in addition light, temperature, saltiness, and pH (Venkatesan et al. 2015). The use of microalgae mainly in wastewater treatment depends on light capacity of phototrophic microorganisms to supply oxygen to

Table 3 Comparison between cultivation conditions (Chen et al. 1996)

	Cultivation condition			
	Photoautotrophic	Heterotrophic	Mixotrophic	Photoheterotrophic
Energy source	Light	Organic	Light and organic	Light
Carbon source	Inorganic	Organic	Inorganic and organic	Organic
Cell density	Low	High	Medium	Medium
Cost	Low	Medium	High	High
Reactor scale-up	Open pond/PBR	Conventional fermentor	Closed PBR	Closed PBR
Issues with scale-up	Low cell density High condensation cost	Easily contaminated High substrate cost	Easily contaminated High equipment cost High substrate cost	

vigorous natural contamination which could degrade and improve the absorption of supplements and pathogens (Kamyab et al. 2016b).

Major greenhouse gas is CO_2 leading to global warming. Most of CO_2 emission is from electrical power plants, automobiles, and industrial sources such as cement processing. Using algae-based CO_2 sequestration to reduce CO_2 is a sustainable solution to reduce global carbon footprint. CO_2 sequestration is a notion based on capturing the total CO_2 emitted from various sources by growing microalgae which are used to make biofuel (Eloka-Eboka and Inambao 2017). Many algal species such as *Chlorella vulgaris*, *Nannochloropsis* sp., *Scenedesmus quadricauda*, *Chlamydomonas reinhardtii*, and *Nannochloris* sp. have been studied to sequester CO_2. One of the most attractive features of microalgae is to trap gaseous CO_2 in ponds or photobiorectors and have higher photosynthetic efficiencies than terrestrial plants. CO_2 dissolves in water and exists in the form of CO_2, HCO_3^-, $H_2CO_3^-$, and CO_3^{2-}. Among them, microalgae transport CO_2 and HCO_3^- into cell for photosynthesis (Zhao and Su 2014). Features of microalgae such as high protein, lipid, and carbohydrate contents make them attractive feedstock for biofuel production (Pavlik et al. 2017). The algal lipids can be extracted and converted to biodiesel to be used as biofuel (Mondal et al. 2017). The potential benefit of making biofuel from algae is it reduces lifecycle of greenhouse gases (GHG), as algae biomass converts CO_2 through photosynthesis into bio-plant material which is eventually released back to the atmosphere via microorganisms when used as a fuel, via engine tail-pipe emissions (Shirvani 2012).

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Electronic Waste Pollution

Environmental Occurrence and Treatment Technologies

Editors: Muhammad Zaffar Hashmi, Ajit Varma

Comprehensive overview on e-waste sources and entry routes in soil, air, water and sediment

Addresses impact of e-waste on soil microbial community diversity

Provides strategies for the management of e-waste pollution

Part of the book series: Soil Biology (SOILBIOL, volume 57)

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About this book

Electronic and electric waste (e-waste), defined as end-of-life electronic products, including computers, television sets, mobile phones, transformers, capacitors, wires and cables, are a major global environmental concern. The crude recycling of e-waste releases persistent toxic substances, such as heavy metals, polybrominated diphenyl ethers (PBDEs), polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs), and the environmental pollution and health risks caused by the improper disposal of e-waste has become an urgent issue.
This book offers an overview of e-waste history, sources, and entry routes in soil, air, water and sediment. It also addresses e-waste transport and fate, bioavailability and biomonitoring, e-waste risk assessment, impacts on the environment and public health. In addition, it discusses the impact of e-waste on soil microbial community diversity, structure and function and reviews the treatment and management

strategies, such as bioremediation and phytoremediation, as well as policies and future challenges.

Given its scope, it is a valuable resource for students, researchers and scholars in the field of electronics manufacturing, environmental science and engineering, toxicology, environmental biotechnology, soil sciences and microbial ecology, as well as and plant biotechnology.

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Keywords

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Chapter 17
Aspects of E-waste Management in India



Rajiv Ganguly

Abstract Increased urbanization and globalization have led to marked increase in use of consumer products with the use of electronics being the most prevalent. Wherein in one aspect it has led to global connectivity and social inclusivity, adversely it has led to generation of e-waste in massive proportions. In principle, e-waste comprises of precious heavy metals which are highly toxic in nature and thereby have severe human and environmental effects if disposed of unscientifically. The chapter deals with the different aspects of e-waste generation in India, its potential environmental health and environmental impacts, and associated legislative measures and discusses sustainable methods for effective disposal of generated e-waste including the commercial viability of such waste.

Keywords E-waste management · Environmental effects · E-waste management handling rules

17.1 Introduction

Increased urbanization and globalization have led to rapid urban development leading to rise of use of electronic goods and appliances in our daily lives. These electronic goods and appliances enhance our living standards but have a definitive shelf life. The problem arises when it comes to the disposal of such electronics after the completion of shelf lives of such electronics. This is primarily because such electronics comprise of precious and toxic metals which have severe human health and environmental effects if they are not disposed of carefully. The increased generation of such electronic wastes (e-waste) is a rising concern, particularly in the context of presence of both toxic and precious metals (Babu et al. 2007). The production of e-waste is expected to rise continually with an expected production of

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about 72 million tons in 2017 (Garlapati 2016) with China and the United States being the major producers (Nisa 2014). Recent reports (Bhutta et al. 2011) suggest that annual generation of electronic waste worldwide varies from 20 to 50 million tons having the potential to cause significant human health and environmental damage. In the context of developing countries, earlier reports suggest that such electronic waste would comprise 1% of the total municipal solid waste generated and will rise to 2% by 2010 (Chaturvedi et al. 2007) with the total generation between the periods 2007 to 2011 being estimated at 2.5 metric tons (Dwivedy and Mittal 2010) (Fig. 17.1). Recent studies conducted by Associated Chambers of Commerce of India (ASSOCHAM) reveal that the growth rate of e-waste in India is about 25% with an expected generation quantity of 15 metric tons by 2015 (Nisa 2014). From the existing statistics, it is quite evident that the usage of such products will continue to increase, and the fact that electronic industry is one of the fastest-expanding industries in present context leads to more manufacture and generation of electronic waste (Garlapati 2016). Figure 17.1 shows the increasing trend of generation of e-waste in India.

The major drawback associated with the safe disposal and recycling of such electronic wastes is its harmful human health and environmental impacts. For example, older televisions and computer monitors have toxic metals like lead, cadmium, and mercury as their major constituents, while other electronic circuitry have nickel, beryllium, and zinc as primary constituents (European Union 2012). Hence, it is imperative to have an effective waste management system for such e-wastes which pose significant challenges to both government and common public as it comprises both precious and toxic elements. In this context, special e-waste handling rules have been formulated for safe handling practices of such wastes.

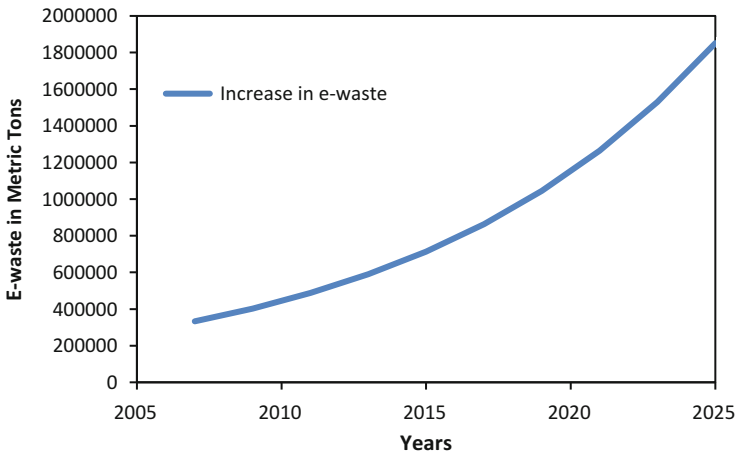

Fig. 17.1 Increasing trend of generation of e-waste in India

17.2 Definition and Classification of E-waste

E-waste or waste electrical and electronic equipment (WEEE) is a terminology that is used to define all electronic and electrical products achieving the end of shelf life. It also incorporates discarded appliances or electronic goods that are rejected during the manufacturing, refurbishing, and the repair process (Ganguly 2016). In practice, e-waste includes a broad denomination with both personal and household electronic equipments varying from television, mobiles, refrigerator, microwave, juicer grinder, mixer, and personal computer all falling within its purview (Puckett et al. 2002). Since the term e-waste encompasses a broad category, certain definitive bodies and researchers have given the definition of e-waste, the most important of which are highlighted in Table 17.1.

As per the definition of electronic waste by EU WEEE directives 2002/96/EC and 2012/19/EU, there exist ten different classifications of e-waste which have been summarized in Table 17.2 along with their respective percentages.

The constituents of e-waste is widely varied as they not only include metals (both ferrous and non-ferrous) but also ceramics, plastics, and different other combinations (APME 2004). The specifications of the electronics depend on the different constituents present in the manufactured product being categorized as both hazardous and non-hazardous waste. Classification of the metal components is primarily done on the basis of presence of ferrous and non-ferrous metals, whereas other components include plastics, ceramics, glass woods, and other inert and non-reactive materials (Garlapati 2016). In the category of non-ferrous metals, metals like aluminium, copper, silver, platinum, etc. are considered precious metals and often considered for recovery. Presence of other metals like mercury, lead, arsenic, cadmium, selenium, and chromium classifies the e-waste as hazardous in nature (Garlapati 2016).

Table 17.1 Definition of E-waste as per different conventions

EU WEEE Directive (EU 2002)	'Electrical or electronic equipment which is waste including all components, sub-assemblies and consumables, which are part of the product at the time of discarding.' Directive 75/442/EEC, Article 1 (a) defines 'waste' as 'any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force'
Basel Action Network	'E-waste encompasses a broad and growing range of electronic devices ranging from large household devices such as refrigerators, air-conditioners, cell phones, personal stereos, and consumer electronics to computers which have been discarded by their users'
OECD (2001)	'Any appliance using an electric power supply that has reached its end of life'
Sinha (2008)	'An electrically powered appliance that no longer satisfies the current owner for its original purpose'
Gregory (2009)	E-waste refers to 'the reverse supply chain which collects products no longer desired by a given consumer and refurbishes for other consumers recycles or otherwise processes wastes'

Table 17.2 Definition of e-waste as per different conventions

Sr. no.	Waste category	Label	Contribution (%)
1.	Major household gadgets	Large HH	42.1
2.	Minor household gadgets	Small HH	4.7
3.	IT and telecommunication gadgets	ICT	33.9
4.	User gadgets	CE	13.7
5.	Illumination gadgets	Lighting	1.4
6.	Electrical and electronics appliances	E&E tools	1.4
7.	Toys, leisure, and sports gadgets	Toys	0.2
8.	Medical device	Medical equipment	1.9
9.	Monitoring and control instruments	M&C	0.1
10.	Automatic dispensers	Dispensers	0.7

17.3 E-waste Generation in Global and Indian Context

Recent studies mention that the proportion of e-waste generated from developing countries will double within the next decade. Further by 2030, it is expected that developed and developing countries will have obsolete computer wastes of 200–300 and 400–700 million, respectively (Duan et al. 2015). The rapid increase in generation of e-waste can be attributed to the discontinuance of the electronic goods. Primarily in developed countries, the lifespan of such electric products is only 2 years after which therein they are discarded or are then exported to developing countries as there is a demand for such used electronic goods (Ganguly 2016). In the context of production of such voluminous quantities of e-waste, it is imperative to have proper regulations for handling of such wastes. As per United Nations Environmental Program (UNEP), developing countries like China, India, Mexico, and Brazil would encounter the maxim of the environmental and health effects of such wastes.

The problem is more compounded for developing countries wherein there exist almost no governmental records on the production of e-waste in the country. Available data from studies conducted by Non-Governmental organizations (NGO) and other sources are reported. An earlier study conducted by the Comptroller and Auditor General (CAG) of India suggested the presence of 1.5 MT of plastic waste, 7.5 MT of industrial wastes, 1.7 MT of medical waste, and about 4 lakh tones of electronic waste being generated in the country (Agarwal 2010).

Another primary concern is the import of used electronics goods from developed countries to developing countries for usage and dumping which is of serious concern. There exists no official figures for import of such wastes, and they are often passed into developing nations on basis of false pretences like goodwill, reusable category, and charity purposes (Garlapati 2016). Such increased burden of e-waste severely affects the local population and the surrounding environment.

17.4 Health and Environmental Effects of E-waste

The hazardous components of the e-waste generated have the propensity to cause severe environmental damage. Primary emissions involve release of PCB and heavy metals (selenium, cadmium, chromium, etc.), whereas dioxins and furans are generated from secondary sources. Secondary emissions arise from untreated or improper treatment of the e-waste, whereas tertiary treatment involves emissions from those hazardous chemicals involved in treatment of e-waste (Gupta 2014). In simpler terms, electronic appliances can be classified into white category (household electronics), brown category (televisions, camera), and grey category (PC and other associated subsidiaries), and earlier studies have reported that the grey category is more hazardous than the other two categories (Sheng and Etsell 2007; Jomova et al. 2011). The practice of unscientific and lay methods in handling leads to hazardous emissions from such wastes.

Human health effects associated with exposure to emissions from such e-wastes lead to adverse functioning of reproductive system, thyroid, nervous system, lung functioning, and stunted growth (Grant et al. 2013). Workers associated with handling of e-waste without protective equipments can develop further ailments like skin cancer, tumours, anaemia, and related diseases (Janagam and Jeymani 2011). In this context, it is important to mention that exposure to e-waste is highly detrimental to human health. In particular, the effects are more profound for developing countries like India wherein there is a lack of proper implementation of handling of such e-wastes. The worst affected population groups are those living nearby the landfill dumpsites and the personnel involved in the handling of these wastes (Ganguly 2016).

17.5 Existing Practices of Handling of E-waste

Handling of e-waste is highly complex and requires special expertise primarily due to its constituents which are toxic in nature to both the environment and the human health. Generated e-wastes from LCDs, CRTs, capacitors, electrical circuitry, copier, and cartridges are highly toxic due to presence of heavy metals like mercury, selenium, lead, and chromium. Further, incineration (secondary emission source) of circuitry boards, plastic casings, and PVC materials leads to generation of dioxins and furans.

In developing countries, most of the e-wastes are generally disposed of in open landfills. For example, land filling of such burnt wastes can lead to severe groundwater pollution if hydrographical and soil conditions are favourable in nature. Cadmium (from mobile phones) alone has the potential for polluting 600 m^3 of water and has the potential for long-lasting effects (Garlapati 2016). Further, land filling of sites with e-waste can produce highly toxic nature of leachate which can severely contaminate the groundwater (Rana et al. 2018). Additionally, acid

treatment of dissolving computer chips can cause acidification of soil and the groundwater (Milovantseva and Saphores 2013).

Similarly, incineration of such wastes leads to air pollution. For example, flammable components of electrical equipment when burnt (incinerated in dump sites) releases brominated flame retardants causing extensive damage to human health and surrounding environment. Hence, continual methods of open dumping and incineration have the potential to cause severe and long-lasting health and environmental impacts (Osibanjo and Nnorom 2007; Chen et al. 2011; Milovantseva and Saphores 2013; Rana et al. 2018).

17.6 Strategies for Management of E-waste

17.6.1 Responsibility and Role of Industries Including Sustainable Design Philosophy

It is given that management of e-waste is imperative for electronic goods and other appliances stored in warehouses which account for almost 75–80% (Garlapati 2016). It is imperative that if the generation of e-waste is controlled at the manufacturing phase, it will be highly beneficial. This can be achieved by reducing the volume of hazardous waste in the manufacturing process and also reducing the stock quantity of such process will reduce the generation of e-waste. Further the implementation of reuse and recycle policy could significantly reduce associated disposal costs and raw material procurement and also boost resale of such electronics. In principle, both on- and off-site recovery of wastes can be carried out along with the possibility of exploring inter-industry exchange (Garlapati 2016). These may involve inventory management, post-production, modification, and salvaging of such wastes (Freeman 1997).

The concept of managing inter-industry exchange of such wastes can be easily maintained by an updated inventory management system. A proper inventory system will regulate the use of such hazardous materials in the industry and will also help in alleviating the generation of excess wastes. This is primarily achieved by reducing the use of hazardous and surplus raw materials, verification of material purchase, and evaluation and regulation of control procedures (Garlapati 2016). In general, the first step involves using a detailed methodology for identifying the process and than followed by material procurement. Alternatively, a procedure of ordering required volume of materials may be implemented followed by detailed inventorisation to reduce purchase of any surplus hazardous material (Gaidajis et al. 2010).

Further to the above, reduction in e-waste generation can be controlled by using accomplished and natural materials in the manufacturing process and by altering the production process thereby conceptualizing new product design. This can be achieved by material alteration and amendment in manufacturing process, better working measures, and more endurable end products. For example, plant and

bio-based plastics and plant-based polymers may be used in the design system instead of those made from petrochemicals. Similarly, natural (bio-based) inks and toners glue could be used more periodically. Proper implementation of abovementioned schemes can help in optimizing the system in utilization of such hazardous materials. Finally, the personnel involved in such activities should be provided training and made aware of process of optimizations, safety guidelines, etc. in handling of such wastes as they play a significant role in this aspect (Gaidajis et al. 2010).

Similarly, the use of natural and non-hazardous materials for production of electronic goods can significantly reduce the generation of e-waste, thereby reducing disposal costs in the future (Gaidajis et al. 2010). This can be successfully carried out by source segregation and waste concentration methods. The former involves the separation of metal components and application of treatment methods for recovery of such precious metals and is one of the most economical options. Treatment techniques generally involve reverse osmosis, bioleaching, ultrafiltration, and other pressure-based filtration techniques (Dasgupta et al. 2017). This is also termed as 'reverse production' (Ganguly 2016). Possible recovery of such metals leads to a closed-loop system minimizing the potential health and environmental impacts (Dasgupta et al. 2017). Labelling on packaging should be done to make aware of potential environmental hazards by the industries.

17.6.2 Extended Producer Responsibility (EPR) and Producer Responsibility Organization (PRO)

The EPR is the newer concept wherein the control of e-waste generation focuses primarily on the system instead of the production facilities, i.e., the manufacturer takes the responsibility for post-consumer stage of the product's life cycle, including its final disposal. In this aspect, the manufacturer bears the full responsibility of the manufacture, performance, and the care needed after the shelf life of the equipment. This in turn induces the industry in promoting and using sustainable product design and technology thereby preventing pollution. The main aim of EPR is promoting sustainable development via environmentally friendly product development and recovery.

EPR has been successfully implemented in developing countries but is still in its infancy in developing countries. For example, Germany was the first country to implement EPR policies in spirit followed by other European countries in facilitating legislative policies for implementation of EPR. In the United States, it is the state's prerogative for implementing EPR wherein the state directives dictate policies like disposal fees and refund system and compulsory take-back of old electronics. Similar policies are also implemented in Japan, but the regulations allow charging the consumers for the benefit.

17.6.3 Responsibility of Citizens

Another important aspect in controlling e-waste generation is proper management of such electronic products used by the consumers. In this context, consumers should be advised to use the electronic products till the end of its shelf life with proper servicing schedules to increase their life spans. Further old and unwanted electronic products should be given away for refurbishing and reusable purposes. Further, the consumers should be made aware of environmentally friendly products including their maintenance, recycling, and disposal methods.

17.6.4 Responsibility of Government

It is the government's prerogative in setting up regulatory bodies for integrating policy decisions of different authorities for management of hazardous wastes. In principle, the government should lay down regulations, laws, administration, and penalties for management of such wastes. The regulations should entrust the agency in monitoring the activities of the government. It should provide information on raw materials procured and used by the different manufacturers and supervisory authority on checking the roster of the industry (Skinner et al. 2011).

Further, relevant information on the toxicity of the materials and the results of their testing for adverse health and environmental effects should be made available to the regulatory authority. Policies related to risk management should be clearly mentioned for the manufacture, processing, distribution, use, and disposal of electronic wastes. The government should promote the concept of reuse of e-waste and discuss potential business avenues for the same. Similarly, they should impart education to the consumers on the environmental and health effects of such wastes and suggest precautionary measures for such cases (Skinner et al. 2011). Finally, the government should use the endeavours of NGOs in managing such voluminous quantities of waste and can explore partnerships with them for promoting reuse and recycling of the wastes.

17.7 E-waste Legislation in India

In the context of management of health effects of such wastes, the government has highlighted the latest E-waste Management and Handling Rules, 2011. It was approved in May 2011 and came into effect in May 2012. A year's time was given to the industries to make them aware of the rules and policies so as to help them abide and consider the products they manufacture. Some of the important excerpts from the rule are as follows: (Garlapati 2016)

- As per Schedule-I, regulations will be applicable to producer, purchaser, collection centres, and recycling of the wastes. The CPCB and SPCB will be the main regulatory authorities.
- The Battery Management and Handling Act passed in 2001 will encompass all industries producing lead batteries, whereas the Enterprises Development Act will be responsible for handling all micro- and small-scale industries. Similarly, the Atomic Energy Act of 1962 will cover all radioactive wastes.
- Schedule-I will be applicable to all manufacturing equipment's and raw products involved in the generation of the electronics and the electrical appliances and will be functional part of the product till the shelf life of the goods.
- The regulations also impose stringent measures on the hazardous materials used in the production and enables reduced use of such materials in electronic goods and appliances. This suggests that the manufacturers have to abide by the specified ranges of heavy metals used for the manufacture of such goods.
- The MOEF/CPCB has the final authority in deciding the use of any hazardous waste material which does not conform to Schedule-I components after comparison.
- The manufacturing unit is beyond the scope of Schedule-I components; the wastes generated from such manufacturing processes have to be transferred to a recycling facility and ensured that complete recycling takes place.

In the context of management of health effects of such wastes, the government has highlighted the 'E-waste Management and Handling Rules, 2011' which was approved in May 2011. The potential drawbacks of the legislation have been discussed in detail elsewhere (Ganguly 2016). However, to summarize, one of the major potential flaws of these regulations is subdivision of enforcement policy between state and the centre. This could possibly induce 'spillover' from those states which diligently implement the regulations to other states which might be slightly lax in imposition. This would also involve additional administrative costs to the states in keeping detailed roster about the details of formal recycling units within their jurisdiction (Skinner et al. 2011). The regulations also discuss about bringing the informal sector within the purview of the governmental monitoring but do not discuss in detail how the process will be implemented and the fate of the workers associated with the informal sector. Further, the regulations also fail to describe how awareness about the hazards of e-waste would be distributed to the consumers. This is particularly important as manufacturers do not describe the potential pitfalls of electronic wastes on the packaging as a result of which consumers are unaware about safe disposal of these products after their life span.

17.8 Recycling of E-waste

Recycling of hazardous wastes is one of the most economical methods for preventing environmental problems associated with them and is even commercially viable. However, setting up of recycling of such wastes involves detailed logistical planning and requirement as it involves collection, transportation, segregation, treatment, recovery, and disposal of such wastes. In principle, such logistical functioning should be supervised by the pertaining regulatory authority and incentives should be provided for improving the functioning of the entire system. As mentioned earlier, the NGOs at national and state levels may be involved for smooth functioning of such systems (Garlapati 2016).

Further, skilled personnel should be involved to ensure environmentally friendly practices of recycling as they help in separating out toxic materials and recover materials from the complex electronic system. Recycling facilities should have control equipment for capturing air emissions released from the toxic pollutants during the recovery process. Proper control equipment and safety measures should be provided to the personnel involved during the recovery process. In this context, methods like bioleaching which involves use of microbes for recovery of precious metals are more favourable as it prevents exposure to personnel and is an environmentally friendly method.

This is particularly important in Indian context as majority of the recycling operations are carried out by the unorganized (informal) sector. This sector is responsible for about 90–95% of all recycling activities in India with an efficiency of about 30% in recovery of precious metals. The sector mainly comprises of unskilled labourers who reside from city slum areas and use pristine methods to carry out such recycling methods, exposing them to such harmful toxics like acidic solutions, fumes, burnt residual ashes, and other agents and in turn causing asthma and respiratory, reproductive, and physical injuries. Long-term exposure may also lead to cancer. Since the informal sector falls outside the purview of the government, they are not guided by governmental healthcare policies and hence suffer from such repeated exposures.

In contrast, the organized sector (under governmental regulations) accounts for only 10–15% of the recycling process carried out in the country. The problems experienced by the formal sector of recycling are the competition faced from the informal sector in the collection and disposal of e-waste leading to financial losses. Further, many of the collected e-waste are transferred for refurbishing or resold with only a small proportion accounting for the recycling process. The treatment process used by the formal recycling sector is an environmentally friendly process without the use of toxic chemicals or open incinerations. Primarily, the clients of such formal recycling units are surrounding industries and even MNCs.

17.9 Economic Potential from E-waste

E-waste is a potential income-generating source for industries and also has the potential for creating a new job market in India. This is primarily because a large proportion of e-waste consists of precious material in sufficient quantity to be harnessed for potential economic viability. Further, there exists scope for reusing some materials from older e-wastes to newly built electronic equipments like circuit boards, capacitors plastics, and other components. Further, thermo-chemical treatment is a viable option for treating plastic waste generated from e-waste as it is an environmentally friendly process (Garlapati 2016). This treatment process can lead to production of synthetic fuel from plastics which can be used to power diesel generators (Kantarelis et al. 2011). The plastic waste generated from the e-waste can also be used as a raw feed for production of hydrogen using two-stage pyrolysis-gasification systems (Acomb et al. 2013). Other possible recovery from e-waste includes use of LCD computer screens as electrodes for electricity generation from Microbial Fuel Cell (MFC) (Gangadharan et al. 2015). Such business initiatives can possibly reduce dumping of e-waste.

17.10 Conclusions

E-waste is one of the fastest-growing wastes in both developed and developing countries due to rapid obsolescence of present-day modern electronics. The chapter discusses about the existing condition of e-waste generation both globally and in the Indian context and the need for quantification of overall wastes generated. Discussion on health effects of exposure to such hazardous wastes has also been presented in the chapter. The chapter further discusses some of the E-waste management strategies in India including the specific roles of the government, manufacturers, and the consumers in reducing generation and impacts of e-waste. This includes important tools like EPR, implementation of legislations, and establishment of recycling facilities to ensure safe disposal of such wastes in an environmentally friendly manner. The chapter also discusses in detail the importance of recycling such e-wastes including the roles of both the formal and informal sectors involved in the process. The chapter also discusses the existing legislation of handling such e-wastes in India and some of the potential drawbacks associated with the existing legislation. A discussion on potential business initiatives from the generated e-wastes has been presented.

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Emerging and Eco-Friendly Approaches for Waste Management

Editors: Ram Naresh Bharagava, Pankaj Chowdhary

Comprehensive knowledge on the various natural and anthropogenic sources of toxic environmental pollutants

Elucidate biodegradation and bioremediation approaches for the management and clean-up of polluted environments for sustainable development.

Provides detailed knowledge on the various physico-chemical and biological techniques of waste management with their merits, demerits and future prospects.

Elaborates emerging and environmental friendly approaches and their sustainable by-products.

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About this book

Rapid industrialization is a serious concern in the context of a healthy environment. With the growth in the number of industries, the waste generated is also growing exponentially. The various chemical processes operating in the manufacturing industry generate a large number of by-products, which are largely harmful and toxic pollutants and are generally discharged into the natural water bodies. Once the pollutants enter the environment, they are taken up by different life forms, and because of bio-magnification, they affect the entire food chain and have severe adverse effects on all life forms, including on human health. Although, various physico-chemical and biological approaches are available for the removal of toxic pollutants, unfortunately these are often ineffective and traditional clean up practices are inefficient. Biological approaches utilizing microorganisms (bacterial/fungi/algae), green plants or their enzymes to degrade or detoxify environmental pollutants such as endocrine disruptors, toxic metals, pesticides, dyes, petroleum

hydrocarbons and phenolic compounds, offer eco-friendly approaches. Such eco-friendly approaches are often more effective than traditional practices, and are safe for both industry workers as well as environment.

This book provides a comprehensive overview of various toxic environmental pollutants from a variety natural and anthropogenic sources, their toxicological effects on the environment, humans, animals and plants as well as their biodegradation and bioremediation using emerging and eco-friendly approaches (e.g. Anammox technology, advanced oxidation processes, membrane bioreactors, membrane processes, GMOs), microbial degradation (e.g. bacteria, fungi, algae), phytoremediation, biotechnology and nanobiotechnology. Offering fundamental and advanced information on environmental problems, challenges and bioremediation approaches used for the remediation of contaminated sites, it is a valuable resource for students, scientists and researchers engaged in microbiology, biotechnology and environmental sciences.

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Chapter 6
Bioremediation Approaches for Degradation and Detoxification of Polycyclic Aromatic Hydrocarbons



Pavan Kumar Agrawal, Rahul Shrivastava, and Jyoti Verma

Abstract Waste from industry is a noteworthy risk to the earth as it contains different poisonous, mutagenic and cancer-causing substances including polycyclic aromatic hydrocarbons (PAHs). PAHs are a class of different organic compounds with two or more intertwined benzene rings in a linear, angular or cluster array. Eviction of PAHs is crucial as these are persevering toxins with ubiquitous event and adverse natural impacts. There are several remedial techniques, which are productive and financially savvy in elimination of PAHs from the affected environment. These removal approaches are not just eco-friendly; they additionally display an emerging and new strategy in mitigating the ability of PAHs to cause potential risk to living beings. Accessible physical and synthetic techniques are neither eco-accommodating nor financially viable in this way. Natural strategies such as bioremediation techniques are most appropriate for biodegradation of PAHs. Such techniques require less chemicals, less time and less contribution of energy and are cost-effective and eco-accommodating. The lethal PAH mixes can be changed into non-harmful and more straightforward ones utilizing normally occurring microorganisms like algae, bacteria and fungi in a procedure called biodegradation. This chapter mainly focuses on the enhancement in biodegradation of hazardous PAHs by using bioremedial approaches.

Keywords Polycyclic aromatic hydrocarbons · Enzymatic approach · Biodegradation · Bioremediation

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1 Introduction

PAHs are effective environmental toxicants that consist of fused aromatic rings. PAHs are originated in unrefined petroleum, coal tar and blacktop (Ukiwe et al. 2013). PAHs are included in the US Environmental Protection Agency (EPA) and European Community (EC) Contaminant Candidate List. EPA currently regulates 16 PAH compounds as priority pollutants in water and as 'aggregate PAHs' in defiled soil and sediments (Hadibarata et al. 2009). PAHs are of big concern to humans and animals as contaminant, some even recognized as cancer causing, mutagenic or teratogenic.

PAH compounds have two- to seven-membered benzene rings. They are lacking water affinity mixes with aqueous solubility declining almost linearly with increases in molecular mass (Parrish et al. 2004). Physicochemical properties and molecular weight of PAHs vary with the number of rings in the atom. Increment in subatomic weight of PAHs leads to decrease in chemical reactivity, aqueous solubility and volatility of PAHs. High-molecular-weight PAHs have high resonance energies because of the thick mists of pi-electrons surrounding the aromatic rings making them steady in the earth and recalcitrant to degradation. The recalcitrant nature of compounds may be attributed to their low water solubility and high soil sorption (Parrish et al. 2004).

PAH degradation is controlled by several physicochemical as well as biological processes, which vary their fate and transport in the surface environment. Biodegradation of hydrocarbons is achieved either by microorganism such as bacteria (Hamamura et al. 2013), fungus (Cerniglia and Sutherland 2010) or algae (Chan et al. 2006) or by enzymatic approaches. Fungi are considered as a productive competitor for effective degradation of PAHs. In any case, filamentous growth has capacity to develop on wide spectrum of substrates by secreting extracellular hydrolytic enzymes, even equipped for growing under non-ambient environment (Juhasz and Naidu 2000). Bioremediation includes either indigenous or exogenous microbial population, which is known as not proficient degraders in contaminated site (Yadav et al. 2017; Bharagava et al. 2017). Fungi have advantages over bacteria because of their fungal hyphae and potent hydrolytic enzymes, which can enter and corrupt the hydrocarbons affected environment (Venkatesagowda et al. 2012). Fungal enzymes especially oxidoreductases, laccase and peroxidases have noticeable application in removal of PAH contaminants either in fresh, marine water or terrestrial. Nevertheless, interest on growths gets an impressive consideration for bioremediation of hydrocarbon contaminated sites associated fungi for enzyme discharge (to expel hydrocarbons from nature). The persistence, toxicity and carcinogenicity of PAH molecules draw public concern to decontaminate PAH-polluted sites.

2 Sources of Polycyclic Aromatic Hydrocarbons in the Environment

For the most part, PAH contamination happens by unprocessed and processed oil, which comes from tanker accidents, refinery effluents, metropolitan and modern release from pipelines and seaward productions and waste oil from two-wheeler and four-wheeler administration stations, which causes contamination (Uzoamaka et al. 2009). Polycyclic aromatic hydrocarbon compounds are formed, what's more, discharged into the earth through both natural and anthropogenic sources. Natural sources of PAHs include their development as exudates from trees woods and rangeland fires, fungi and bacteria (Fig. 6.1). In nature, PAHs remain prevalently distributed as parts of plant oils, cuticles of insects, components of surface waxes of leaves and lipids of microorganisms. PAHs are formed naturally during thermal geologic reactions associated with fossil fuel and mineral generation.

Anthropogenic sources like fuel ignition, vehicles, spillage of petroleum products, electric fuel generation, internal ignition motors and waste incinerators are critical sources of PAHs into the environment (Arulazhagan and Vasudevan 2011). Anthropogenic wellsprings of PAHs are the real reason for natural contamination and, hence, the focus of a lot of bioremediation programmes. PAHs remain saved in the environment through generally scattered sources covering significantly the land surface area. At such sources PAHs are observed to be consumed strongly to soil particles.

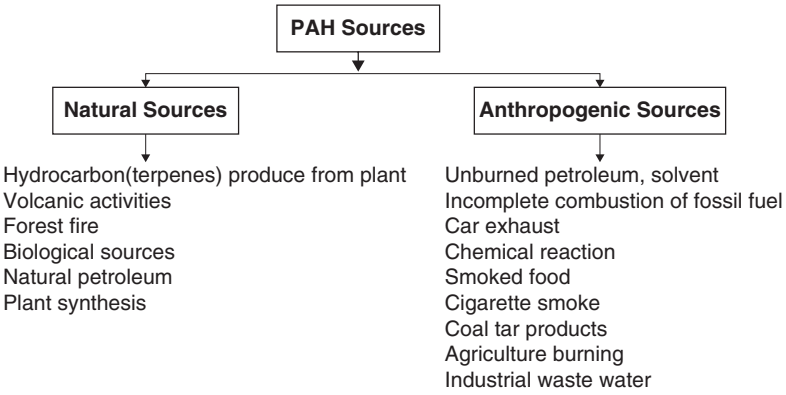

Fig. 6.1 Natural and anthropogenic sources of polycyclic aromatic hydrocarbons (PAHs)

3 Environmental Problems of PAHs

Increasing knowledge of potent adverse effects of toxicant on human health and environment has led to enhanced attention and measures for remediation and renovation of environment contaminants. Polycyclic aromatic hydrocarbons (PAHs) are omnipresent organic pollutants with serious environmental concerns. PAHs are distributed in various ecosystems and are pollutants of severe concern due to their potential toxicity, mutagenicity and carcinogenicity.

PAHs have an innate property for bioaccumulation in food chains, which makes their presence in any ecosystem alarming for human health (Morehead et al. 1986; Xue and Warshawsky 2005). Accumulation of PAHs in plants poses hazardous effect to human health because of their position in the food chain. Experimental studies have also demonstrated interference with plant carbon allocation and root symbioses by PAHs, which ultimately affect plant growth and the environment. Because of their concentration and toxicity, 16 PAHs have been enlisted as priority environmental pollutants by the US Environmental Protection Agency (US EPA).

4 Various Techniques for PAH Degradation

4.1 Chemical Degradation

The availability of PAHs in anaerobic conditions relies on certain components, which incorporate substrate interaction, pH and redox conditions (Chang et al. 2002). The most oxidation reactions in the environment are initiated by oxidants such as peroxides (H_2O_2), ozone (O_3) and hydroxyl radicals generated by photochemical processes. The degradation pathways are such that the oxidation reactions involving hydroxyl radicals or O_3 react with aromatic compounds such as PAHs at near diffusion-controlled rates by abstracting hydrogen atoms or by expansion to twofold bonds (Ukiwe et al. 2013). The reaction proceeds with complex pathways creating various intermediates. In such reactions, the last response products include a mixture of ketones, quinones, aldehydes, phenols and carboxylic acids for both oxidants (Reisen and Arey 2002). During chemical reaction PAHs are transformed into other polyaromatic hydrocarbons (they do not lose their aromatic character). Their aromaticity is conserved since considerable amounts of energy are required to change an aromatic compound into a non-aromatic compound. PAHs could be degraded through fermentative digestion system, while some studies have demonstrated that PAH degradation in anaerobic environment is much slower than in aerobic environment (Ambrosoli et al. 2005). Effects of carbon (C) and nitrogen (N) on PAH degradation have also been investigated by several authors (Quan et al. 2009). The efficiency of PAH chemical degradation is limited by their low aqueous solubility and vapour pressure (Fernando et al. 2009). However, surfactants enhance the

solubility of hydrophobic compounds (Ukiwe et al. 2013). Several reports have been focused on the significance of surfactants to expand the solubility of PAHs by decreasing the interfacial surface tension amongst PAH and the dirt/water interphase (Li and Chen 2009).

4.2 Phytodegradation

It is characterized as the utilization of plants to expel contaminations from the earth to render them nontoxic (Table 6.1). Plants can take the toxicant up and accrue them in their tissues. It is an in situ, solar energy-regulated technique, which minimizes environmental disturbance and reduces costs (Haritash and Kaushik 2009). Researchers have indicated that various grasses and leguminous plants are potential candidates for phytodegradation of organics (Newman and Reynolds 2004; Ukiwe et al. 2013). Some tropical plants have also been reported to show effective degradation tendency due to inherent properties such as deep fibrous root system and tolerance to high hydrocarbon and low nutrient availability (Dzantor et al. 2000; Chandra et al. 2012). Many species of grass such as *Agropyron smithii*, *Bouteloua gracilis*, *Cynodon dactylon*, *Elymus canadensis*, *Festuca arundinacea*, *Festuca rubra*, *Melilotus officinalis*, etc. are known to degrade PAHs (McCutcheon and Schnoor 2003). Researchers are also investigating that grasses and legumes induce the removal of PAHs from affected soil. Plants also play an indirect role in the removal of PAHs by releasing of enzymes by roots. These enzymes are capable of transforming organic contaminants by catalysing chemical reactions in soil (Ndimele et al. 2010). Plant enzymes also act as causative agents in the transformation of contaminants mixed with sediment and soil. The identified enzyme systems included dehalogenase, nitroreductase, peroxidase and laccase (Thomson and Ndimele 2010). Rasmussen and Olsen studied the efficiency of orchard grass (*Dactylis glomerata*) towards PAH removal. The study reported that a soil/sand mixture vegetated with orchard grass exhibited high treatment efficiency with an input from the microbial catabolic degradation by plant exudates (Parish et al. 2004).

Table 6.1 Plants useful in phytodegradation of PAHs

S.No.	Isolate name	Compound	% Removal	Incubation	References
1.	*Festuca arundinacea*	Pyrene	38%	190 days	Chen et al. (2003)
2.	*Pannicum virgatum*	Pyrene	38%	190 days	Chen et al. (2003)
3.	*E. crassipes solani*	Naphthalene	45%	7 days	Nesterenko et al. (2012)
4.	*Scirpus Grossus*	Petroleum hydrocarbons	81.5%	72 days	Al-Baldawi et al. (2015)

4.3 Biodegradation

Biodegradation is a reasonable technique for degradation of natural contaminations. It is the use of microorganisms to degrade or detoxify environmental pollutants (Bamforth and Singleto 2005; Saxena and Bharagava 2017). Several additional factors affecting rate of degradation incorporate pH, temperature, nearness of oxygen and supplement accessibility. The concentration of nutrients and the state of the nutrients (organic, inorganic) are important for biodegradation. The biodegradation of PAHs is financially savvy, eco-friendly (as it prevents environmental damage during transportation of contaminants). Biological degradation is an approach that presents the possibility to remove organic pollutants with the help of natural biological activity available in the substrate (Zeyaullah et al. 2009; Bharagava and Chandra 2010). The microorganisms used for biodegradation could be indigenous to the contaminated region or site (Das and Chandran 2011). The complete mineralization products of the pollutant by biodegradation process include CO_2, H_2O and cell biomass (Gratia et al. 2006). During biodegradation process optimization involves many factors such as microbial consortia capable of degrading the pollutant, bioavailability of the pollutants to microbial attack and soil type, temperature, soil pH, oxygen level of soil, electron acceptor agents and nutrient content of soil (environmental factors) contributing to microbial growth (Gratia et al. 2006; Epelde et al. 2009; Mulla et al. 2017; Bharagava and Chandra 2010). Complete degradation of PAHs to CO_2, water, microbial carbon and other inorganic compound is the ultimate goal. Haeseler et al. (2001) showed enhanced, but incomplete, degradation of PAH compounds in a field study. When remediation was complete, final toxicity was very less because the metabolites tended to be less stable and more soluble than the parent compounds, making them more available to degraders (Haeseler et al. 2001). Microbial degradation is the most suitable alternative and effective method of removal of those toxic chemicals. Microbes (including bacteria, fungi and algae) can biologically degrade PAH compounds during direct microbial metabolism of carbon energy sources or by co-metabolism while consuming another substrate (Lundstedt et al. 2006) (Table 6.2).

5 Role of Various Microorganisms in Bioremediation

The problem linked with the PAHs can be mitigating by the use of conventional approaches, which involve degradation, modification or isolation of the toxicant. These approaches involve excavation of contaminate and its incineration or containment. These technologies are expensive and in many cases transfer the pollutant from one phase to another. On the other hand, bioremediation is the tool to transform the compounds to less hazardous/nonhazardous forms with less input of chemicals, energy and time (Ward et al. 2003; Yuan et al. 2001; Chandra et al. 2011). Microorganisms are known to be their catabolic activity in biological remediation

Table 6.2 Movement and fate of organic chemicals, such as PAHs, in the environment

S.No.	Degradation process	Consequence	Factors	Advantages/ disadvantages
1.	Chemical degradation	Alteration of PAHs by chemical processes such as photochemical (i.e., UV light) and oxidation-reduction reactions	High and low pH, structure of PAH, intensity and duration of sunlight, exposure to sunlight and same factors as for microbial degradation	Limited effectiveness and can be expensive
2.	Phytodegradation	Breakdown of contaminants or pesticides through metabolic processes within the plant	Molecular weight of PAHs, sunlight, enzymes	Low-cost methods for cleaning the environment
3.	Biodegradation	Degradation of PAHs by microorganisms, biodegradation and co-metabolism	Environmental factors (pH, moisture, temperature, oxygen), nutrient status, organic matter content, PAH bioavailability, microbial community present, molecular weight of PAH (LMW or HMW)	Cost-effectiveness and complete cleanup, catabolic versatility of microorganisms, less labour-intensive, relying on solar energy, have a lower carbon footprint and have a high level of public acceptance

(Bharagava et al. 2009), but changes in microbial communities are still unpredictable, and the microbial community is still termed as a 'black box' (Dua et al. 2002). The PAH-degrading microorganism could be algae, bacteria or fungi. It involves the breakdown of organic compounds either usually by microorganism in to less complex metabolites or through mineralization into inorganic minerals, H_2O, CO_2 (aerobic) or CH_4 (anaerobic). The extent and rate of contaminant degradation depend on many factors including pH, temperature, O_2, microbial population, degree of acclimation, convenience of nutrients, compounds chemical structure, properties of cellular transport and chemical partitioning in the growth medium (Singh and Ward 2004).

5.1 Biodegradation of PAHS by Fungi

Fungus is known to have the properties of degradation of persistent organic pollutants (Table 6.3). Distinct properties differentiate filamentous fungus from other life forms to decide why they are potent biodegraders agents. First, the mycelial growth habit gives a competitive benefit over single cells such as bacteria and yeasts, especially with respect to the colonization of insoluble substrates (Bennet et al. 2002). The isolates identified as *Deuteromycetes* belonging to the genera *Cladophialophora*, *Exophiala* and *Leptodontium* and the ascomycete *Pseudeurotium zonatum* are

Table 6.3 Fungal isolates involve in degradation of PAHs

S.No	Isolate name	Compound	% Removal	Incubation	References
1.	*Phomopsis liquidambari*	Indole	41.7%	6 days	Chen et al. (2013)
2.	*Fusarium verticillioides*	Naphthalene	87.78%	8 days	Mohamed et al. (2012)
3.	*Fusarium solani*	Anthracene, benz[a]anthracene	40% and 60%, resp.	40 days	Wu et al. (2009)
4.	*Aspergillus terreus*	Naphthalene, anthracene	98.5% and 91%, resp.	4 weeks	Mohamed et al. (2012)
5.	*Fusarium* sp.	Naphthalene	42%	7 days	Ahirwae and Dehariya (2013)

toluene-degrading fungi; they use toluene as sole carbon and energy source (Francesc et al. 2001). Clemente et al. (2001) reported that degree of degradation of PAH varies with a variation of lignolytic enzymes producing deuteromycete ligninolytic fungal isolates.

Low-molecular-weight PAHs (two to three rings) were found to be degraded most extensively by *Aspergillus sp.*, *Trichocladium canadense* and *Fusarium oxysporum*. For high-molecular-weight PAHs (four to seven rings), maximum degradation has been observed by *T. canadense*, *Aspergillus sp.*, *Verticillium sp.* and *Acremonium sp.* Such studies have found that fungi have a great capability to degrade a broad range of PAHs under low-oxygen conditions. As a large and novel microbial resource, endophytic fungi have been paid more attention in their ecological functions.

The effect of microbes on litter component decomposition (Osono and Hirose 2011) but extended fungal degradation to more recalcitrant carbohydrate (Russell et al. 2011).

PAHs degradation by fungi has mostly focused on white-rot fungi. Their broad-range degradation potential is one reason of PAHs, such as *Irpex lacteus* found with a degradative ability of ANT, phenanthrene, pyrene as well as fluoranthene, and their degradative mechanisms were also investigated (Cajthaml et al. 2002). The other reason is because of their efficient production of ligninolytic enzymes; e.g. *Phanerochaete chrysosporium* could degrade ANT and phenanthrene by producing lignin peroxidase (LiP) and manganese-dependent peroxidise (MnP) (Hammel 1995). *Lentinus* (*Panus*) *tigrinus* showed out the MnP transformation ability after carrying out in vivo and in vitro degradation of PAHs (Covino et al. 2010). *Cunninghamella* sp. and *Aspergillus* sp. were reported for their potential in the transformation of benzo[a]pyrene and the conjugation mechanisms during the degradation (Wu et al. 2009). *Fusarium* spp. have shown their capability to degrade high-molecular-weight organic compounds such as coal cellulose, xylan, pectin,

different hydrocarbons (Kang and Buchenauer 2000) as well as PAHs (Chulalaksananukul et al. 2006). Lignin peroxidase (LiP), manganese peroxidase (MnP) and laccase (Lac) have shown to degrade not only lignocellulose but also pollutants such as crude oil wastes, textile effluents, distillery wastewater pollutants, organochloride agrochemicals and pulp effluents which are a cause of serious environmental pollution (Mtui and Nakamura 2004; Chandra and Chowdhary 2015; Chowdhary et al. 2017a, b, 2018).

5.2 Biodegradation by Bacterial Isolates

Several reports refer to degradation ability of different bacterial isolates of environmental pollutants (Table 6.4). Many bacterial spp. are even known to nourish completely on hydrocarbons (Yakimov et al. 2007). Degradation of PAHs can occur under aerobic and anaerobic conditions, as in the case for the nitrate-reducing bacterial strains *Pseudomonas* sp. and *Brevibacillus* sp. isolated from petroleum contaminated soil (Grishchenkov et al. 2000). Several species of microorganisms have been successfully utilized in major hazardous waste cleanup processes (Levinson et al. 1994). Abd et al. (2009) reported that two- to three-ring PAHs (naphthalene, anthracene and phenanthrene) can be degraded using *Pseudomonas geniculata* and *Achromobacter xylosoxidans*. Bacterial isolates capable of chrysene metabolism include *Rhodococcus* sp. strain UW1 (Walter et al. 1991) and *Sphingomonas yanoikuyae* which oxidized chrysene (Boyd et al. 1999), while *Pseudomonas fluorescens* utilized chrysene and benz[a]anthracene as sole carbon sources (Caldini et al. 1995). The microorganisms capable of surviving in such a polluted environment are those that develop specific enzymatic and physiological responses that allow them to use hydrocarbon as a substrate. Kafilzadeh et al. (2011) reported ten genera as follows: *Bacillus*, *Corynebacterium*, *Staphylococcus*, *Streptococcus*, *Shigella*, *Alcaligenes*,

Table 6.4 Biodegradation of PAHs by various bacterial isolates

S.No	Isolate name	Compound	% Removal	Incubation	References
1.	*Pseudomonas* sp.	Naphthalene, fluorene	95%	4 days	Kumar et al. (2010)
2.	*Pseudomonas* sp.	Anthracene	74.8%	10 days	Kumar et al. (2010)
3.	*Bacillus* sp.	Anthracene	82.6%	72 h	Neelofur et al. (2014)
4.	*Mesoflavibacter zeaxanthinifaciens*	Benzo[a]pyrene	86%	42 days	Okai et al. (2015)
5.	*Mycobacterium flavescens*	Pyrene	89.4%	2 weeks	Dean-Ross et al. (2002)
6.	*Rhodococcus* sp.	Anthracene	53.0%	2 weeks	Ross et al. (2002)

Acinetobacter, *Escherichia*, *Klebsiella* and *Enterobacter* out of 80 bacterial strains. *Bacillus* was the best hydrocarbon-degrading genus. Bacterial strains that are able to degrade aromatic hydrocarbons have been repeatedly isolated, mainly from soil. The bacterial genera *Mycobacterium*, *Corynebacterium*, *Aeromonas*, *Rhodococcus* and *Bacillus* have been also reported for biodegradation pathways (Mrozik et al. 2003).

5.3 Biodegradation of PAHs by Algal Isolates

Algae are important microbial members in both aquatic and terrestrial ecosystems; reports are insufficient regarding their concern in hydrocarbon biodegradation (Table 6.5). (Das and Chandran 2011; Walker et al. 1975) isolated an alga, *Prototheca zopfii* which was capable of utilizing crude oil and a mixed hydrocarbon substrate and exhibited extensive degradation of n-alkanes and isoalkanes as well as aromatic hydrocarbons. Cerniglia and Gibson (1977) observed that nine cyanobacteria, five green algae, one red alga, one brown alga and two diatoms could oxidize naphthalene. Some research has demonstrated that certain fresh algae (e.g., *Chlorella vulgaris*, *Scenedesmus platydiscus*, *S. quadricauda* and *S. capricornutum*) are capable of uptaking and degrading PAHs (Wang and Zhao 2007). Warshawsky et al. (2007) found that *Selenastrum capricornutum*, a freshwater green alga, metabolizes BaP to cis-dihydrodiols using a dioxygenase enzyme system as found in heterotrophic prokaryotes. Certain algae have been reported to enhance the removal fluoranthene and pyrene when present with bacteria. Borde et al. (2003) first reported that photosynthesis enhanced degradation of toxic aromatic compounds by algal-bacterial microcosms in a one-stage treatment. *Pseudomonas migulae* and *Sphingomonas yanoikuyae* were studied for phenanthrene degradation. The green alga *Chlorella sorokiniana* was cultivated in the presence of the pollutants at different concentrations, showing increasing inhibitory effects in the order salicylate < phenol

Table 6.5 Biodegradation of PAHs by various algal isolates

S.No	Isolate name	Compound	% Removal	Incubation	References
1.	*Prototheca zopfii*	Petroleum hydrocarbons	12–41%	3 days	Kirk et al. (1999)
2.	*Selenastrum capricornutum*	Benzo[*a*]pyrene	41%	4 days	Warshawsky et al. (2007)
3.	*Selenastrum capricornutum*	Fluoranthene	99%	7 days	Ke et al. (2010)
4.	*Lyngbyala gerlerimi*	Naphthol	36.6%	5 days	Mostafa et al. (2012)
5.	*Nostoc linckia*	Catechol	56.38%	5 days	Mostafa et al. (2012)
6.	*Oscillatoria rubescens*	β-naphthol	3.04%	7 days	Mostafa et al. (2012)

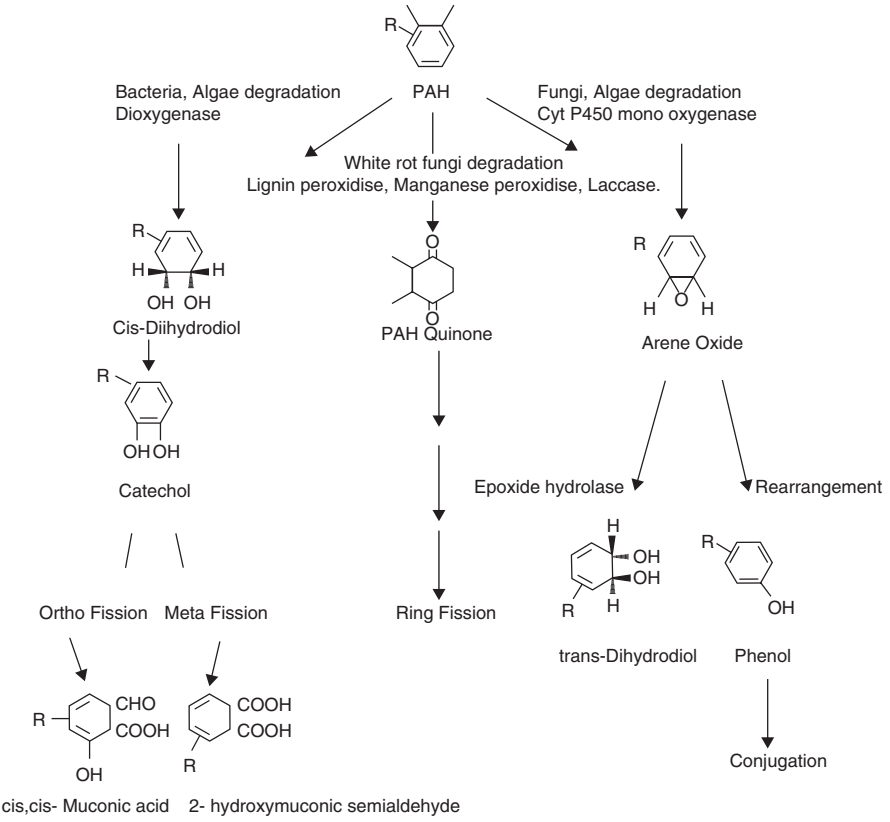

Fig. 6.2 The three main pathways for polyaromatic hydrocarbon degradation by fungi and bacteria. (Adopted by Muthuswamy et al. 2008)

<phenanthrene (Lei et al. 2007). The study of fluoranthene, pyrene and a mixture of fluoranthene and pyrene by *Chlorella vulgaris*, *Scenedesmus platydiscus*, *Scenedesmus quadricauda* and *Selenastrum capricornutum* has shown that removal is algal species-specific and toxicant-dependent. PAH removal in 7 days of treatment was 78% and 48%, respectively, by *S. capricornutum* and *C. vulgaris*. Hong et al. (2008) studied the accumulation and biodegradation of phenanthrene and fluoranthene by the algae enriched from a mangrove aquatic environment (Fig. 6.2).

6 Enzymatic Degradation of PAHs

Major enzymes useful in PAH degradation belong to oxygenase, dehydrogenase and lignolytic categories. Lignolytic enzymes secreted by majority of fungal species are lignin peroxidase, manganese peroxidase and laccase, which are

extracellular in nature and are secreted for catabolism of substrate food material (Chandra and Chowdhary 2015). Spent mushroom compost (SMC) is often used as an inoculum source which enhances the rate of PAH degradation. The SMC are high in laccase and Mn-dependent peroxidase, whereas the production of ligninase is reported to be low in SMC (Haritash and Kaushik 2009). In which most of enzymes are active at many temperature and have optimum activity at mesophilic temperatures and it reduces with very high and very low temperatures. Some of the enzymes are reported to be active even at extremes of temperatures (Haritash and Kaushik 2009). Enzymes also show substrate specificity, but ligninolytic enzymes are non-specific in nature, acting on phenolic and non-phenolic organic compounds via the generation of cation radicals after one e^- oxidation (Lau et al. 2003).

6.1 Lignin Degrading Enzymes

Oxidoreductive enzymes play a key role in transformation and degradation of polymeric substances (Table 6.6). The less degraded or oxidized items can without much of a stretch be taken up by microbial cells where they are totally mineralized. A class of oxidoreductive enzymes include lignin-degrading compounds (LDEs) which have practical application in bioremediation of polluted environment (Husain 2006). LDEs belong to two classes, viz., the heme-containing peroxidases and the copper-containing laccases. A progression of redox responses are started by the laccases. LDEs degrade the lignin or lignin-derived pollutants. The LDEs oxidize the aromatic compounds until the aromatic ring structure is cleaved, which is followed by further debasement with different compounds.

Table 6.6 Biological functions of ligninolytic enzymes

Enzymes	Applications	References
Lignin peroxidase	Biodegradation of lignin	Martínez et al. (2005)
	Degradation of azo	Stolz (2001)
	Mineralization of environmental contaminants	Harms et al. (2011)
	Degradation of pharmaceuticals and their metabolites	Marco-Urrea et al. (2009)
Manganese peroxidase	Degradation of lignin	Martínez et al. (2005)
	PAH degradation	Baborová et al. (2006)
	Synthetic dyes, DDT, PCB, TNT	Hernández et al. (2008)
	Textile dye degradation and bleaching	Kalyani et al. (2008)
Laccase	Spore resistance	Lu et al. (2012)
	Rhizomorph formation	Ranocha et al. (2002)
	Pathogenesis	Langfelder et al. (2003)
	Fruit bodies formation	Nagai et al. (2003)
	Pigment synthesis	Eisenman et al. (2007)

Enzymes involved in the degradation of PAHs are oxygenase, dehydrogenase and ligninolytic enzymes. Fungal ligninolytic enzymes are lignin peroxidase, laccase and manganese peroxidase. They are extracellular and catalyse radical formation by oxidation to destabilize bonds in a molecule (Hofrichhter et al. 1999).

Peroxidases perform heme-containing degradation with other enzymes. Peroxidases are heme-containing enzymes that comprise manganese-dependant peroxidase (MnP), lignin peroxidase (LiP) and versatile peroxidase (VP). They oxidize lignin subunits using extracellular hydrogen peroxide generated by unrelated oxidases as co-substrate. Most mineralization activity of the lignin polymers to CO_2 and H_2O in terrestrial ecosystem is performed by fungal species. These fungi produce a wide range of lignin-degrading enzymes (LDEs), which in turn act on lignin and lignin-analogous compounds. PAHs are primarily degraded using extracellular oxidative enzymes, although use of laccases and peroxidases in PAH bioremediation is currently being studied (Harms et al. 2011). The white-rot fungi (WRF) belonging to the basidiomycetes produce various isoforms of extracellular ligninolytic enzymes, laccases (Lac) and different peroxidases, including lignin peroxidase (LiP), manganese peroxidase (MnP) and versatile peroxidase (VP), the latter sharing LiP and MnP catalytic properties (Martínez 2002). The natural substrate of these enzymes (lignocellulose) is degraded in the environment by the WRF, along with various xenobiotic compounds, including dyes (Wesenberg et al. 2003). Some WRF produce all the three lignin-modifying enzymes, while others produce only one or two of them. Lignin-modifying enzymes are produced by WRF during their secondary metabolism since lignin oxidation provides no net energy to the fungus (Eggert et al. 1996).

6.1.1 Lignin Peroxidases (EC 1.11.1.14)

LiPs (EC 1.11.1.14) are an extracellular hemeprotein. They are related to the family of oxidoreductases (Higuchi 2004). LiP has high redox potential and low optimum pH (Piontek et al. 2001) and is capable of oxidizing a variety of reducing substrates including polymeric substrates (Oyadomari et al. 2003). Due to their high redox potentials and enlarged substrate range, LiPs have more potential for application in several industrial processes (Erden et al. 2009). Enzymatic activity of LiP is H_2O_2 dependent; here H_2O_2 gets reduced to H_2O by picking up an electron from LiP (which itself gets oxidized). The oxidized LiP then returns to its native reduced state by picking up an e^- from veratryl alcohol and oxidizing into veratryl aldehyde. Veratryl aldehyde then gets reduced back to veratryl alcohol by picking up an electron from lignin or equivalent structures such as xenobiotic compounds.

6.1.2 Manganese Peroxidases (EC 1.11.1.13)

MnP (EC 1.11.1.13) belong to the family of oxidoreductases (Higuchi. 2004). Studies have shown that MnP is distributed in almost all white-rot fungi (Hofrichter 2002). Manganese peroxidases (MnP) seem to be distributed amongst white-rot

fungi than LiP (Hammel and Cullen. 2008). MnP oxidizes Mn^{2+} to highly reactive Mn^{3+}, which oxidizes phenolic structures to phenoxyl radicals (Hofrichter 1999). The Mn^{3+} forms complex with chelating organic acids resulting in products such as oxalates or malates (Makela et al. 2002). The redox potential of the Mn peroxidase system is lower than that of lignin peroxidase, and it has shown capacity for preferable oxidation of phenolic substrates. On the other hand, studies indicate that contrary to LiP, MnP may oxidize Mn (II) without H_2O_2 with decomposition of acids and concomitant production of peroxyl radicals that may affect lignin structure. Versatile peroxidase (VP) enzymes produced by *Pleurotus* spp. are also able to oxidize phenolic compounds and dyes efficiently that are substrates of generic peroxidases and related peroxidases or the well-known horseradish peroxidase (HRP). VP (EC 1.11.1.16) oxidizes Mn^{2+}, similar to MnP, and have a high redox potential aromatic as LiP enzymes. Due to these qualities, interest in VP has increased during the last years (Martínez et al. 2009).

6.1.3 Laccases (EC 1.10.3.2)

Laccases (EC 1.10.3.2) belong to a multicopper oxidase family (Alcalde 2007), present in bacteria, e.g., *Azospirillum lipoferum*, *Actinomycetes* like *Streptomyces*, fungi, plants and insects (Baldrian 2006; Chandra and Chowdhary 2015). This enzyme had been reported more than a hundred years ago (Desai and Nityanand 2011), but the significance and broad studies over the role of this enzyme in wood degradation have been conducted in the last few decades. However, many laccases were reported from fungi, and most biotechnologically useful laccases also originated from fungus (Kalmis et al. 2008).

7 Challenges

In spite of considerable progress made in the study of the biodegradation of PAHs over the past few decades, removal of petroleum hydrocarbons in the environment is a daunting problem of the real world. Advancement in various approaches such as genomics, proteomics and metabolomic study has contributed immensely in understanding the PAH-degrading microorganisms and the biochemistry involved in the degradation pathways; however, challenges are posed by various aspects of PAH bioremediation which are either unknown or insufficient information is available regarding them.

Little or no information is available related to genes, enzymes and molecular mechanism of PAH degradation in high-salt environments or low-oxygen and anaerobic environments. Scarce data and research are there on the transmembrane trafficking of PAHs and their metabolites; no transporter molecule/protein has been characterized till date with specific role in the transport of PAHs into microorganisms.

Thorough understanding of genetic regulation of the pathways involved in PAH degradation by different bacteria and fungi has been used for efficient biotransformation or metabolism of PAH pollutants in recent past; a deeper understanding of the microorganism-mediated mechanisms of PAH catalysis will enable strategizing novel methods to enhance the bioremediation of PAHs in the environment.

The use of genetically modified organism in bioremediation represents a research frontier with broad implications to improve the degradation of hazardous wastes under laboratory conditions. The potential benefits of using genetically modified microorganisms are significant. Combining genetic engineering tools such as gene conversion, gene duplication and mutation, enzyme overexpression and novel strains can be produced with desirable properties for effective bioremediation applications. Ecological and environmental concerns and regulatory constraints pose major obstacles and challenges for testing genetically modified organism in the field. These problems must be solved before a genetically modified organism can provide an effective, safer and more efficient method than the present alternatives for removal process at very low-cost and eco-friendly way.

8 Conclusion

The present status of work done on biodegradation of biologically toxic PAHs using different microorganism has been reviewed. The environmental toxicity and persistence of PAHs have resulted in several laboratory-based experiments to change these substances into less unsafe/nondangerous substances with the use of microorganisms in the process called as biodegradation. Removal of PAHs from the affected environment is a tough job. Therefore, it is very essential to understand the mechanism of several degradation processes. Degradation of PAHs remains affected by numerous factors, which need to be addressed and explored. Biological approaches appear be the most efficient, cost-effective and eco-friendly method to mitigate/remove PAHs from affected area.

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Protein Design

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Introduction

A cursory search of the Protein Data Bank (PDB) with the keyword "*de novo*" returns 962 entries, while for the keyword "designed", 6225 entries were returned [as of August 2017]. Although these numbers (*de novo* or designed structures) are 1000 times lesser in magnitude (compared to the total number of structures the PDB holds, which is close to 135,000 structures), these ~7000 structures indicate how far the field of protein design has advanced, since 1950s. Protein designing projects are ambitious in their goal due to the simple yet complex problem of protein folding. Much has been learned about how a protein folds, and these fundamental knowledge have helped further the area of protein design to conceive proteins with imaginative structures (Richardson and Richardson, 1989; Bowie *et al.*, 1991).

The impetus for protein design is two-fold: (i) assumption that we can design a complex natural system from first principles, and (ii) the "made to order" macromolecules that can solve important biochemical hurdles. The basic or fundamental problem with protein design in achieving a three dimensional, stable, and functional macromolecule is to cross the conformational entropy from the primary to the tertiary structure (Bowie *et al.*, 1991; Dahiyat and Mayo, 1997). There are many methods that can be used to reduce the conformational entropy (Baxa *et al.*, 2014). These include covalent cross-links and other artificial constraints that limit the conformational possibilities of the designed molecule (Leitner *et al.*, 2010; Sinz *et al.*, 2015).

There have been two basic design principles employed in designing proteins *de novo*: positive design and negative design (DeGrado *et al.*, 1989). Positive design of protein structures is the idea to design a protein with the desired structure as the goal, and rationally add/remove residues to achieve that structure. In contrast, negative design involves designing a structure along with ways to reduce formation of or competition from alternative conformations that may arise. While both methods involve rational design, there are advantages of using one over the other. Nevertheless, *de novo* design of protein structures using both methods has been successful to a varying degree. **Fig. 1** shows a representative set of structures that have been successfully designed and have advanced the field of protein design.

Since 1950s, designing alpha helices took precedence than the beta sheets, due to:

a) The stabilizing hydrogen bond network (**Fig. 2**).
b) The observation of isolated helices being stable in solution (Brown and Klee, 1971; Kim and Baldwin, 1984; Marqusee and Baldwin, 1987; Shoemaker *et al.*, 1987; Marqusee *et al.*, 1989).
c) Its oligomerization property observed by Crick, Pauling and Corey in supercoiled helices that when two helices twist around each other there are 3.5 residues per turn, which is less than the ideal 3.6 residues per turn rule, thereby leading to a repetition of the entire structure at every seven residues (Crick, 1953; Pauling and Corey, 1953).
d) The possibility of designing the minimal sequence, which can be repeated to construct a four- or six-bundle helices that can either self assemble or assemble in the presence of an external assembly inducer (Schafmeister *et al.*, 1997).

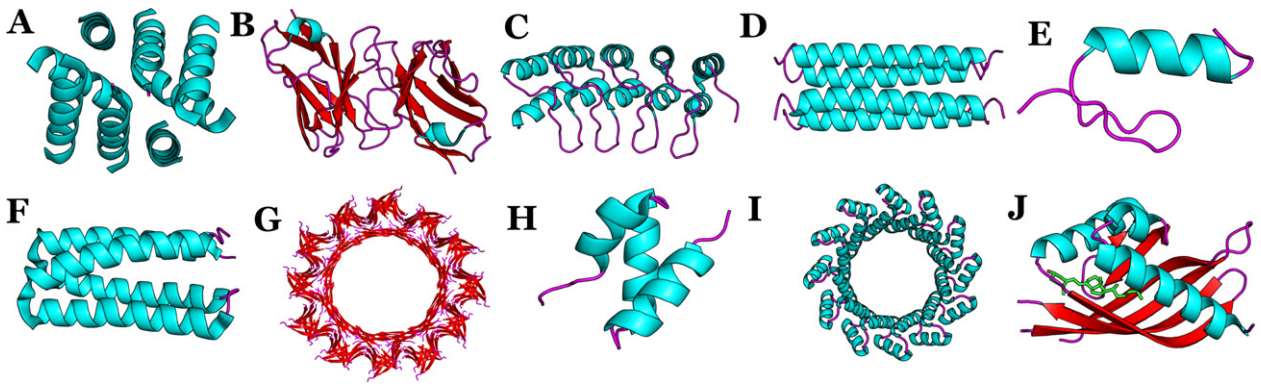

Fig. 1 A representative set of structures that have been designed *de novo*, where they are shown in cartoon representation with helices colored cyan, β-strands colored red, and loops colored magenta. (A) Octameric *de novo* Designed Peptide (pdb id:1l4x), (B) *de novo* Design of an Antibody Combining Site (pdb id:1ivl), (C) Self-Assembling Cyclic Protein Homo-Oligomer (pdb id:4hb5), (D) Right-Handed Coiled Coil Tetramer (pdb id:1rh4), (E) Beta Beta Alpha Protein Motif (pdb id:1fsv), (F) *de novo* Design of a Hyperstable Non-Natural Protein-Ligand Complex (pdb id:5tgw), (G) Giant Double-Walled Peptide Nanotube (pdb id:5vf1), (H) *de novo* Designed Mini Protein Hhh_Rd1_0142 (pdb id:5uoi), (I) Computationally Designed Left-Handed Alpha/Alpha Toroid With 12 Repeats (pdb id:5byo), and (J) Computationally Designed Vitamin-D3 Binder (pdb id:5iep).

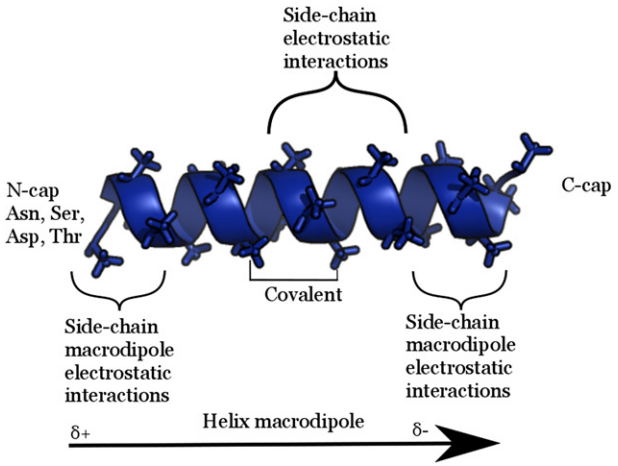

Fig. 2 Helix stabilizing properties. Schematic representation of an ideal helix indicating the various properties that stabilize the helix. Adapted from Bryson, J.W., *et al.*, 1995. Protein design: A hierarchic approach. Science (New York, NY) 270 (5238), 935–941.

Fundamentals

Before taking a sequence and designing it into a novel structure (α-helical or β-sheets or mixed), few pointers need to be kept in mind:

1. Similar stretch of residues can form different secondary structure.
   It has been observed that the same residue stretch of up to five amino acids can form different conformations, such as α-helix, β-strand, and loop. This indicates that a sequence forming a structure is dependent on its local environment.
2. There are only so many folds present.
   The relatively limited number of folds in the protein universe can be considered as a double edged sword. The 1000 odd folds we know today indicate that proteins tend to fold in one of the restricted ways. It also suggests the possibility of creating new folds using computational tools. The former has led to the reverse folding problem, called threading, where a sequence is checked for its compatibility to fold into one of the known folds.
3. Reducing the entropy of protein by introducing disulfide bonds (Wetzel, 1987).
4. Glycine introduces relatively more conformational freedom than the other 19 amino acids.
5. In contrast, Proline introduces less conformational freedom due to its covalent bond with the main chain.
6. It is known that the residues at the end of a helix are positively (at the C-terminus) and negatively (at the N-terminus) charged, which help in stabilizing the helix by balancing the helix dipole charge. Thus, changing the helix stabilizing residues influences the stability of a protein (Nicholson *et al.*, 1988; Richardson and Richardson, 1988).
7. If a core of a protein has a cavity, filling the cavity makes the protein destabilize it.

Designing an α-Helical Structure

Historically, alpha helical peptides and all-α proteins were relatively easier to design. In order to design alpha helical proteins, the sequence under consideration should be scrutinized with the following guidelines.

1. The sequence should be able to form amphiphilic secondary structures, where there is a periodicity of polar and nonpolar residues. For example, every third or fourth position being nonpolar.
2. A general rule of thumb is that the sequence should have residues that are highly likely to be part of a helix (Ala, Glu, Leu, and Met) (Richardson, 1981). Specifically, multiple alanine residues stabilize the helix. However, if the nonpolar periodicity of 3 or 4 is not maintained, then there is a lower preference to form a helical structure (Xiong *et al.*, 1995).
3. Introduction of salt-bridges and hydrogen bonds between side chains of residues that are one helical turn away (Marqusee *et al.*, 1989; Lyu *et al.*, 1990; Huyghues-Despointes *et al.*, 1993; Park *et al.*, 1993; Scholtz *et al.*, 1993).
4. A charged residue can be introduced at the N or C terminus of the α-helix, creating a macrodipole (**Fig. 2**).
5. Capping the helix ends with Asn, Ser, Asp, or Thr to satisfy the hydrogen-bond donors and acceptors.
6. Adding hydrogen bond(s) between side chains of residues that are one helical turn away.
7. In the case of Ser, Thr, and other amino acids that can be phosphorylated, their location in the interior of the helix may lead to destabilization. However, the N-terminus capping of a phosphorylated residue leads to stabilization of the helix. This is due to the electronic interaction of the phosphorylated residue with the peptide backbone.

Certain tools that can be used specifically to design helices are helical wheel and predicting helicity.

Helical wheel is a simple tool to identify if the distribution of charged residues and hydrophobic residues would lead to aggregation. When the helix has majorly hydrophobic or nonpolar residues on one side, there is a high chance of protein aggregation. This highly efficient tool has been used for designing proteins that are primarily coiled coil, and for helix bundles comprised of 3, 4, 5, and 6 helices. Specifically, the tool becomes effective when these helices are linked by loops or turns and to check if the "ridges in groove" or "knobs in holes" packing needs to be checked.

Some of the tools that plot a helical wheel for a given sequence are: DrawCoil 1.0 (see Relevant Websites Section), Pepwheel (see Relevant Websites Section), and Helical Wheel Projection (see Relevant Websites Section).

Also, the designed sequence can be checked for its propensity to form helices by submitting the sequence to AGADIR (see Relevant Websites Section) that calculates helicity (Munoz and Serrano, 1994, 1995a,b, 1997; Lacroix *et al.*, 1998).

Designing a β-Sheet Structure

β-sheets can be parallel, antiparallel, and mixed in nature. Due to absence of planarity, parallel β-sheets are less stable than antiparallel sheets. This is due to the relative absence of inter-strand hydrogen bonds in parallel β-sheets, which provide for stronger interaction. **Fig. 1(B), (G),** and **(J)** highlight the successful design of a β-strand rich proteins.

In 1996, the design of a decapeptide adopting a β-hairpin structure involving a β-bulge and three other dodecapeptides adopting a type I′ β-turn made the protein design possible for β-rich proteins (de Alba *et al.*, 1996; Ramirez-Alvarado *et al.*, 1996; Stanger and Gellman, 1998). These reports fueled enthusiasm in four different groups to design a three stranded antiparallel β-sheet proteins (each differing in residue length) (Kortemme *et al.*, 1998; Schenck and Gellman, 1998; Sharman and Searle, 1998; de Alba *et al.*, 1999). Irrespective of the method they employed, some of the criteria that were included in all the above mentioned β-sheet proteins are:

1. Residues that have higher β-strand propensities were included in the sequence.
2. Inter-strand pairs were selected that have higher preference to make a stable bond.
3. Involving positively charged residues (2 to 5 residues, at least) so that aggregation of proteins is eliminated, and increases solubility.

Positive charge distribution is essential in designing β-sheet proteins, because when they are distributed on both sides of the sheet, aggregation of proteins is reduced to a large extent. Another method to design a β-sheet protein with a stable hydrophobic core involves adding a type I′ β-turn to the designed β-hairpin protein by using residues, such as Phe, Trp, Asn, and Gly, so that the side chains face the other strand's hydrophobic residues' side chains (Tyr and Val) (Griffiths-Jones and Searle, 2000).

Similar to α-helices, some of the guidelines to be used while designing β-sheet proteins are as follows:

1. The role of a β-turn is crucial, as it dictates the β-strand. This is a necessary but not a sufficient condition while designing β-sheet proteins. For example, the D form of Pro in the turn stabilizes the β-hairpin structure, compared to the L form.
2. Residues that have high propensity to form β-sheet should be used. For example, Val, Ile, Phe, Trp, Tyr, Leu, and Thr.
3. Gly should be avoided, as its incorporation leads to destabilization.
4. Including salt-bridge forming residues in inter-strands stabilize the β-sheet protein. For example, a salt-bridge formed between Glu and Lys residues. On the same note, salt-bridges at the ends of β-hairpin are more stabilizing.
5. Presence of interactions between hydrophobic residues, such as Ile-Trp, Ser-Thr, and Trp/Val-Tyr/Phe stabilize the protein as their contributions are larger.
6. Side chain-side chain interactions from diagonal directions between two strands also contribute towards stability. For example, Tyr-Lys, Phe/Trp-Lys/Arg interactions.
7. Presence of a right-handed β-sheet twist.
8. The hydrophobic cluster between the strands contributed by Trp, Val, Phe, and Tyr residues vastly stabilize the β-sheet proteins.
9. As a general rule of thumb, incorporating disulfide bonds stabilize the protein with β-hairpin structures.

Relatively speaking, there are fewer examples of β-sheet proteins designed *de novo*. However, α/β mixed structures have been designed with great success (Struthers *et al.*, 1996). For example, Top7 by David Baker group and a $\beta\beta\alpha$ motif structure that is similar to a zinc-finger, which has a β-hairpin structure (Kuhlman *et al.*, 2003).

Tools Currently Available for Protein *de novo* Design

Irrespective of topology of the intended protein to be designed, some tools are listed below that are routinely used for *de novo* protein design, and also keeping in mind the ease of use from user's perspective.

Rosetta and Rosetta Design

Among the tools that are currently available, Rosetta (Simons *et al.*, 1999), developed by David Baker group at University of Washington, has been the most popular and widely used (Jiang *et al.*, 2008; Siegel *et al.*, 2010; Damborsky and Brezovsky, 2014). The suite of software (see Relevant Websites Section) has sped the design of protein structures. Details of Rosetta's design algorithm and specifics are discussed in Simons *et al.* (1997, 1999), Raveh *et al.* (2010) and DiMaio *et al.*, (2011) and they have been reviewed elsewhere (Mandell and Kortemme, 2009; Der and Kuhlman, 2011). Specifically, Rosetta Design (see Relevant Websites Section) can be accessed via the command line interface of Rosetta or via webserver (Lyskov *et al.*, 2013).

Evodesign

Evodesign (see Relevant Websites Section) developed by Zhang group at University of Michigan is a web based server to design protein sequences using a scaffold as an input. The scaffold is searched against the known protein families and the resulting conformation takes into consideration local environmental factors, such as solvent accessibility, packing, and secondary structure (Mitra *et al.*, 2013).

Protein WISDOM

Protein Wisdom (see Relevant Websites Section) is a web server tool for designing proteins from sequence information. The design and validation involves two steps: using either a rigid or flexible scaffold (or template), a sequence is selected from a pool of candidate sequences; and validation is done by fitting the sequence into known folds to calculate the "fold specificity" (Smadbeck *et al.*, 2013).

OSPREY

Open Source Protein REdesign for You (OSPREY) (see Relevant Websites Section) like Rosetta is a suite of programs developed by Donald group at Duke University. While Rosetta is licensed free for academics, OSPREY is open-source and freely available to download and use. OSPREY uses protein flexibility to create low-energy corpus of structures to identify the globally optimal structure. From the user's perspective, OSPREY runs as a standalone tool and is not available as a web-server (Gainza *et al.*, 2013).

ISAMBARD

Intelligent System for Analysis, Model Building And Rational Design (ISAMBARD) (see Relevant Websites Section) is another open-source suite of software for designing proteins developed by Woflsoon group at University of Bristol. Keeping with the popularity of Python, ISAMBARD uses predefined python object based method to design protein structures. Those with a basic python skill will be able to use this modular and scalable software to design protein structures (Wood *et al.*, 2017).

FireProt

Rather than a general protein design tool, FireProt (see Relevant Websites Section) is a specific protein design tool for designing multiple-point mutant proteins that are likely to be thermostable (Musil *et al.*, 2017).

iRDP

Similar to FireProt, in-silico Rational Design of Proteins (iRDP) (see Relevant Websites Section) is a webserver that uses a four-step approach to rationally design proteins. Specifically, from the input it compares existing protein structures for structural stability factors, followed by mutational analysis, and their impact to local environmental changes, and identifying the optimal structure that would have a higher thermostability than the previous structure (Panigrahi *et al.*, 2015).

IPRO

Iterative Protein Redesign and Optimization procedure (IPRO) (see Relevant Websites Section) from the Maranas group at Pennsylvania State University, uses a combinatorial approach to redesign a protein library using energy based scoring functions. As claimed by the developers, it uses a iterative process to make additive mutations that improve the designed protein's substrate specificity (Saraf *et al.*, 2006; Fazelinia *et al.*, 2007).

Scaffold Selection

Keeping in view that new protein can be designed from pre-existing structures; ScaffoldSelection (see Relevant Websites Section) is a tool that scans large sets of structures for a particular reaction scaffold (Malisi *et al.*, 2009). For the user, the tool can be downloaded as binaries for Linux, Mac, and Windows operating systems and run as a standalone software/tool.

Pocketoptimizer

Pocketoptimizer (see Relevant Websites Section) is an allied tool that can be used to design active site region, either to improve or modify ligand/substrate binding (Stiel *et al.*, 2016).

Conclusions

Protein design is an active, exciting area of research that has wide applications in drug design, medicine, and advancing the study of protein folding. When designing protein structures, one has to ask few questions and these questions drive or direct the use of tools to answer those questions.

1. Is the aim to engineer a protein's function/activity or designing a structure *de novo*?
2. Is the design fitting with the already known do's and don't's?
3. Is there another variable that is specific for the protein and its intended use?

There can be more additional questions added and the framework/checklist can act as a guide to the specific task in hand.

While, there are many success stories in *de novo* protein design, there are some challenges for the road ahead. Some of the challenges that have been discussed (Kuhlman *et al.*, 2009) are:

1. Sampling the conformational space of the backbone to move towards a completely flexible backbone based design. Currently, majority of the *de novo* designed proteins are on the basis of having a rigid scaffold or frame throughout the design pipeline.
2. To reduce the presence of alternate conformations from the desired/designed conformation.
3. Designing specific protein-protein interactions using a much easier and faster method.

Recently, Rocklin *et al.* from David baker's lab have used minimal proteins (proteins having a residue length below 50 amino acids) to understand the factors that determine protein folding. Specifically, they used computationally driven approach, where four topologies ($\alpha\alpha\alpha$, $\beta\alpha\beta\beta$, $\alpha\beta\beta\alpha$, and $\beta\beta\alpha\beta\beta$) were designed using 5000–40,000 sequences for each topology. Using yeast based proteolysis assay, a stability score was given to each designed protein, which enabled them to identify 2788 stable proteins. Such "massively-parallel" design has indeed pushed the limits of high-throughput design and the method can be applied to proteins of more than 50 amino acids in length (Rocklin *et al.*, 2017).

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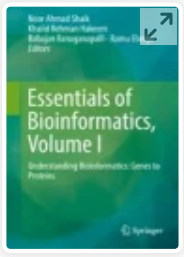

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Essentials of Bioinformatics, Volume I

Understanding Bioinformatics: Genes to Proteins

Editors: Noor Ahmad Shaik, Khalid Rehman Hakeem, Babajan Banaganapalli, Ramu Elango

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About this book

Bioinformatics is an integrative field of computer science, genetics, genomics, proteomics, and statistics, which has undoubtedly revolutionized the study of biology and medicine in past decades. It mainly assists in modeling, predicting and interpreting large multidimensional biological data by utilizing advanced computational methods. Despite its enormous potential, bioinformatics is not widely integrated into the academic curriculum as most life science students and researchers are still not equipped with the necessary knowledge to take advantage of this powerful tool. Hence, the primary

purpose of our book is to supplement this unmet need by providing an easily accessible platform for students and researchers starting their career in life sciences. This book aims to avoid sophisticated computational algorithms and programming. Instead, it mostly focuses on simple DIY analysis and interpretation of biological data with personal computers. Our belief is that once the beginners acquire these basic skillsets, they will be able to handle most of the bioinformatics tools for their research work and to better understand their experimental outcomes.

Unlike other bioinformatics books which are mostly theoretical, this book provides practical examples for the readers on state-of-the-art open source tools to solve biological problems. Flow charts of experiments, graphical illustrations, and mock data are included for quick reference. Volume I is therefore an ideal companion for students and early stage professionals wishing to master this blooming field.

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Keywords

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Chapter 17
Modeling and Optimization of Molecular Biosystems to Generate Predictive Models

Ankush Bansal, Siddhant Kalra, Babajan Banaganapalli, and Tiratha Raj Singh

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17.1 Introduction

A system can be defined as a complex structure in which different components have a specific role, and when they work together, they accomplish tasks in much efficient manner compared to each component separately (Kitano 2002). The system is a collection of elements or components that are organized for a common purpose. The biological system analysis provides us tools and techniques that help in

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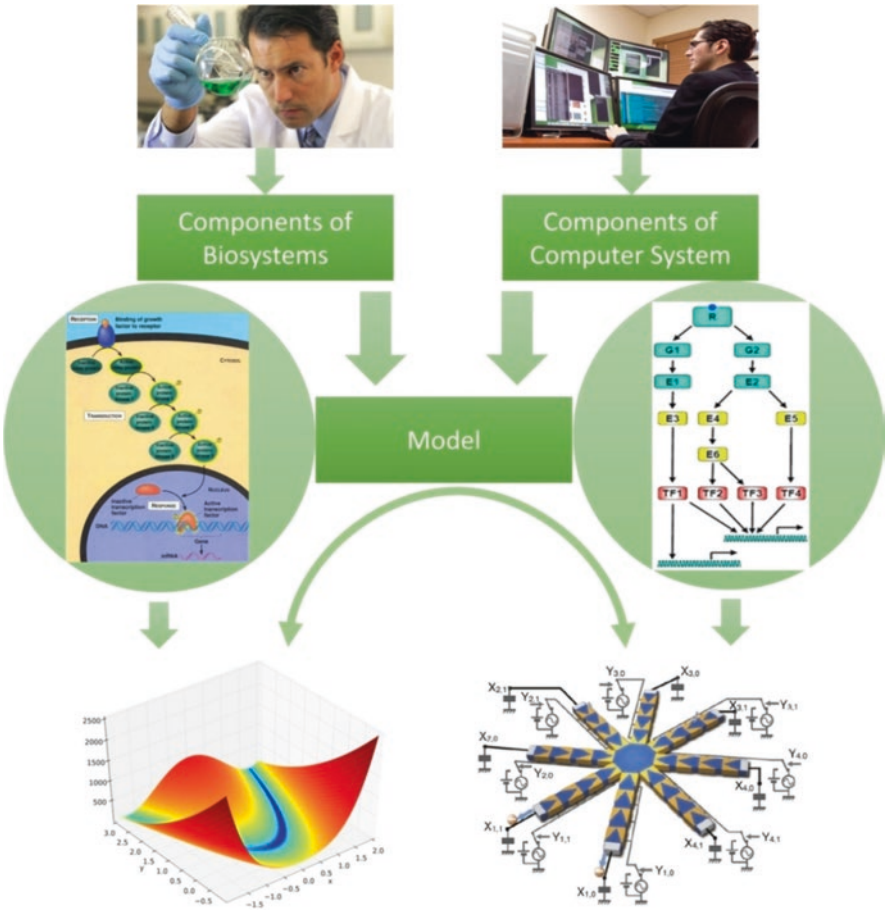

Fig. 17.1 System level understanding of bio-models

organizing the diverse piece of information and data gathered from traditional biological experiments. Development, integration, and experimental testing of hypothesis help us to analyze these systems, as depicted in Fig. 17.1.

Modeling means converting our hypothesis or assumptions into computational programs which further can be used for prediction. Some suitable assumptions are essential for model construction which includes modeling of the system into mathematical form. The mathematical model includes all kind of variables, real numbers, integers, Boolean flags, matrices, and other data structure. Each interaction represents a state in the model, and the final step involves converting the mathematical model into a computer program which is done by suitable genetic algorithms and other differential equation analysis-based algorithm. Once the computational model is built, it requires testing and verification in terms of validation. Models are

helpful as they help us to test the different hypothesis, refine and interpret experiment, and integrate knowledge, leading to new approaches by investigating coupling and feedback. The model helps us to unlock biological systems as they offer different perspectives compared to the perspective provided by experiments and theory. Though models cannot replace lab experiments and cannot prove mechanism, still they serve as a standard feature for scientific investigations.

The illustrative models are precise representation of real situations. Here, we specifically focus on the controlling element from the real world which can be used as a deterministic factor to control our modeled system. Mathematics plays a dominant role in defining system using variables which precisely define real-world scenario. Using mathematical equations we can simply find the solution of various common problems. There are various network level studies exist in literature to perform modeling for individual nodes or high throughput data (Bansal and Ramana 2015; Bansal and Srivastava 2018; Davis et al. 2017; Giraud et al. 2017; Griffen et al. 2017; Jindal and Bansal 2016; Jo et al. 2017; Kim et al. 2017; Nordholt et al. 2017; Romero & López 2017; Vreven et al. 2017; Xie et al. 2017).

Once the model has been generated, it should be optimized. Optimization means to find the best solution that helps in better decision making. The key elements in optimization problems are decision variables and objective function (Zheng et al. 2017). Decision variables are the variables that can be varied during the search of the best solution. An objective function helps us to quantify the quality of a solution, and constraints are the conditions that should be fulfilled in order to achieve the desired results. Different optimization techniques such as linear programming, nonlinear programming, parameter estimation, dynamic optimization, etc. are used for different problems.

Modeling is of no use until it is optimized as per the real situation. Thus, it is a key process for any kind of real model establishment. Optimization mainly controlled the principles of machine learning. We are considering one dataset for analysis and splitting it into two datasets, commonly known as training and test dataset. Various modelers use machine learning-based approaches in their algorithms for better efficiency. Henceforth, we can say that model is typically dependent on optimization using set of variables or parameters which can be used to regulate or control the models as per the need of optimizer. Mathematical modeling is compiled with various machine learning approaches in applicable manner which came into market in the form of various development tools and software.

With the increase of computer power and advanced mathematical techniques, mathematics is now playing the prominent role of integrating information and generating predictions, through the generation of the computationally inspired hypothesis. Therefore, mathematical models can be used to understand the complex biological problems to unbind various diseases and drug effects to benefit the society in utmost sophisticated manner. Mathematical model allows a systematic approach for investigating system perturbations and is not limited to experimental constraints (Fan et al. 2017). These models are able to determine the systematic behavior of any real-world disease scenario.

17.2 Development of Concept Map Models

Biological experiments deal with understanding of hidden processes in the layers of various unannotated datasets. The major goal of such analysis is to provide new insight about regulation mechanisms so that the system can be controlled in an efficient manner. A variety of homogeneous and heterogeneous data are generated through various big data approaches using high-throughput methods. Generation of data is not sufficient to perform analysis to reveal the function of the system. There is a great need of concept map modeling to understand the systematic way to deal with such big data (Kumar et al. 2017).

Concept map modeling focuses on understanding and developing concept for development of methods for mathematical analysis. This approach is time-consuming as it involves the development of a model for the process and response for each level. Therefore it is important to derive such models that allow the incorporation of simple as well as complex methods for complete as well as incomplete datasets at defined instance (Sun et al. 2017). The main objective of this approach is to get acquainted with the quantitative formalization of the biological phenomenon by developing mathematical model for the hypothesis.

The initial step of this approach consists of converting or transforming a stable or static map to dynamic biological map. The next step consists of interpretation of local dynamic response under a set of conditions. By following these two steps, one can determine a parameterized model which is further analyzed and refined. A flow diagram of this approach is shown in Fig. 17.2.

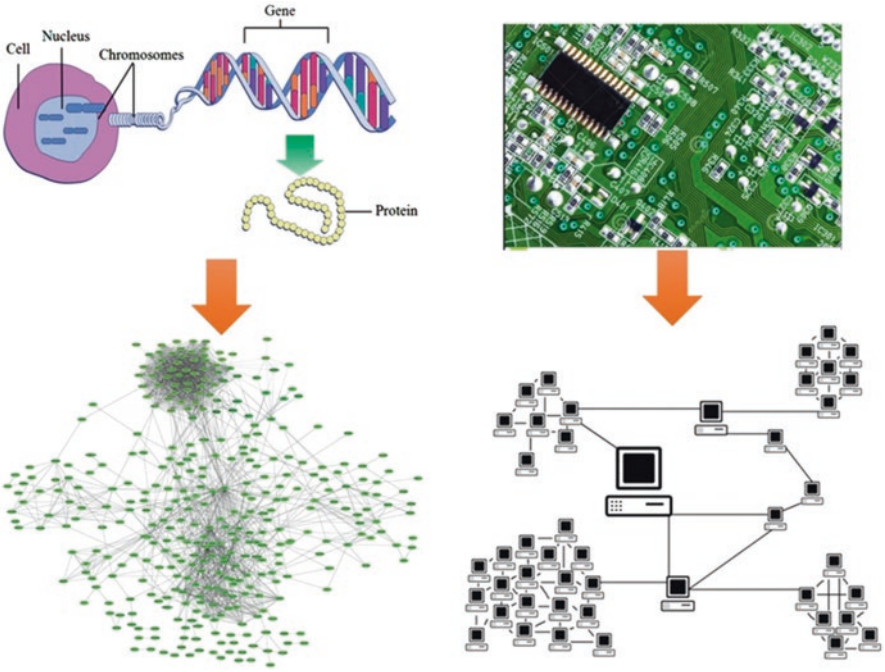

Fig. 17.2 Molecular classification of system to modeling and optimization

One needs to examine how the components and process in a concept map relate to each other and contribute to the overall functioning. Conversion of the map into mathematically testable structures is an essential part of maps as such system cannot provide quantitative analysis themselves. Considering a modeling method, regulatory interactions can be inferred using mathematical variables or symbolic representations (Fig. 17.3).

The static maps can be converted into Boolean or semiquantitative dynamics (SOD) map if a biologist has some prior knowledge about the information contained in the static map such as the type of reaction or time required to convert gene expression (Kumar and Singh 2017; Teku and Vihinen 2017). The Boolean case determines the close relationship of having direct control on the components within the global system. For instance, gene X is essential for process Y to occur. It helps us to determine the accurate function which is applied in inverse methods.

In the real case, the concept of the model represents control about dynamics of each node available rather than the detailed time series. An initial model can be constructed with the help of this minimum information. Once the model is substituted by actual time series, a simple function can be determined that captures the dynamics at each node (Sehgal et al. 2015). The overall mathematical formulation and understanding to develop models are not always a critical task as generalized

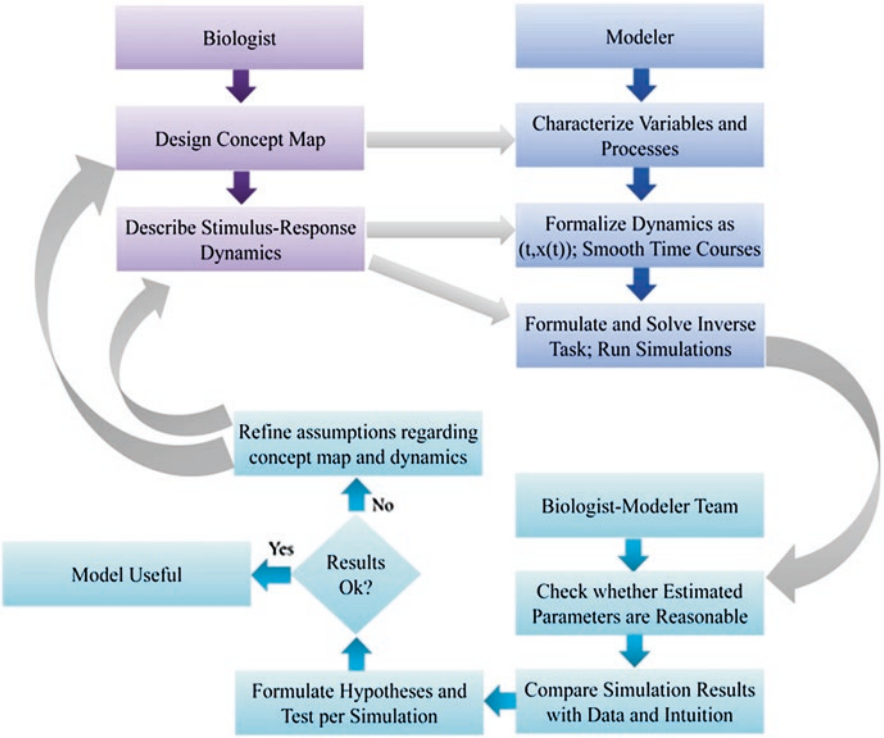

Fig. 17.3 Flow diagram of the proposed approach to formalizing biological concept maps

models can be used for depictions of user-specific data. This data can be further customized in the forms of graphs or curves. For instance, dynamicity of the system can be represented in the form of various distributional curves or sigmoid curves. Once we have constructed these model-derived curves, we can switch on or off the functions and change the curves as per the need in the presence or absence of defined variables or parameters. Condition-based approximation and differential analysis on the basis of conditions can be applied on these generated models.

17.3 Network of Networks

A network helps in understanding and combining scattered data at various dimensions. One of the key features of systems biology is focusing on "network of networks." In the human body, *n* number of networks is integrated in such a fashion so that efficient communication can happen at molecular and cellular levels. Generating understandable biosystems may help us to get insights about biological functions and variations and trace out changes at cellular to phenotypic levels. Figure 17.4 represents the structure of "network of networks" which gives an idea about various system biology approaches which differs from traditional biological approaches.

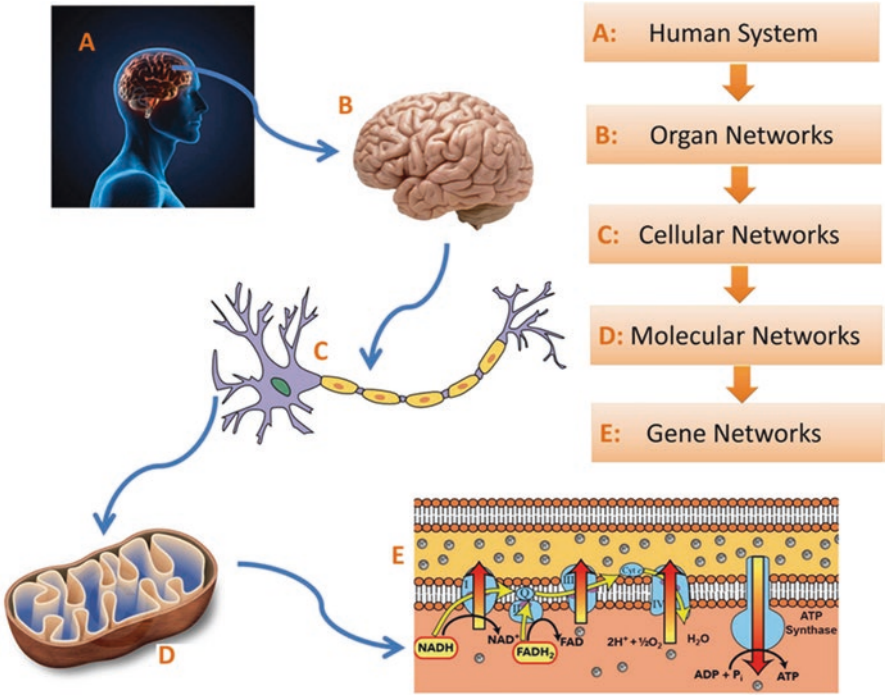

Fig. 17.4 Systems Dissection in terms of networks of networks

17.4 System Dissection into Components

Biological systems can be implemented in various ways; precisely it can be dissected using four components.

1. High-throughput methods for data generation which includes identifying unknown information from the depth of biological aura.
2. Developing concept, logic, and computational methods to combine various biological datasets to infer meaningful information.
3. Hypothesis generation and testing on newly generated data and comparison of the same existing data in various online portals and literature.
4. Understanding global scenario as big data and solving the phenotypic effects related to problems in differential data analysis for new information discovery.

17.5 Types of Modeling

Mathematical modeling is composed of various standard parameters, conceptual framing of tools, and interpretation of any kind of real system in mathematical form to decipher the control mechanics of the system. Mathematical representation of biological systems not only constructs the models but also optimizes and predicts in much efficient way compared to various traditional approaches. Thus, mathematical models can be implemented in terms of stochastic process, continuous process, or any other black box representation which doesn't have well-known information of composition.

For all the cases, the modeling process consists of the following same steps. First, using physical laws from first principles, a symbolic model is constructed which serves as an extension to the already known existing model (Athanasiou et al. 2017). This model consists of variables and parameters. The analysis requires comprehension of all parameter values obtained from biological knowledge. Variables in mathematical modeling can represent anything, whether it is a plant, animal, metabolite, pathway, or gene expression. Approximation and estimation of any parameter in biological terms is quite difficult as biological phenomenon doesn't reveal complete information in one go as other modeled systems do. The analysis of the model is done with the techniques and tricks of mathematics and computer science once the parameters are estimated. Due to the complexity of biological systems, optimization and analysis of differential conditions and large datasets are performed using computational approaches. Interpretation in terms of graphs and matrix provides an edge to scientific community to accurately depict the behavior of the aligned system.

The identification of unknown parameters in terms of biological entities is the genuine deterrent in the progress of biomathematical modeling. A non-specific approach called *biochemical systems theory* is used for biological systems modeling and analysis which is used for the improvements, developments, and applications of

thousands of research papers. BST was initially used to study the control systems and biochemical pathways.

The fundamental precepts of BST are very basic and transparent. Every variable that progresses after some time is given a name X and is represented in the form of the different orders of differential equation and depicts the variation in such a way so that it can affect other variables or parameters in positive or negative regulatory ways. BST also addresses the problem where the modeler has some broad data about the procedures but does not know their mathematical representation to develop a structure to solve the complexity of biological systems. Sometimes it is very difficult for a developer to develop a system which doesn't contain absolute values, or sometimes a developer is not having an idea of unknown things in the systems, but logically if we speak about linear regression, we are not sure about what kind of data points are there which need to be included or excluded at initial point. Both approaches are somehow similar while dealing with unknown information and positively providing an edge to mathematical modeling to structure the unstructured data. As biological networks don't follow the Poisson distribution and converge toward scale-free networks which comprises the properties of power law. So, it will not be wrong to say that such approaches can result in successful analysis toward validation of real dataset.

17.5.1 Forward Modeling

Identification of a parameter in a system is based on local information which subsequently deals with small component integration and formation of complete network. For instance, for metabolic pathway construction, there is a need to understand the enzymes involved in pathway, transporters involved, co-factors playing the role in regulation, and ultimately metabolite formation through secondary metabolisms. All these terms need to be integrated to form mathematical equations and depict the understanding of biological phenomenon. Biological modeling is generally dealt with Michaelis-Menten or power law function. Dynamicity of the system is controlled by various rate law and parameter approximations like Km and Vmax, and forward rate of reactions can be controlled on the basis of concentration assigned to each entity defined in the model (Apostolopoulos et al. 2017). In such modeling methods, there is a need to study the direct rate law to control the local parameters and test various hypotheses on the basis of developed models.

The main utilization of this method is the use of kinetic equations, using enzyme concentration for tracing the rate of reaction. Variation in the rate of reaction subsequently leads to variation at phenotypic levels. Construction of such models and their refinements always has been a crucial task for scientists in biological community.

17.5.2 Inverse Modeling

Variables are observed from high end to low end which means reduction approach. The most important advantage of this technique is that data is originated from the same organism, acquired in a similar trial condition, and represented in all the procedures within the organism that could affect the factors of the framework (Kallhovd et al. 2017). Computational time complexity is a major issue with such kind of analysis. Moreover, various biological entities are ignored in case of modeling. The inverse modeling also use time-dependent analysis where pathways information is not absolute.

17.5.3 Partial Modeling

A specific issue with any model building approaches emerges due to the presence of the "omnipresent" metabolites like energy molecules (ATP) which cannot be modeled as they are additionally required in different reactions. As a result, a mathematical buffer is constructed that absorbs the excess material, thus adjusting the dynamic changes in concentration at an already determined rate (Yalçın et al. 2017). Better-characterized statements are defined as differential conditions in BST, and their progression includes energy molecules as factors.

17.6 Inference from Qualitative Data to Computational Simulation

Biological system usually deals with enormous methods and tools whether they are qualitative or quantitative. Sometimes, there are exact implications of a system that are missing, and semiquantitative methods are prioritized over other measures of data segmentation or integration for network model construction. For instance, graphical methods represent directional flow of the information by connecting components of a system in a systematic fashion. Moreover, network construction and hypothesis testing on the basis of available information and predicting the information of missing links in the networks provide more insights about qualitative measurement from raw unstructured data. Various probabilistic measures like Markov chains which are used to represent Hidden Markov models and Bayesian model-based networks deal with graphical presentation of unknown entities in a network through random measure.

Sometimes, these graphical methods do not represent the dynamicity of the network and do not express much detailed information as per real-time scenario;

therefore mechanistic models come to existence where data can be analyzed in an automated manner.

Computer-based models and simulations provide an easy tool to understand biological systems in terms of complex nonlinear dynamics. The first is that "instinctive thinking about MAP kinase pathways led to the long-held view that the obligatory cascade of three sequential kinases serves to provide signal intensification. In contrast, computational studies have suggested that the purpose of such a network is to achieve extreme positive cooperativity so that the pathway behaves in a switch-like, rather than a graded, fashion."

Simulations present an understanding of biological phenomenon over differential time. Using differential equations on the same biological dataset can reveal hidden properties of the systems. But it will be unfair to expect accurate prediction through computational methods as these methods are developed to get insight about candidate entity selection. More data leads to more simulation time and subsequently increases the rate of precise selection of prediction attribute. Optimization can be performed on the basis of simulation measures of selected parameter. Simulation results in certain biological behavior analysis especially can be used in case of complex disease like cancer, diabetes, and neurodegenerative diseases. Simulations are modern and nontraditional techniques. In earlier days, people used conferences, abstract, and poster presentations to grab the idea of one's understanding. With the advancement in the internet world, these techniques can be integrated to form network to get holistic view of understanding of different people across the world (Huang et al. 2017). With the advancement in computational resources, the time and space complexity has not been an issue in the present world. So, mathematical simulations remain as the best alternative to reduce the time, effort, and resources of any wet lab experiments.

17.7 Protein Class Identification

The helix-turn-helix structural motif has an important and crucial role in various cellular pathways that are involved in transcription, DNA recombination and repair, and DNA replication. At present, methods that are used for motif identification are dependent on the amino acid sequence. The major drawback of these methods is that motif members belong to different sequence families that do not share common ancestry or homology, and hence these methods are incapable to identify all motif members (Qing and Gerson 2017).

So to overcome this drawback, a new method based on three-dimensional structure was created that involved the following steps:

1. Selecting a conserved component of the motif.
2. Computing structural features relative to that component.

3. Generating categorization models by comparing the relevant measurements of structures that contain motifs and those structures that do not contain motifs.

With the establishment of classification model, the entire Protein Data Bank of experimentally measured structures was searched, and new examples of motifs were identified that do not show any sequence homology with previously known examples. Two such examples are Esa1 histone acetyltransferase and flavone 4-O-methyltransferase. This result shows the importance of classification-based method that is proven helpful for the two abovementioned examples. The sequence-based methods are used to recognize a functional class of protein which can be improved by using the classification model that is based on three-dimensional structure information.

17.8 Computational Structure and Function Prediction

With the help of X-ray, NMR, and computational method techniques, structural genomics is now showing great enhancement in producing the three-dimensional structures of proteins. The important and crucial step after this is to understand how protein structure and functions are related. Studying protein structure individually impairs the overall understanding of the protein as various missing links will exist while studying a part of the protein. The availability of the expected surfeit protein structures has resulted in the development of computational methods that examines multiple protein structures at once and returns the important biophysical and biochemical features. Apart from this, these methods can also recognize important features in new protein structures (Winter et al. 2015) (Fig. 17.5).

FEATURE is an automated system developed by Wei and Altman. This system applies statistical parameters to study vital functional and structural sites in protein structures such as active sites, binding sites, disulfide bonding sites, and so forth. By collecting all known examples of a type of site and non-site, FEATURE computes the spatial distributions of defined biophysical and biochemical properties. It applies various statistical measures to calculate accurate, active, and binding sites. The use of parametric and nonparametric test provides this tool a high-level sensitivity and specificity.

SBML, Gepasi, and CellML are specialized systems for biological and biochemical modeling (Webb and White 2005). Madonna is a general-purpose system for solving a variety of equations (differential equations, integral equations, and so on). This has been represented in Fig. 17.6.

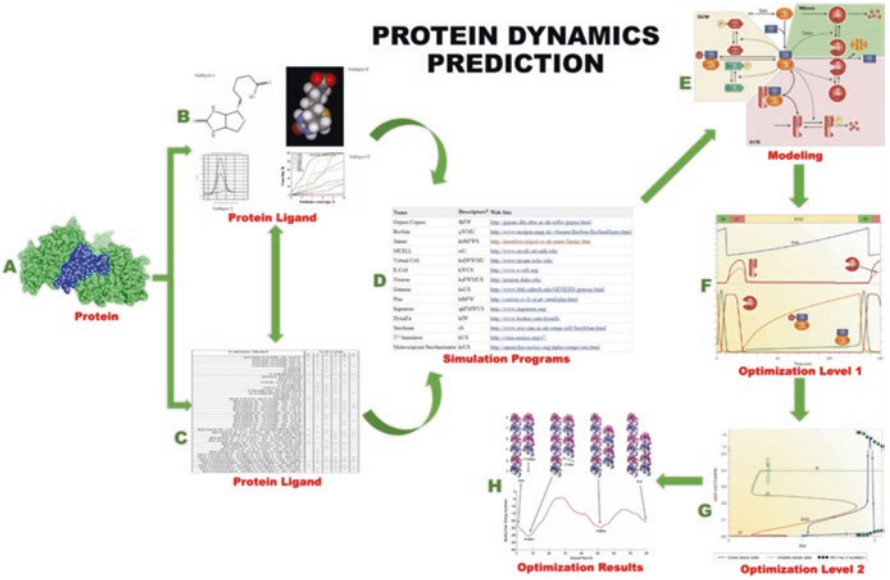

Fig. 17.5 Protein structure, docking and dynamics study

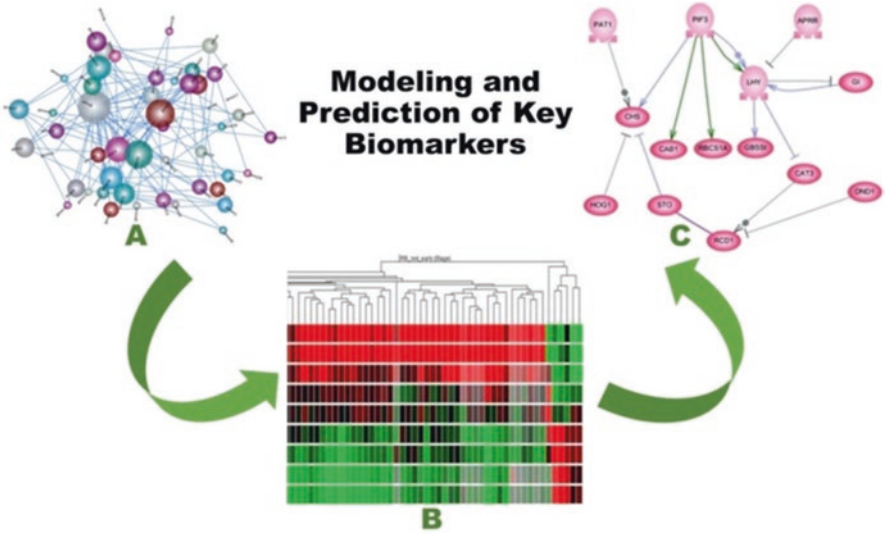

Fig. 17.6 Modeling system and screening key biomarkers

17.9 Forest Dynamics

SORTIE is a stochastic and mechanistic model that has been developed to simulate the growth of northeastern forests. This model mimics the fate of individual tree and its offspring. The model is based on the species-specific information regarding the growth rates, fecundity, mortality, and seed dispersal distances as well as some information regarding local regimes. SORTIE generates dynamic map by following tens of thousands of trees. This dynamic map depicts the distribution of nine dominant or subdominant species of trees that look like real forests. The model also predicts the realistic forest responses to certain minor and major disturbances like destruction of tress within small circle of forest boundary and improved tree mortality.

17.10 Cell Designer: A Computational Tool for Modeling

CellDesigner is a software developed by Systems Biology Institute using Systems Biology Markup Language and graphical notation. Different kinds of boxes were used to represent different kinds of biological entities. And different kinds of flux box reactions are present in the model to define kinetic equations. Interaction between one entity (i.e., node) to another is represented by edges. The graphical design of the software is supported by Jarnac, Plot, and Gibson, while associated databases are BioModels, PubMed, IHOP, KEGG, and SABIO. With the help of all these integrated modules, a user can model biochemical and gene regulatory networks. Using cell designer the user can create graphical notation for gene, RNA, and protein and also make a complex of protein. There are options to import and control the models developed by other people in systems biology field. The major parameter in this software is to perform simulation at molecular level using genes, proteins, or metabolite concentration at different time periods. Ordinary differential equations are used to create the simulation profiles. Simulation profiles can be analyzed and compared within a model, same organism model or other model. Another important feature of this modeling tool is to study the small pathway by considering a system as a whole which implies that the user need not to study complete information at one instance. The user can split their pathway of interests into different modules and later integrate them to reduce the time complexity for the simulation. Apart from this, there are various plugins which can be integrated with this software.

Cytoscape is a similar tool for model development on the basis of topological analysis. This tool lacks the use of simulation to study differential conditions, but statistical analysis and beautiful graphical layouts for representing networks provide an edge for this tool over other modeling softwares.

17.11 Conclusion

Major purpose of modeling and optimization in research is to systematically assemble and simulate all the molecules and their interactions that are occurring inside the living cell. There is a need to understand how these molecular interactions take place and how to determine the function of this complex machinery that cannot be solved only by biotechnology lab experiments. The advancement in the modeling techniques indicates that cellular networks are governed by diverse universal properties and offer a new conceptual structure that could potentially renovate our view of biology and drug therapies.

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Performance Investigation of Energy Efficient HetSEP for Prolonging Lifetime in WSNs

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Abstract. In this work, we investigate the performance of heterogeneous stable election protocol (HetSEP) for prolonging the network lifetime. An order-5 heterogeneous energy network model is proposed in this work that can defines the order-1, order-2, order-3, order-4, and order-5 heterogeneity. We consider the SEP protocol to calculate the lifetime of the network and consequently describe its accomplishments as HetSEP-1, HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5. The SEP protocol is HetSEP-1 in which all the sensor nodes have same amount of energy. The HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5, contain two, three, four, and five orders of energy, respectively. The network lifetime increases as increasing the order of heterogeneity. The HetSEP-2, HetSEP-3, HetSEP-4, & HetSEP-5, prolong the lifetime of the network 100.39%, 126.12%, 186.56%, & 285.67%, in respect to the increase the energy of the network by 65.0%, 72.58%, 107.10%, & 208.40% with respect to the HetSEP-1.

Keywords: Network lifetime · Heterogeneity · Round
Stable election protocol

1 Introduction

Now a day, a wireless sensor networks (WSN) have turn out to be an attractive technology, where WSNs deployed easily without increasing the cost of the network in terms of communication infrastructures. These networks become popular because it takes very less time in installation where we want to perform monitoring task in the environment. Sensor networks are a network of network that includes a low size, low battery power, low memory, and low complex devices, known as sensor nodes. A WSN consists of thousands of thousand of sensor nodes installed with different communication, sensing, storing and computing abilities. In the monitoring environment, every sensor has the facility to capture the object in the monitoring environment of an activity and these sensor nodes perform calculation, and computations of the received data from the monitoring environment. Each node create communicates between the sensor nodes and its peers for collecting the monitored data and forward the sensed data to the base station (BS) with the help of other sensor nodes. A lot of

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protocol are exits for data collection from the monitoring environment, and these are energy aware for prolong the lifetime of the network because the substitution of the battery power of the nodes is a extremely complicated practice, once upon a time these sensor nodes have been installed in the monitoring environment. Sensor networks can efficiently utilized the battery power of sensor nodes by considering the different protocols for increasing the lifetime of wireless sensor networks [1]. There are two possible ways to deploy the sensor nodes in the monitoring area namely deterministically or randomly. The deployment of the sensor nodes in the deterministic fashion are additional favorable in different applications such as physically accessibility of the nodes are easy or nodes are placed manually in the monitoring locations. Example are as follows for the deterministic fashion deployment the line in sand for target tracking, city sense for urban monitoring, soil monitoring, etc. Another way of sensor node deployment is the random deployment where sensor nodes are not physically inaccessible in the monitoring area, for example, Mines, bird observation on Great Duck Island etc. In random deployment environment, the nodes are jumped down through an aircraft.

Longevity of the network for prolonging the lifetime of networks is the most important issue in wireless sensor networks, which is directly or indirectly influenced by the energy of network. There are two possible ways to increasing the lifetime of wireless sensor networks, firstly add some extra node in the monitoring environment, and secondly, increase the energy of the existing sensor nodes. Adding some extra node in the monitoring environment is the ten times costlier to increasing the energy of the exiting nodes. Therefore, increasing the energy of the existing nodes is the best way to increasing the lifetime of the networks. The categorizing the sensor nodes into groups are an efficient way for utilizing the network energy called clusters where each cluster has a master sensor node and it is also called the cluster head. This type of nodes has several member nodes and usually called member of the cluster. The cluster head generally performs the data fusion and data aggregation in order to have longer lifetime, the network should have good amount of energy. The wireless sensor networks with different energy levels are called heterogeneous WSNs [2]. In this paper, we propose a 5-order heterogeneous network model for wireless sensor networks to increasing the network lifetime. This model is capable to define order-1, order-2, order-3, order-4, and order-5 heterogeneity. The order-1 describes single type of nodes in a network in term of energy i.e., homogeneous network. The order-2, order-3, order-4, and order-5 describe two types, three types, four types, and five type sensor nodes, respectively. The election of cluster heads probabilities are weighted by the initial energy of a sensor relative to that of other sensors in the network.

The rest of the paper is organized as follows. Section 2 discusses the literature review based on clustering. Section 3 discusses the proposed heterogeneity network model for five order of heterogeneity. In Sect. 4, experimental results are discussed and finally in Sect. 5, the paper is concluded.

2 Related Work

Now a day's WSNs have attracted several researchers due to their potential applications and challenges. Fruitful applications of the WSNs are as military, environmental, health, scientific exploration, area monitoring and structural health monitoring applications, etc. At the same point of time, WSNs have numerous challenges like efficient use of energy, fault-tolerance, connectivity, simplicity, coverage, robustness, scalability, security, etc. The main challenges in wireless networks are related to the improvement in network lifetime for longevity of the sensor networks. The lifetime of the network is an essentially related to the efficient use of energy of the network. Accordingly, lot of protocols have been developed for increasing the lifetime of wireless sensor networks by considering different deployment techniques, and heterogeneous networks models. Papers [6, 10] discuss an extremely first protocol for prolonging the lifetime in WSNs by Heinzelman et al. in 2000, and this protocol is known as low energy adaptive clustering hierarchy (LEACH) protocol. In this protocol, sensor nodes are divided into several groups called as cluster, and a cluster node in each cluster called cluster head that collects the information from its cluster members and sends that to the base station (BS), and all sensors don't send the data directly to the BS. They send their data through cluster heads that is why this protocol is called hierarchical protocol. In this protocol, the cluster heads may not be dispersed uniformly. The solution of this problem has been given in LEACH-C and fixed LEACH [10], by dispersing the cluster heads all over the network so that it can produce better performance in terms of network lifetime and energy consumption.

From the past few decades researcher mainly focuses on the homogeneous network technologies but recently researchers are shifted to the heterogeneous network technology because it become more popular due to its better performance. It has been proved by the researchers that lifetime in case of heterogeneous networks is large as compare to the homogeneous networks. Due to that region many researchers are shifted to heterogeneous networks and some works has been done the heterogeneous networks models. In paper [11], stable election protocol (SEP) is proposed by Smaragdakis et al. for heterogeneous networks, and it is an extension of LEACH and a very first protocol in the field of energy heterogeneity. The selection of cluster head in SEP is based on weighted election probability that can be calculated by the remaining energy of the nodes and node initial energy. SEP considers two level of heterogeneity, which contains two type of nodes namely normal and advance nodes. In this protocol, advanced node energy is higher than that of the normal nodes. In paper [13], a distributed energy efficient clustering (DEEC) protocol is discussed by Qing et al. using 2-level and multilevel heterogeneity. The 2-level heterogeneity network model is precisely identical as discussed in [12] and multilevel heterogeneous model, the energy of each node is arbitrarily to be paid from a given energy interval. Therefore, in this network levels of energy can be infinite due to random allocation of the energy. This model is hardly of any use because each node has different amount energy level and designing of such type of nodes may not be practically feasible. In paper [12], an EEHC protocol for heterogeneous WSNs is discussed by Mao et al. and it considers 3-levels of heterogeneity is discussed by using 3 types of nodes namely: normal nodes, advanced nodes,

and super nodes. Advanced node energy is higher than normal node energy and the super node energy is higher than advanced node energy. The selection of cluster head is based on the weighted election probability so that the sensor nodes energy is efficiently utilized. In [14] authors discuss a balanced energy efficient network integrated super heterogeneous (BEENISH) protocol to compute lifetime of the network on the basis of its average energy and its residual energy of nodes. In [15–22] authors discuss a modified HEED protocol for heterogeneous WSNs. It describes 1-level heterogeneity, 2-level heterogeneity, and 3-level heterogeneity by considering level or order of energies. It considers one additional parameter for fuzzy clustering called distance between the sensor node and the cluster head to determine the cluster heads.

In paper [20] a novel energy-efficient clustering protocol (NEECP) for increasing the network lifetime in wireless sensor networks is proposed. It selects the cluster heads in an effective way with an adjustable sensing range and performs data aggregation using chaining approach. It also avoids transmission of redundant data by using a redundancy check function for improving the network lifetime. It is implemented by considering the data with aggregation and without aggregation. In paper [21, 22] a 3-level heterogeneous network model for WSNs to enhance the network lifetime, which is characterized by a single parameter is proposed. Depending upon the value of the model parameter, it can describe 1-level, 2-level, and 3-level heterogeneity. The proposed heterogeneous network model also helps to select effective active sensor nodes for scheduling and compute the network lifetime by implementing two protocols for our network model, which include ALBP and ADEEPS. The ALBP and ADEEPS protocols are implemented for the existing 1-level, 2-level, and 3-level heterogeneous network models, and for the proposed 3-level heterogeneous network model, the ALBP implementations. The simulation results indicate that heterogeneous protocols prolong the network lifetime as compared to the homogeneous protocols. Furthermore, as the level of heterogeneity increases, the lifetime of the network also increases.

Paper [23] discusses a cluster based approach is proposed to increase the network lifetime and throughput of the heterogeneous wireless sensor networks. This approach combined the direct data transmission to base station with the cluster head transmission of data in wireless sensor networks. It uses the twice energy for advanced nodes in comparison to normal nodes. It is observed that results are found good with the use of 10% of advanced nodes along with normal nodes in the network in this approach. However, on further increasing the advanced node deployment beyond deployment 30%, network lifetime and throughput of network start degrading. So, the proposed solution with 10% advanced node may be considered as the best suitable and acceptable solution for better network throughput and life time in WSNs. This paper [24] gives a new reputation based OR metric and some rules, in which the next hop selection is based on its reputation. This metric considers the reputation level as a primary selection parameter for next-hop. A new OR metric relies on energy efficiency and packet delivery ratio of next-hop. This OR protocol selects all middle position neighbors as next-hop and potential forwarder will be decided on the basis of new OR metric. Energy consumption is considered to be dynamic. It has been compared with Middle Position Dynamic Energy Opportunistic Routing (MDOR), and Trust and Location Aware Routing Protocol (TLAR). Paper [25] discusses a data aggregation approach for

analyzing in wireless sensor network. This approach minimizes the traffic between the clusters and the sensor nodes by removing the duplicate data at the cluster heads.

In this work, we discuss an order-5 energy network model for increasing the lifetime of a wireless sensor networks. We consider SEP implementations for performance evaluation of the proposed model and accordingly the implementation of SEP is denoted as HetSEP-1, HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5. The variants of HetSEP-1, HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5 are one, two, three, four, and five order of nodes, respectively. The heterogeneity is beneficial in networks because increasing the network energy by adding more sensors is much costlier than by increasing the energy of some of the nodes. In next section, we will discuss network assumptions and propose our heterogeneous network model.

3 Proposed Method

We assume the following for the WSNs.

- All the nodes have similar abilities such as its memory, processing power, communication range and having equal significance.
- Sink is stationary in our networks and situated in middle in the networks.
- Sensor nodes have capabilities of data fusion and aggregation.
- The categorization of sensor and their energies depends on the order of heterogeneity.
- All the sensor nodes are randomly deployed.
- All the nodes have same capability such as link, memory, sensing range and microprocessor except energy.

We propose an order-5 heterogeneity or non homogeneous network energy model i.e., capable to describe the order-1, order-2, order-3, order-4, and order-5 heterogeneity. Let N be the total number of nodes in the network. The numbers of nodes for all five order of heterogeneity in the network are denoted as N_1, N_2, N_3, N_4, N_5 and they necessity assure the inequality $N_5 < N_4 < N_3 < N_2 < N_1$. The sum of energy/battery power of the heterogeneous networks is denoted by E_{total} and given by

$$E_{total} = E_0 * \beta * N + E_1 * \beta^2 * N + E_2 * \beta^3 * N + E_3 * \beta^4 * N + E_4 * \beta^5 * N \quad (1)$$

where, β is a parameter and E_0, E_1, E_2, E_3 and E_4 are the energies of order-1, order-2, order-3, order-4, and order-5 nodes that necessity assure the inequality $E_4 > E_3 > E_2 > E_1 > E_0$. The battery power of order-i sensor nodes is related to the battery power of order-1 sensors is give by

$$E_j = E_0 + \mu_j \quad (2)$$

Using (1), (2) can be written as

$$E_{total} = E_0 * \beta * N + (E_0 + \mu_1) * \beta^2 * N + (E_0 + \mu_2) * \beta^3 * N + (E_0 + \mu_3) * \beta^4 * N + (E_0 + \mu_4) * \beta^5 * N$$

$\mu_1, \mu_2, \mu_3,$ and μ_4 are the new model parameters. E_{total} can be simplified as follows:

$$E_{total} = N * \left(E_0 * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \left(\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 + \beta^5 * \mu_4\right)\right) \quad (3)$$

Order-1 Heterogeneity: For $\mu_1 = \mu_2 = \mu_3 = \mu_4 = 0$, the model defined in (3) described one non zero term or one type of nodes (order-1) i.e., called order-1 heterogeneity. The total network energy of order-1 is as follows:

$$\mathrm{E}_{\mathrm{order}-1} = \mathrm{E}_0 * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right)$$

The total no. of sensor nodes in order-1 heterogeneity is defined as

$$N_1 = \mathrm{N} * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right)$$

With the following condition

$$\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5 = 1.$$

Order-2 Heterogeneity: For $\mu_2 = \mu_3 = \mu_4 = 0$, the model defined in (3) contains two non zero. It defines order-2 heterogeneity and contains order-1 and order-2 nodes. The total network energy of order-2 is as follows:

$$\mathrm{E}_{\mathrm{order}-2} = \mathrm{E}_0 * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \beta^2 * \mu_1$$

The total no. of order-1 and order-2 nodes in order-2 heterogeneity, denoted by N_1 and N_2, respectively, are given as

$$N_1 = \mathrm{N} * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right), \quad \text{and } N_2 = \mathrm{N} * \beta^2 * \mu_1$$

With the following conditions

$$\left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) * 100 = N_1 \text{ and, } \beta^2 * \mu_1 = \mathrm{N} - N_1.$$

Order-3 Heterogeneity: For $\mu_3 = \mu_4 = 0$, the model defined in (3) contains three non zero terms and define three types of nodes as called order-1, order-2, and, order-3 nodes. The total network energy of 3-order is as follows:

$$E_{order-3} = E_0 * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \beta^2 * \mu_1 + \beta^3 * \mu_2$$

The total no. of order-1, order-2 and order-3 nodes in 3-order heterogeneity, denoted by N_1, N_2 and N_3, are respectively, given as

$$N_1 = N * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right), N_2 = N * \beta^2 * \mu_1, \text{and } N_3 = N * \beta^3 * \mu_2.$$

With the following conditions

$$\left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) * 100 = N_1, \text{and } \beta^2 * \mu_1 + \beta^3 * \mu_2 = N - N_1.$$

Order-4 Heterogeneity: For $\mu_4 = 0$, the model defined in (3) contains four non zero terms and define four types of nodes as order-1, order-2, order-3, and order-4 nodes. The total network energy of order-4 heterogeneity is as follows:

$$E_{tire-4} = \left(E_0 * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \left(\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3\right)\right)$$

The total no. of order-1, order-2, order-3, and order-4 nodes in *order-4* heterogeneity denoted by N_1, N_2, N_3, and N_4, are respectively, given as

$$\begin{aligned} N_1 &= N * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right), \\ N_2 &= N * \beta^2 * \mu_1, \\ N_3 &= N * \beta^3 * \mu_2, \text{ and} \\ N_4 &= N * \beta^4 * \mu_3. \end{aligned}$$

With the following conditions

$$\begin{aligned} \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) * 100 &= N_1, \text{ and} \\ \beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 &= N - N_1. \end{aligned}$$

Order-5 Heterogeneity: the model defined in (3) contains all non zero terms and define five order heterogeneity. The five typ of are as order-1, order-2, order-3, order-4, and order-5 nodes. The total network energy of order-5 heterogeneity is as follows:

$$E_{tire-5} = \left(E_0 * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \left(\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 + \beta^5 * \mu_4\right)\right)$$

The total no. of order-1, order-2, order-3, order-4, and order-5 nodes in order-5 heterogeneity denoted by $N_1, N_2, N_3, N_4,$ and N_5, are respectively, given as

$$\begin{aligned} N_1 &= \mathrm{N} * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right), \\ N_2 &= N * \beta^2 * \mu_1, \\ N_3 &= \mathrm{N} * \beta^3 * \mu_2, \\ N_4 &= \mathrm{N} * \beta^4 * \mu_3, \text{ and} \\ N_5 &= \mathrm{N} * \beta^5 * \mu_4 \end{aligned}$$

With the following conditions

$$\begin{aligned} &\left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) * 100 = N_1, \text{ and} \\ &\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 + \beta^5 * \mu_4 = \mathrm{N} - N_1. \end{aligned}$$

The selection of master node or cluster head is depends on the probability of nodes. We determine the probability of order-5 heterogeneity nodes i.e., order-1, order-2, order-3, order-4, and order-5 nodes as follows:

$$\left.\begin{aligned} \mathrm{p}_{\mathrm{order}-1} &= \frac{\mathrm{p}_{\mathrm{opt}}}{\left(\left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \left(\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 + \beta^5 * \mu_4\right)\right)} \\ \mathrm{p}_{\mathrm{order}-2} &= \frac{\mathrm{p}_{\mathrm{opt}} * (\mu_1)}{\left(\left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \left(\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 + \beta^5 * \mu_4\right)\right)} \\ \mathrm{p}_{\mathrm{order}-3} &= \frac{\mathrm{p}_{\mathrm{opt}} * (\mu_2)}{\left(\left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \left(\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 + \beta^5 * \mu_4\right)\right)} \\ \mathrm{p}_{\mathrm{order}-4} &= \frac{\mathrm{p}_{\mathrm{opt}} * (\mu_3)}{\left(\left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \left(\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 + \beta^5 * \mu_4\right)\right)} \\ \mathrm{p}_{\mathrm{order}-5} &= \frac{\mathrm{p}_{\mathrm{opt}} * (\mu_4)}{\left(\left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \left(\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 + \beta^5 * \mu_4\right)\right)} \end{aligned}\right\} \quad (4)$$

In Eq. (1), replace the value of $\mathrm{p}_{\mathrm{opt}}$ by the weighted probability for the threshold i.e., applied to select the master node in each and every round. The threshold of order-1, order-2, order-3, order-4, and order-5 nodes are define as $\mathrm{T}(\mathrm{s}_{\mathrm{order}-1})$, $\mathrm{T}(\mathrm{s}_{\mathrm{order}-2})$, $\mathrm{T}(\mathrm{s}_{\mathrm{order}-3})$, $\mathrm{T}(\mathrm{s}_{\mathrm{order}-4})$, and $\mathrm{T}(\mathrm{s}_{\mathrm{order}-5})$, respectively, as in (5).

$$
\left.
\begin{aligned}
T(s_{order-1}) &= \begin{cases} \dfrac{p_{order-1}}{1-p_{order-1}\cdot\left(r \bmod \frac{1}{p_{order-1}}\right)} & \text{if } s_{order-1}G^1 \\ 0 & Otherwise \end{cases} \\
T(s_{order-2}) &= \begin{cases} \dfrac{p_{order-2}}{1-p_{order-2}\cdot\left(r \bmod \frac{1}{p_{order-2}}\right)} & \text{if } s_{order-2}G^2 \\ 0 & Otherwise \end{cases} \\
T(s_{order-3}) &= \begin{cases} \dfrac{p_{order-3}}{1-p_{order-3}\cdot\left(r \bmod \frac{1}{p_{order-3}}\right)} & \text{if } s_{order-3}G^3 \\ 0 & Otherwise \end{cases} \\
T(s_{order-4}) &= \begin{cases} \dfrac{p_{order-4}}{1-p_{order-4}\cdot\left(r \bmod \frac{1}{p_{order-4}}\right)} & \text{if } s_{order-4}G^4 \\ 0 & Otherwise \end{cases} \\
T(s_{order-5}) &= \begin{cases} \dfrac{p_{order-5}}{1-p_{order-5}\cdot\left(r \bmod \frac{1}{p_{order-5}}\right)} & \text{if } s_{order-4}G^5 \\ 0 & Otherwise \end{cases}
\end{aligned}
\right\} \quad (5)
$$

where, r is the current round, G^1, G^2, G^3, G^4, and G^5, are the set of order-1, order-2, order-3, order-4, and, order-5 nodes that have not yet turn into master node in last $\left\{\frac{1}{p_{order-1}}, \frac{1}{p_{order-2}}, \frac{1}{p_{order-3}}, \frac{1}{p_{order-4}} \text{ and } \frac{1}{p_{order-5}}\right\}$ rounds, and $T(s_{order-1})$, $T(s_{order-2})$, $T(s_{order-3})$, $T(s_{order-4})$, and $T(s_{order-5})$ are the thresholds applied to the population of order-1, order-2, order-3, order-4, and order-5 nodes, respectively.

In the next section, we will discuss the simulation of the exiting SEP i.e., HetSEP-1, HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5 protocols.

4 Simulation Results

In this section, we present the simulation results for our proposed heterogeneous network model by considering SEP protocol and the implementation of SEP protocol over our proposed model is called HetSEP. Section 3 has discussed a proposed model and it can define order-1 (original SEP), order-2, order-3, order-4, and order-5 heterogeneity of the WSNs. On the bases of heterogeneity, we call the implementations as HetSEP-1, HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5 heterogeneity. In this work, we compute the network lifetime, no. of alive nodes, no. of dead nodes, no. of packets sent at the sink and total energy consumption for the proposed heterogeneous network model. In this work, we have randomly deployed 100 no. of nodes in an area of size 100 M $\times$ 100 M. The energy dissipation model is used in this work as same given in [2, 6, 10]. Table 1 shows the input parameters which are used in our simulations.

For different order of heterogeneity, the proposed model has characterized by different parameters $\beta, \mu_1, \mu_2, \mu_3$ and μ_4. For order-1 heterogeneity (HetSEP-1), we assume the total no. of sensor nodes are 100 with initial energy 0.5 J. For order-1

heterogeneity (HetSEP-2), we compute the no. of order-1 and order-2 nodes are 75 and 25 and the energies of order-1 & order 2 are as 0.5 J and 1.80 J, respectively. For order-3 heterogeneity (HetSEP-3), we compute the no. of order-1, order-2, and order-3 nodes are 70, 20 and 10 and the energies are 0.5 J, 1.64 J and 1.85 J, respectively. For order-3 heterogeneity (HetSEP-4), the no. of order-1, order-2, order-3, and order-4 nodes are 65, 20, 10 & 5 and the energies are 0.5 J, 1.75 J, 2.06 J & 2.45 J, respectively. For order-5 (HetSEP-5), we compute the no. of order-1, order-2, order-3, order-4, and order-5 nodes are 60, 15, 12, 8 & 5, and the energies are 0.5 J, 1.54 J, 2.69 J, 4.34 J & 6.82 J, respectively.

Table 1. Simulation parameters

Heterogeneity	No. of Nodes	β	μ_1	μ_2	μ_3	μ_4	E_0	E_1	E_2	E_3	E_4	E_{total}	Lifetime
Order-1	100	NA	NA	NA	NA	NA	0.5	NA	NA	NA	NA	50.00	1815
Order-2	75 + 25	0.44	1.31	NA	NA	NA	0.5	1.80	NA	NA	NA	82.50	3637
Order-3	70 + 20 + 10	0.42	1.14	1.35	NA	NA	0.5	1.64	1.85	NA	NA	86.29	5201
Order-4	65 + 20 + 10 + 5	0.40	1.25	1.56	1.95	NA	0.5	1.75	2.06	2.45	NA	103.55	4104
Order-5	60 + 15 + 12 + 8 + 5	0.38	1.04	2.19	3.84	6.31	0.5	1.54	2.69	4.34	6.82	154.20	7000

NA- not applicable

In Fig. 1, we have work out for different orders of heterogeneity by considering the no. of alive nodes with respect to the number of rounds. It is evident from the analysis of simulation of results, as the order of heterogeneity increases, the network lifetime of the network increases. It is also clear from the Fig. 1 that the last sensor nodes dead come about in 1815th, 3637th, 5204th, 4104th and 7000th no. of rounds for all five variants of HetSEP protocols, respectively. The HetSEP-5 performs the better than among all others in terms of no. of alive sensor nodes. We also computed the no. of dead nodes in Fig. 2 for different orders of heterogeneity with respect to the number of rounds.

In Fig. 2, the first nodes dead become 402th, 662th, 843th, 1020th, and 1602th in no. of rounds for HetSEP-1, HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5, respectively.

In Fig. 3, we have computed the no. of packets delivered to the sink with respect to the no. of rounds for different orders of heterogeneity. The no. of packets transferred to the sink in HetSEP-1, HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5, has been obtained as 1.51×10^4, 2.51×10^4, 2.72×10^4, 3.33×10^4 and 4.73×10^4, respectively, with respect to the no. of rounds. It is also evident that the HetSEP-5 has more no. of data packets delivered to the sink than the HetSEP-1, HetSEP-2, HetSEP-3, and HetSEP-4. In this work, we have also computed the total energy consumption with respect to the number of rounds as shown in Fig. 4. The five order of heterogeneity (HetSEP-5) performs better among all orders of heterogeneity of the HetSEP variants. However, the rate of energy consumption is much slower in case the HetSEP-5 (five order of heterogeneity) than the all other orders of heterogeneity. The HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5, increase the network lifetime 100.39%, 126.12%, 186.56%, and 285.67%, corresponding to the increase in the network energy by 65.0%, 72.58%, 107.10%, and 208.40% with respect to the HetSEP-1.

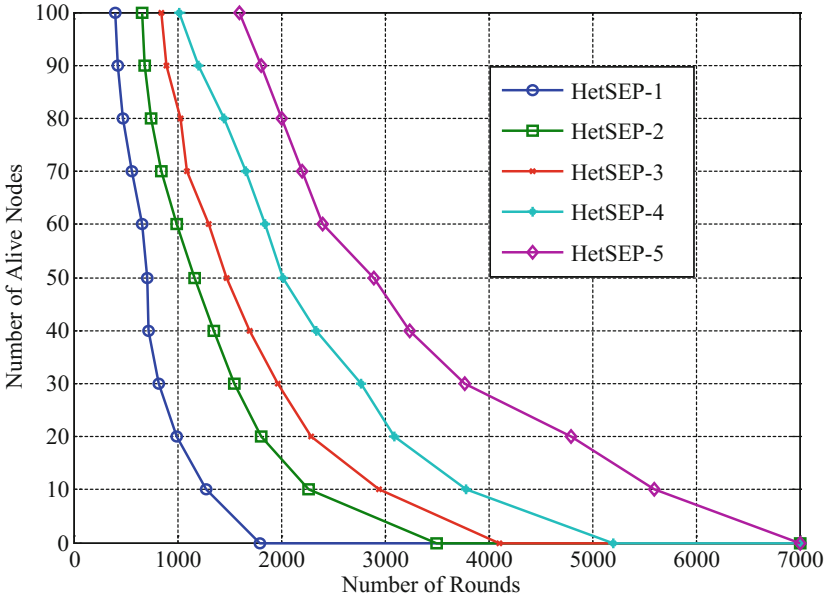

Fig. 1. No. of nodes alive vs. number of rounds

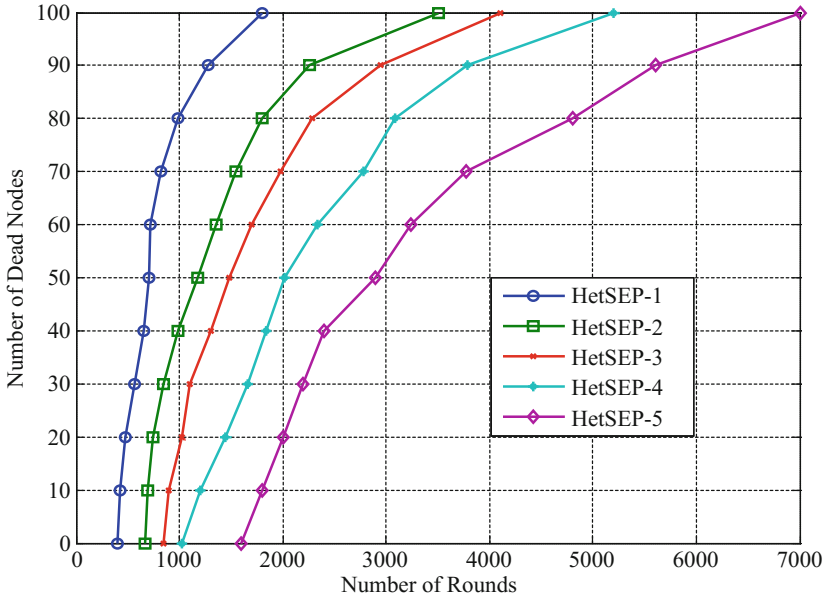

Fig. 2. No. of dead nodes vs. number of rounds

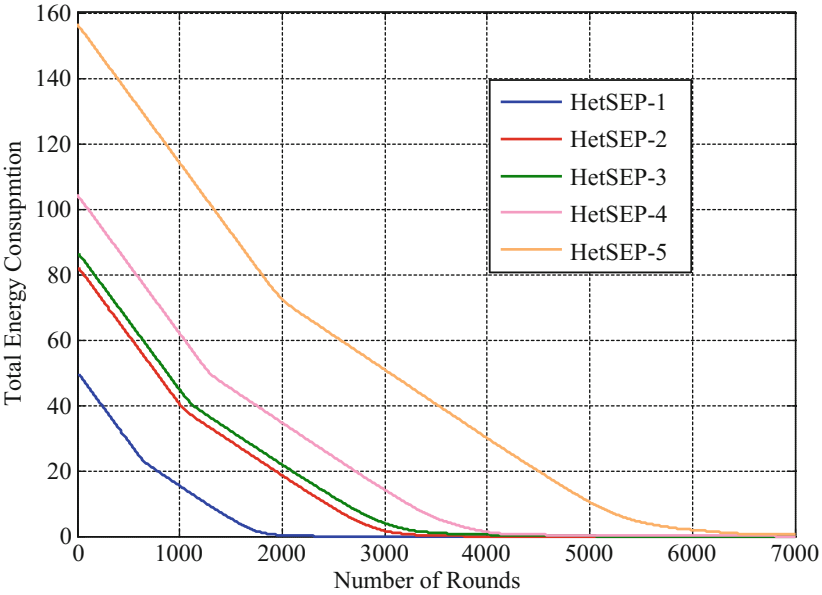

Fig. 3. Total energy consumption vs. number of rounds

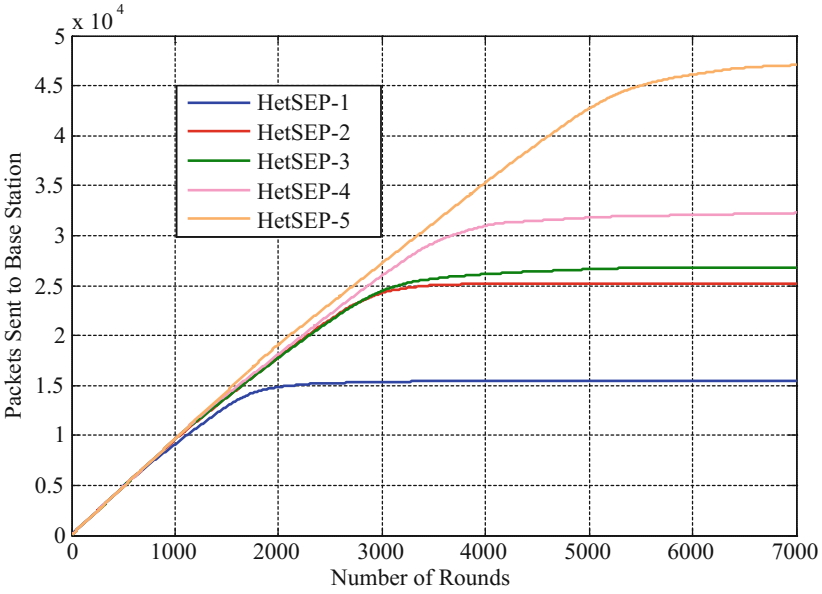

Fig. 4. No. of packets sent to the sink vs. number of rounds

5 Conclusions

In this work, an order-5 heterogeneity network model has been proposed for WSNs, namely: order-1, order-2, order-3, order-4, and order-5 heterogeneity in terms of energy. As the analysis of simulation of results, prolonging heterogeneity order prolongs the network lifetime in much proportion as compared to prolong in the network energy. However, the HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5, prolong the network lifetime 100.39%, 126.12%, 186.56%, and 285.67% corresponding to the prolong in the network energy by 65.0%, 72.58%, 107.10%, and 208.40% with respect to the HetSEP-1. The HetSEP-5 performs better than the HetSEP-1, HetSEP-2, HetSEP-3, and HetSEP-4.

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Global Perspectives on Air Pollution Prevention and Control System Design

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Once pollutants are released into the atmosphere, they cannot be removed easily nor can the reaction with atmospheric constituents be ceased. However, through enhancing our understanding of control technology, further addition of pollution can be forestalled. Through better understanding of innovations in the field of air pollutant control technology and modelling, better cost-effective control equipment can be designed to achieve a clean biosphere for sustainable life in the near future.

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Chapter 3
Indexing Method for Assessment of Air Quality: A Case Study for Dharamshala City in India

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ABSTRACT

Rapid urbanization and globalization has led to severe degradation of existing air quality in the majority of Indian cities. In this context, the general public has been aware of their exposure to ambient air quality and the effects of such air pollutants on human health. Hence, the concept of Air quality indices (AQI) is often used by regulatory authorities in conveying the status of existing ambient air quality to the general public. The chapter presents the application of air quality indices for assessing the existing air quality standards in an Indian city, Dharamshala, a tourist location in Himachal Pradesh, for the period of 2016-2017. Two different methods of determining AQI have been used wherein one method is used as the revised Central Pollution Control Board (CPCB), India with different sub-indices for Indian conditions based on the United States Environmental Protection Agency (USEPA) methodology and another alternative method utilizes contribution from all criteria pollutants.

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INTRODUCTION

Air pollutants generated from vehicular exhausts are one of the major sources of pollution in cities of India and worldwide (Ganguly et al., 2014, 2015; Kumar et al., 2013, 2015, 2016). The important criteria air pollutants generated from traffic sources are nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), volatile organic compounds (VOCs), particulate matter (PM) and several metals (Ganguly and Broderick, 2008). Criteria pollutants are those pollutants whose limiting concentrations in atmosphere has been predefined as per the National Ambient Air Quality Standards (NAAQS) to minimize their effects on human health. Continuous and long-term exposure to such pollutants can lead to severe health impacts including asthma and respiratory problems (Anderson et al., 2011; Clark et al., 2010; Heal et al., 2012), inadequate development of lung functions in infants and small children (Gauderman et al., 2007), cardiovascular diseases (Lindgren et al., 2010) and may lead to cancer (Buffler et al., 2005; Langholz et al., 2002). In this context, ambient air quality standards have been fixed for these criteria pollutants in most of the developing and developed countries. In an Indian context, the Central Pollution Control Board (CPCB) has specified the NAAQS for such pollutants as shown in Table 1.

The major difficulty associated with the representation of these prescribed standards is unifying them over a reference scale for representing the health effects of air pollutants to the citizens (Nagendra et al., 2007). Further, increased air pollution concentrations and their recurrence intervals often pose challenges to general citizens of understanding of the existing ambient air quality. As such, Air Quality Index (AQI) are often used by regulatory authorities of informing the common public of the existing nature of the ambient air quality.

In principle, an AQI is a single number determined on the principle of sub-indices of different criteria pollutants and which defines the nature of the ambient air quality in the context of human health effects (Bortnick et al., 2002; Murena, 2004). The pollutants generally considered for the determination of AQI involves the monitored data of all the criteria pollutants (SO_2, NO_x, SPM and RSPM) in India. The methods of analysis of AQI using different methods primarily depend on pollutants considered, sampling period and the considered breakpoints (Monteiro et al., 2016). Different methodologies are used for determination of AQI with different categorizations and there exists no common single technique which has been universally endorsed. The determination of AQI is a simple yet an effective technique in summarizing the potential heath effects of the surrounding ambient air quality (Kowalska et al., 2009; Monteiro et al., 2016). The AQI provide the status of the ambient air quality to the general public without delving into the computational details and alerts the

Table 1. National ambient air quality standards

Pollutant	Time Weighted Average	Concentration in Ambient Air (CPCB, 2009)			European Union (EU) Air Quality Directive	World Health Organization (WHO) Guidelines
		Industrial Areas	Residential, Rural and Other Areas	Sensitive Areas		
Sulfur dioxide (SO_2) µg/m^3	Annual[a]	80	60	15		
	24 h[b]	120	80	30		
Oxides of Nitrogen (NO_2) µg/m^3	Annual[a]	80	60	15	40	40
	24 h[b]	120	80	30	200 (not to exceed 18 times in a year)	200
Suspended Particulate Matter (SPM) µg/m^3/ PM10	Annual[a]	360	140	70	40	20
	24 h[b]	500	200	100	50 (Not to be exceeded on more than 35 days per year)	50 (99th percentile, 3 days per year)
Respirable Suspended Particulate Matter (RSPM) / PM2.5µg/m^3	Annual[a]	120	60	50	25	10
	24 h[b]	150	100	75		25 (99th percentile, 3 days per year)
Lead (Pb) mg/m^3	Annual[a]	1.0	0.75	0.50		
	24 h[b]	1.5	1.00	0.75		
Ammonia (NH_4) mg/m^3	Annual[a]	0.1	0.1	0.1		
	24 h[b]	0.4	0.4	0.4		
Carbon Monoxide (CO) mg/m^3	8 h[b]	5.0	2.0	1.0		
	1 h	10.0	4.0	2.0		
Ozone µg/m^3	8 h[b]				120	100

However, 2% of the time, it may exceed but not on two consecutive days.

[a]Annual arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at a uniform interval.

[b]24 hourly/8 hourly values should be met 98% of the time in a year.

citizens to take pertinent precautionary steps to prevent themselves from the harmful effects of such air pollutants (Monteiro et al., 2016). The AQI is a single number and is often associated with the preordained categorizations of air quality like *'good', 'moderate', 'poor' and 'severe'*.

In general context, about 80% of the global population living in urban areas experience high doses of pollutant concentrations exceeding the norms as prescribed by World Health Organization (WHO). The most affected population demographics

are the residents living in middle to low income countries wherein about 98% of such cities having a population greater than 100000 do not meet the WHO air quality guidelines. The control of urban air pollution is often beyond the capable of the citizens and needs a concerted effort from governmental and international organizations in measures to reduce the concentrations of air pollution. In such aspects, air quality monitoring in cities is an important tool in determining the existing pollutant concentrations in the city and hence its possible health effect to the residents of the city.

As observed from the WHO report that air pollution is a serious environmental health hazard in developing countries. As per the report (CAI, 2013) more than 100 million people were exposed to contaminated air exceeding the standards. Some of the salient features of the report were that majority of Latin American countries failed in meeting the criteria of particulate pollutants whereas ozone concentrations were exceeded in in cities of Santiago (Chile), Mexico City and Quito. Another important finding was that seven of the countries failed to meet WHO's recommendation on nitrogen dioxide. Major cities in Latin America like Monterrey, Mexico City, Santiago, Lima, Bogota etc all exceeded the specified pollutant concentrations as per WHO limits. In this context, several of the Latin American countries like Chile, Mexico, Brazil are already implementing strict regulations to curb the menacing effect of air pollution. Other countries like Peru, Costa Rica, panama etc are also making holistic effects to reduce the effects of air pollutants. Similarly, the air pollutant concentrations in China are also extremely severe. In this context, Air Quality Index China (AQICN) collects data of air pollutant concentrations and maps them in real time showing the air quality concentrations in those locations. It uses a six-point classification system making easy to discern the existing air quality in the chosen location (Climate and Environment, 2016).

Several reported literature exists on the use of AQI being successfully used for signifying the state of the existent ambient air quality condition. For example, in a study carried out in Athens by Kassomenos *et al.,* (1999) classified the air quality in seven different categories based on AQI determined on the monitoring data between the periods of 1983 to 1995. Other such reported literature has been presented by Longhurst (2005), Landulfo *et al.* (2007), Mayer and Kalberlah (2008), and Elshout *et al.* (2008). Several AQI studies have been carried out in Indian cities including for Delhi (Bishoi et al., 2009; Kumar and Goyal, 2009; Kumar and Goyal, 2011), Bangalore (Nagendra et al., 2007), Kanpur (Sharma et al., 2003), Mumbai (Sharma, 1999), Coimbatore (Saravanakumar et al., 2016) and Keonjhar (Dash and Dash, 2015) using different techniques in assessing and classifying the air quality.

The main aim of the work presented in the book chapter is to determine and analyze the AQI for two newly operational monitoring stations located in Dharamshala city in Himachal Pradesh utilizing the revised CPCB and an alternative methodology for a study period of two years 2016 and 2017 and compare the efficiency of both the selected methods in categorizing the existing ambient air quality.

MATERIAL AND METHODS

Site Location

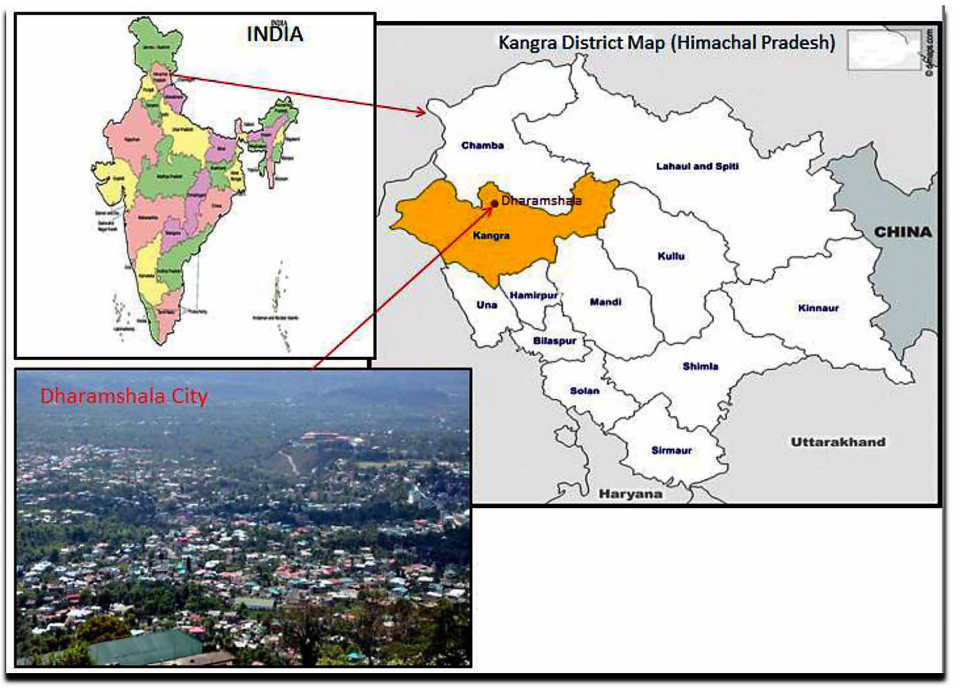
Dharamshala, one of the major cities of Himachal Pradesh lies at an elevation of 1457 m above the MSL with a population count of about 53543 as per the National Census Record of 2015. The city lies with in the latitude and longitude locations of 32.218º N to 76.320ºE covering an area of 27.6 km^2. The city can be classified as experiencing mild temperate climate (*Cwa*) as per the *Koppen climate classification.* Figure 1 shows the location of the study site.

There exist two new monitoring stations in Dharamshala namely Municipal Corporation (MC) Office (Station I) and Office Building (Station II) functioning under the National Ambient Monitoring Program (NAMP) governed by the CPCB and became operational in 2016. The monitoring data of the criteria pollutants for the study period of 2016 and 2017 were obtained from the website (http://xgn.hp.nic.in/naaqm.aspx) of Himachal Pradesh Pollution Control board (HPPCB) which is maintained in collaboration with National Ambient Air Quality Monitoring (NAAQM) of India.

Monitoring Details

The monitoring of the different pollutants at both the stations of the study location conforms to the method as prescribed by CPCB. To summarize, determination of SO_2 concentrations are carried out using the modified *West and Gaeke Method* (Ganguly and Thapa, 2016; Saravanakumar et al., 2016). The process involves passing a known volume of air in a solution of *sodium tetrachloromercurate* to form a stable compound *dichlorosulphitomercurate* which is then reacted with *formaldehyde solution*. The colour intensity of the final end product compound so formed is then determined using spectrphotometer analysis for analyzing the SO_2 concentrations.

Figure 1. Geographical location of Dharamshala City



Similarly, the pollutant NO_x is analyzed using the *modified Jacobs and Hochheiser method* (Ganguly and Thapa, 2016; Saravanakumar et al., 2016). This methodology involves passing of a fixed volume of ambient air in an initial mixture of a solution of *sodium hydroxide* and *sodium arsenite*. The resulting nitrite ion concentration is then determined on the basis of color intensity formed due to the reaction of nitrite ion with phosphoric acid, sulfanilamide, and N-(1-naphthyl)- ethylenediamine dihydrochloride (NEDA) based on spectrophotometer analysis at 540 nm

Measurement of Respirable Suspended Particulate Matter (RSPM) are carried out using Respirable Dust sampler (RDS) which functions on the principle of air suction via cyclonic connector for collection of the suspended particulate matter (>10 μm). The average flow rate to be maintained during the collection process is 1.1 m^3/min (Ganguly and Thapa, 2016). Thereafter, the collected particulate matter on a filter paper is tested in the laboratory to determine the mass of RSPM which when divided by the air volume sampled leads to the concentration of RSPM denoted in units of μg/m^3 or ppm (Saravanakumar et al., 2016).

Air Quality Index

Air Quality Index by CPCB Method

The principle of determination of AQI by the CPCB methodology is based on the USEPA technique but using distinct breakpoint indices for Indian conditions. The methodology in principle for an AQI involves the determination of sub-indices for the criteria pollutants considered and their relative agglomeration (Kumar and Goyal, 2009; Kumar and Goyal, 2011). In contrast to the USEPA methodology the breakpoint indices for criteria pollutants for Indian conditions are based on the NAAQS standards and the potential health hazards posed by the considered criteria pollutants (Nagendra et al., 2007; Kumar and Goyal, 2009; Kumar and Goyal, 2011). Table 2 summarizes the breakpoint concentration and proposed sub-indices for Indian conditions which have already been previously reported in literature (Nagendra et al., 2007; Kumar and Goyal, 2009; Kumar and Goyal, 2011)

Table 2. Proposed sub-index and breakpoint pollutant concentration for Indian-AQI (Nagendra et al., 2007)

SI. No.	Index Values	Descriptor	SO_2 (24-h avg.) (µg/m^3)	NO_2 (24-h avg.) (µg/m^3)	SPM (24-h avg.) (µg/m^3)	RSPM (24-h avg.) (µg/m^3)
1.	0–100	Good	0–80	0–80	0–200	0–100
2.	101–200	Moderate	81–367	81–180	20–260	101–150
3.	201–300	Poor	368–786	181–564	261–400	151–350
4.	301–400	Very poor	787–1572	565–1272	401–800	351–420
5.	401–500	Severe	>1572	>1272	>800	>420

[a]Good: Air quality is acceptable; however, for some pollutants, there may be a moderate health concern for a very small number of people.

[b]Moderate: members of sensitive groups may experience health effects.

[c]Poor: Members of sensitive groups may experience more serious health effects.

[d]Very Poor: Triggers health alert, everyone may experience more serious health effects.

[e]Severe: Triggers health warnings of emergency conditions

Table 3. Air quality categories based on air quality index as per alternative methodology guidelines

SI. No.	Index Values	Descriptor
1.	0–50	Good
2.	51–100	Moderate
3.	101–150	Unhealthy for sensitive groups
4.	151–200	Unhealthy
5.	≥ 200	Hazardous

(Rao and Rao, 1986)

The formulae used for determination of AQI using the USEPA method is as follows

$$I_p = \left[\frac{\left(I_{HI} - I_{LO}\right)}{\left(BP_{HI} - BP_{LO}\right)}\right]\left(C_p - BP_{LO}\right) + I_{LO} \quad (1)$$

Where,

I_p = the AQI for pollutant p
C_p = the actual ambient concentration of pollutant p
BP_{HI} = the breakpoint given in Table 2 that is greater than or equal to C_p
BP_{LO} = the breakpoint given in Table 2 that is less than or equal to C_p
I_{HI} = the sub-index value corresponding to BP_{HI}
I_{LO} = the sub-index value corresponding to BP_{HI}

The highest value amongst the AQI determined for the criteria pollutant is considered to be the overall AQI (Nagendra et al., 2007; Kumar and Goyal, 2009; Kumar and Goyal, 2011).

2.3.2 Air Quality Index by alternative method (AQI_{am})

The determination of AQI using the alternative methodology uses the following expression (Dash and Dash, 2015; Saravanakumar et al., 2016).

$$I_p = \frac{1}{4}\left(\frac{I_{PM10}}{S_{PM10}} + \frac{I_{PM2.5}}{S_{PM2.5}} + \frac{I_{SO2}}{S_{SO2}} + \frac{I_{NO2}}{S_{NO2}}\right) \times 100 \quad (2)$$

Where I_p is the overall AQI values. I_{values} is the actual ambient concentrations of pollutants PM_{10}, $PM_{2.5}$, SO_2 and NO_2. S_{values} is the NAAQS of pollutants PM_{10}, $PM_{2.5}$, SO_2 and NO_2 as per CPCB.

The interrelationship between the AQI determined on the alternative methodology (AQI_{am}) and the particular the air quality divisions associated with using this methodology has been summarized in Table 3 (Rao and Rao, 1986). A higher value of AQI indicates higher impacts of air pollutants on human health.

RESULTS AND DISCUSSION

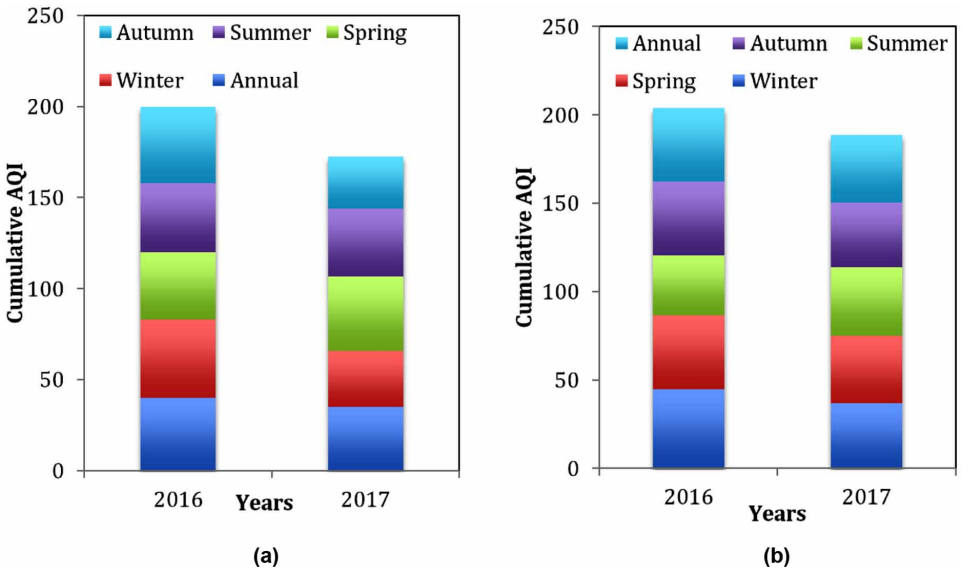
AQI Values Using CPCB Methodology

The AQI for the two monitoring stations at the study locations have been determined on the basis of monitored concentrations of the important criteria pollutants for the study period of two years of 2016 and 2017. In this context, the determined AQI parameter for both the monitoring stations using the revised CPCB methodology has been presented in Table 4. It is observed from Table 4 that the annual average AQI for monitoring station I is 40 and 35 and for monitoring station II is 42 and 38 respectively for the study years of 2016 and 2017 and hence classified as *'good'* category as per the breakpoint indices value shown in Table 2. In fact, for both the years, the annual AQI value was less than 50 at both the monitoring locations. The highest annual average AQI values for both the monitoring stations were reported in the year 2016. Further, averages of the AQI indicated that the air quality was '*good*' irrespective of seasonal variations at both the monitoring sites. The highest AQI was reported for winter in 2016 (AQI = 43) and spring in 2017 (AQI = 41) for monitoring station I and spring in 2016 (AQI = 42) and summer in 2017 (AQI = 39) for monitoring station II. The annual and seasonal variation of the AQI for the modified CPCB methodology is shown in Figure 2. The most critical pollutant for determining the AQI values at both the monitoring locations was RSPM and is identical to earlier reported literature for Delhi (Kumar and Goyal, 2011; NAMP 2016) and Bangalore (Nagendra et al., 2007). This also acts a corollary to earlier studies based on exceedence analysis wherein it has been reported that exceedence factors for NO_x and SO_2 are often low whereas it may vary from high to low for RSPM (Ganguly and Thapa, 2016). The results of the AQI analysis determined using this technique show compliance with results from other Tier-II cities in India wherein the air quality is generally classified as *good to moderate* levels. The air quality for metropolitan and Tier-I cities are generally classified as *poor to severe* levels.

Table 4. Air quality index values for both monitoring stations for the study period (2016-2017) using CPCB methodology; note that the symbol ("-" refer to the unavailability of the data)

Months	Monitoring Station –I		Monitoring Station –II	
	2016	2017	2016	2017
January	42	39	48	41
February	40	38	51	39
March	32	36	37	34
April	32	37	39	39
May	47	49	49	41
June	49	48	36	42
July	37	-	39	-
August	28	27	27	36
September	38	28	35	37
October	36	26	36	36
November	52	31	54	-
December	52	31	55	37
Annual Average	40	35	42	38

Figure 2. Annual and seasonal variation of AQI over the study period: (a) Monitoring Station –I; (b) Monitoring Station -II



AQI Values Using Alternative Methodology

Similar to the above analysis carried out for determining the AQI using the CPCB methodology, the AQI_{am} for both the monitoring locations of the study area for the study period was determined using the alternative methodology. The results for the AQI_{am} analysis using this technique has been summarized in Table 5. It is observed from Table 5 that the annual averaged AQI values were determined to be 14 and 12 for monitoring station I and 13 and 12 for monitoring station II for the year 2016 and 2017 respectively. A comparative analysis of these AQI values with the air quality descriptors as shown in Table 3 shows that the air can be classified as *'good'* category. The highest annual averages of AQI_{am} for both the monitoring locations were observed for year 2016 similar to the AQI using the modified CPCB methodology. Further, seasonal variations of the AQI_{am} showed that the highest value was observed for winter (AQI_{am} = 14) in 2016 and summer for 2017 (AQI_{am} = 13). The AQI determined using the alternative method uses the limit values of all the criteria pollutants to determine the AQI_{am} = 14. It can be mentioned from the

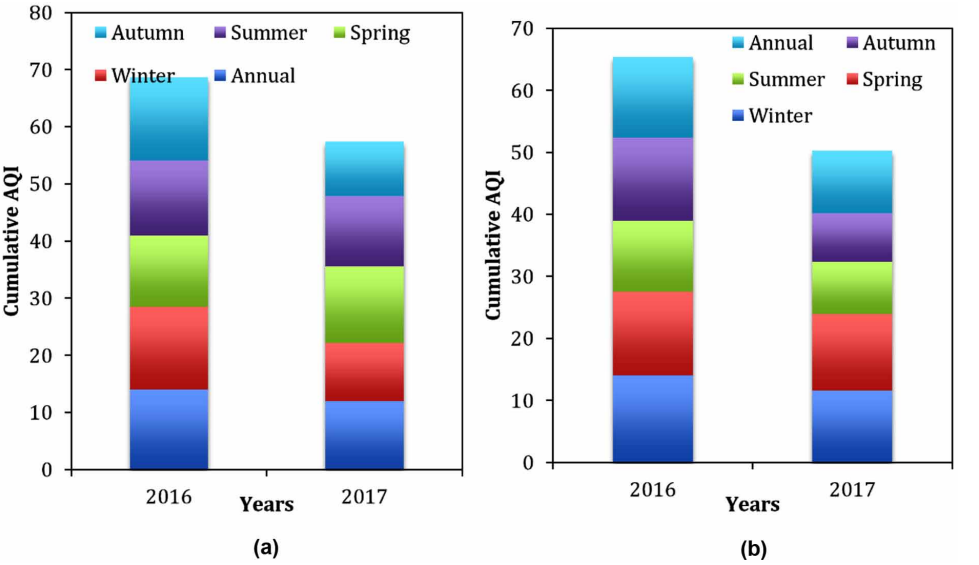
Table 5. Air quality index values for both monitoring stations for the study period (2016-2017) using alternative methodology; note that the symbol ("-"refer to the unavailability of the data)

Months	Monitoring Station –I		Monitoring Station –II	
	2016	2017	2016	2017
January	14	13	15	13
February	14	13	15	12
March	11	12	12	11
April	11	12	12	13
May	15	16	16	13
June	16	15	12	13
July	13	-	13	-
August	11	9	10	12
September	13	9	12	12
October	13	9	12	12
November	17	10	16	-
December	17	10	17	12
Annual Average	14	12	13	12

methodology that there is no single definitive pollutant, yet the maximal fraction for determination of AQI_{am} is from RSPM. The annual and seasonal variation of the AQI_{am} is shown in Figure 3.

Comparative analysis of AQI calculated on the alternative methodology with other Tier-II cities in India showed that the AQI_{am} was *maxim* near industrial sources and *less* in residential areas in a study conducted in Coimbatore (Saravanakumar et al., 2016). In a similar study carried out in Biliepeda (Dash and Dash, 2015) the AQI_{am} was classified as *moderate* with all major sources having relative contributions to the existing air quality. In contrast to the earlier reported literature, wherein the studies were conducted in cities having both industrial and vehicular sources affecting the air quality the monitoring stations in Dharamshala are primarily hilly location having almost no industries and comparatively less traffic flow (even though it is a tourist destination). Further, the meteorological conditions at the study location vary from previously reported literature sources which also have an influence on the existing air quality in Dharamshala.

Figure 3. Annual and seasonal variation of AQI over the study period at station I: (a) Monitoring Station –I ; (b) Monitoring Station -II



Comparison of AQI Values Using CPCB and Alternative Methodology

A detailed analysis of the methodology of determination of AQI using both the methods show that while the CPCB methodology uses the highest value of AQI determined from the concentrations of the criteria pollutants based on the sub-indices for Indian conditions the alternative methodology determines the AQI_{am} based on the contribution of all the relevant criteria pollutants. This can be noted from both *Equations 1 and 2*. In this context, the different methods have distinct and separate AQI categorizations as observed from Tables 2 and 3. Further, a review of literature shows that while the revised CPCB methodology for determination of AQI is more prevalent for metropolitan and Tier-I cities in India (Delhi, Bangalore) (Nagendra et al., 2007; Kumar and Goyal, 2011), the alternative methodology has been well used for predicting AQI for Tier-II and lower category of cities of India (Dash and Dash, 2015; Saravanakumar et al., 2016).

The output results of the comparison of the AQI values of both the monitoring locations in the study area shows that while the annual average AQI using the CPCB methodology is higher for monitoring site –II (AQI = 42 for 2016; AQI = 38 for 2017) the AQI based on the alternative methodology (AQI_{am} = 14 for 2016; AQI_{am} = 12 for 2017) is higher for monitoring site –I. Detailed information regarding the location of the actual monitoring stations are presently a little skewed but can be adjudged to be set in urban locations as per the names of the monitoring sites assigned. Evaluation of annual and seasonal variations of AQI by using both the methodologies showed similar trends for both the monitoring locations for the study period. However, most importantly the AQI values obtained using both the methods were in complete accord and surmised the air quality to be of *good quality* as per their own individual air quality categorization criteria for the entire study period.

SUMMARY AND CONCLUSION

This book chapter presents the evaluation of the existing air quality in Dharamshala city using AQI methodology at both the quality monitoring stations for the study period of 2016 and 2017. Two different methodologies were utilized for determination of AQI. The modified CPCB methodology based on the USEPA method but using different break point indices relative Indian conditions calculates the AQI based on the highest value of the AQI determined for the criteria pollutants whereas the alternative methodology determines the AQI based on the relative fractions of all the considered criteria pollutants. The computed AQI for both the methods showed that

the air quality can be categorized as '*good*' irrespective of any seasonal variations. RSPM was the most significant criteria pollutant affecting the determination of AQI for both the methods. Hence, as such based on the categorizations of AQI there is no need of immediate apprehension in the context of air quality but a detailed environmental plan should be created as slight change in in the air quality can significantly affect the biodiversity of the study location. Till date, continuous monthly air quality monitoring data is available for both the sites at the study location and needs to be continued so as to develop existing baseline concentrations of criteria pollutants in Dharamshala and any significant changes in their concentrations. This is particularly important because the city has been proclaimed as the second capital of the state which could significantly increase vehicular population leading to increased pollutant concentrations. Further, it is a popular tourist spot and also being considered as smart city, regular monitoring of pollutants and computation of AQI is important to keep track of any abrupt changes in air quality in the city.

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Handbook of Multimedia Information Security: Techniques and Applications

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This handbook is organized under three major parts. The first part of this handbook deals with multimedia security for emerging applications. The chapters include basic concepts of multimedia tools and applications, biological and behavioral biometrics, effective multimedia encryption and secure watermarking techniques for emerging applications, an adaptive face identification approach for android mobile devices, and multimedia using chaotic and perceptual hashing function.
The second part of this handbook focuses on multimedia processing for various potential

applications. The chapter includes a detail survey of image processing based automated glaucoma detection techniques and role of de-noising, recent study of dictionary learning based image reconstruction techniques for analyzing the big medical data, brief introduction of quantum image processing and it applications, a segmentation-less efficient Alzheimer detection approach, object recognition, image enhancements and de-noising techniques for emerging applications, improved performance of image compression approach, and automated detection of eye related diseases using digital image processing.

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Chapter 19
3-D Shape Reconstruction Based CT Image Enhancement



Manoj Diwakar and Pardeep Kumar

19.1 Introduction

Computed Tomography has become the diagnostic tool of choice in a wide variety of situations. Computed Tomography images show organ of interest at selected levels of the body. They are the visual equivalent of bloodless slices of anatomy, with each scan being a single slice. CT examinations produce detailed organ studies by stacking individual images. To analyze CT scanned images in depth, three-dimensional (3-D) image surface reconstruction has been an important research area in computer vision. For minimizing the cost function of CT scanning and analyzing in depth, 3D image reconstruction method has a great potential to improve the image quality with noise reduction [1].

2-D image reconstruction is an effective tool for medical specialist to analysis the medical scientific organs [2], which can help to improve the medical diagnostic accuracy greatly. Three dimensional tomography improves the sensitivity of the scanner in terms of shape reconstruction in such a way that photons traverse several slices and 3D reconstructed shape are also recovered [3, 4]. Another way to deal is use projection-based techniques to improve image quality [5]. In this case problems are reduced by improving 2D projection images obtained directly from the scanning device. Projections are processed in a way to reduce the problems in the resulting 3D volume. For that, reconstruction algorithm is applied to provide corrected projections in a 3D volume with reduced problems [6]. Analytic reconstruction

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methods have traditional understanding that incomplete data reconstruction implies some type of approximation of the object to be reconstructed [7, 8].

This paper deals direct 3d surface reconstruction where shading technique is used to reconstruct the image with the help of fast marching method. These methods can be problem from image reconstruction by interpreting an image as the propagating interface to the final position [9, 10].

19.1.1 Radon Transform

CT image reconstruction is one important mathematical representation where CT images are generated via a mathematical model. This mathematical model is known as Radon transform which is only help to generate the CT images. The mathematical model of Radon transform is used to collect all the raw data from n number of angels. These raw data are collected from detectors which were absorbed via X-Ray transmission [11]. The radon transform is an integral transform whose inverse is used to reconstruct the CT images.

In Fig. 19.1, Radon transform is applied over the phantom image with 180° angels. The middle of Fig. 19.1 shows the results of radon transform which indicates the sine waves and it is impossible to understand these sine waves. Hence to understand the meaning of sine waves, inverse Radon transform is applied with same number of angels. Last of Fig. 19.1 shows the results of inverse radon transform. This is the process of CT image reconstruction.

With the help of the Dirac "function" δ, which is zero for every argument except to 0 and its integral is one, $g(0, \theta)$ is expressed as:

$$g\,(0, \theta) = \iint f\,(x, y) \cdot \delta\,(x \cos\theta + y \sin\theta)\; dxdy$$

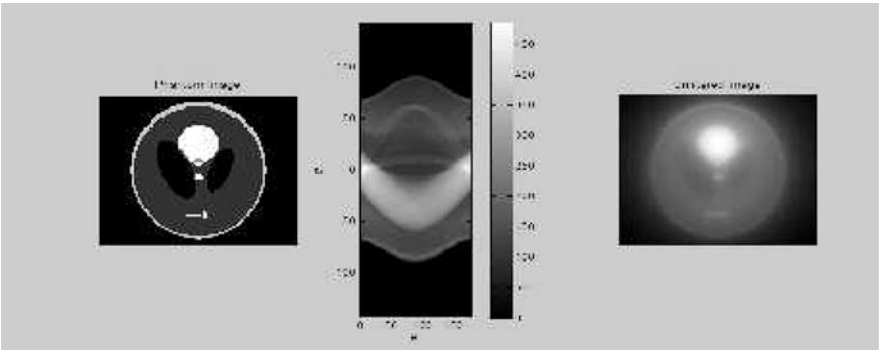

Fig. 19.1 The Radon transform computation over the phantom image: (**a**) Phantom Image, (**b**) Sinogram and, (**c**) Unfiltered reconstructed image

The inverse of Radon transform is calculated by the following equation:

$$f(x, y) = \int_{-\pi/2}^{\pi/2} \rho \cdot R_\theta (s(x, y))\ d\theta$$

19.2 Fast Marching Method

To generate the CT images, CT image reconstruction is a big tool to underhand the processing of reconstruction. Similarly Shape from Shading [12–16] is one other important tool to enhance the shape of images in terms of shape which can be applied via curve analysis. For shape from shading there are number of methods to provide the edges in terms of shape. One of major methods is Fast Marching Method which is introduced by Sethian [11]. There are various problems in CT image reconstructions such as blurring, noise, artifacts and so on, but many solutions are also provided to solve it [18–27]. The main concept of Fast Marching method is to identify the pixels and their neighborhood pixels and give a speed function to identify the curve or line [28–31].

This method is to move the curve from one pixel in a progressive manner according to the speed function while preserving the nature of the implicit function [12]. The Fast Marching method can be defined as follows:

Algorithm

- Definition:
  - Label the set of all grid points as Alive for values which has been reached and will not be changed;
  - Label the set of next grid points (6-connexity neighbors) as Trial for examined and estimate of surface grid;
  - Label the set of all other grid points as Far for which surface grid can't estimate;
- Loop:
  - Let A(i_{min}, j_{min}, k_{min}) be the Trial point with the smallest Value;
  - Move it from the Trial to the Alive set
  - For each neighbor (i, j, k) (6-connexity in 3D) of (i_{min}, j_{min}, k_{min})

    If (i, j, k) is Far, add it to the Trial set and compute T using Loop;

    If (i, j, k) is Trial, recomputed the value of T, and update it.

19.3 Results and Discussion

Synthetic phantom image has been created with the help of ellipse and geometric methods on the MATLAB as Fig. 19.2a. To get the synthetic image in the form of 2D-CT scanned data, some pre-processing methods are applied. After applying radon transform over the synthetic image, the image is filtered with the help of Ram-Lak Kernel. Ram-Lak kernel which acts as high pass filter is recommended for filtered back projection. To obtain the intensities at each pixel in the surfaces should be projected orthographically on $z = 0$ plane. The obtained shaded image of phantom image is in Fig. 19.2b. These shaded images are used as the input FMM algorithms for the possible 3D shape reconstruction. Since the images are synthetic and we have the true depth values corresponding to them, the true depth values are assigned on the minimum singular points. The minimum singular points are chosen by the visualization of image, which are basically the brightest points in the local

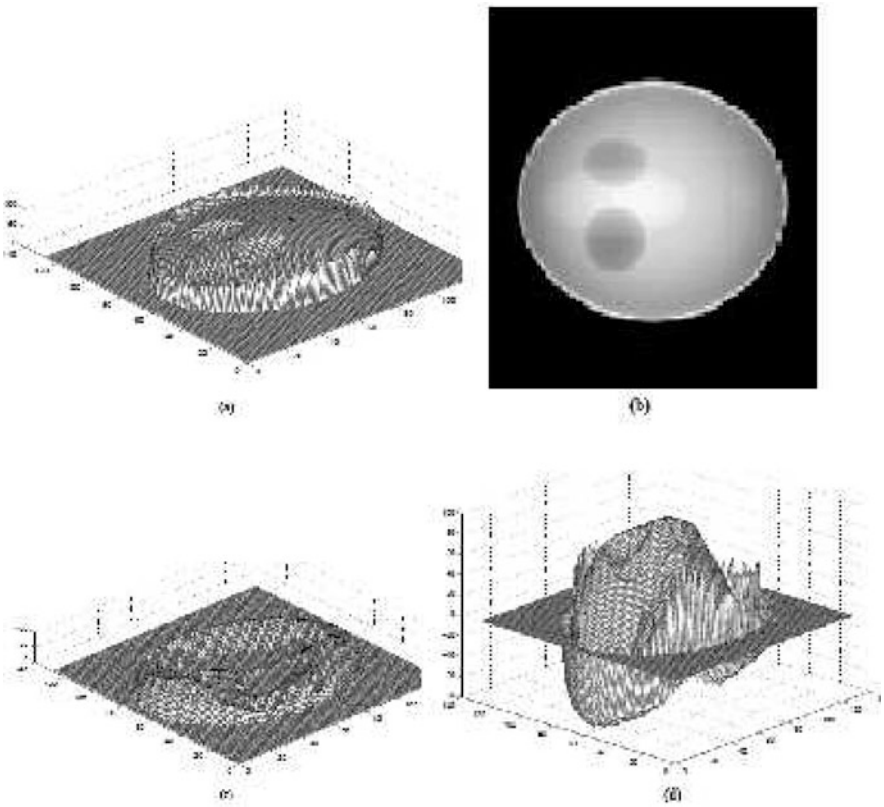

Fig. 19.2 (**a**) True 3D map from simulated image; (**b**) Simulated image; (**c**) Reconstructed 3D map; (**d**) Error map

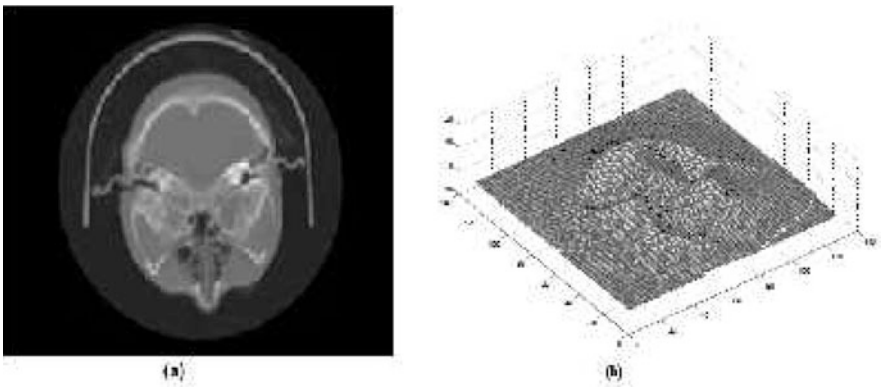

Fig. 19.3 (**a**) Real CT image; (**b**) 3D map from real image

regions of the images. The reconstructed surface is shown in Fig. 19.2c. The error maps corresponding to the synthetic image are shown in the Fig. 19.2d where, we get the value of mean error is 6.88.

We have tested the scheme on real CT scanned images. The original CT image has obtained in the format of DICOM. The size of the image is 128 × 128. We set two minimum singular points in CT scanned image. The reconstructed depth map of CT scanned image is shown in the Fig. 19.3a. The shaded image from the reconstructed depth maps is shown in Fig. 19.3b.

The algorithm for 3d shape reconstruction is coded in C++ and MATLAB is used as a tool to draw the images. The computational time for all synthetic and real images is recorded in milliseconds.

19.4 Conclusion

We have tested CT image reconstruction based on 3D fast marching method for produces significant improvements over direct analytical methods in terms of noise, and resolution. The fast marching is used to extract rough boundaries. The level set is used to fine tune the rough contour. This is because though the level set can smooth the contour, some details can also be lost. Using the level set with no fast marching presumably yields similar results, but takes much longer computation time. As the reconstruction technique remains independent from the exact form of the forward model, Fast Marching Method is applicable to any geometry and is particularly well suited to the reconstruction problem [17]. The orthographic projection and most widely used Lambertian reflectance map are used in SfS problem formulations. For the simplicity of the problem, the light source direction is considered as vertical to the image plane. In this case, Fast Marching Method

is applied and shown that it solves the problem in less memory space and less computation time. Computational time varies according to images and their sizes.

Experiments are conducted on synthetic image and real CT scanned image. The qualitative results are found to be excellent. In case of synthetic data, there constructed shapes are closely matched with the true data, computed errors are also small and in case of real data, the shaded images obtained from the reconstructed depth values are quite similar to the original images. This work can supports for clinical application by providing further control over image quality and analysis.

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Handbook of Multimedia Information Security: Techniques and Applications

Editors: Amit Kumar Singh, Anand Mohan

This Handbook covers the recent trends in multimedia in terms of security, processing and applications at the global level

Provides potential thoughts and methodology which is useful in creating new knowledge to develop/design efficient techniques/algorithms for real world multimedia applications

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About this book

This handbook is organized under three major parts. The first part of this handbook deals with multimedia security for emerging applications. The chapters include basic concepts of multimedia tools and applications, biological and behavioral biometrics, effective multimedia encryption and secure watermarking techniques for emerging applications, an adaptive face identification approach for android mobile devices, and multimedia using chaotic and perceptual hashing function.
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Chapter 24
Wavelet Packet Based CT Image Denoising Using Bilateral Method and Bayes Shrinkage Rule



Manoj Diwakar and Pardeep Kumar

24.1 Introduction

The reconstruction process of Computed tomography (CT) is a typical task to get the CT images. There are certain processes to reconstruct the CT images. X-rays are transmitted to human body; raw data is collected by detectors over the different directions, and finally radon and inverse radon transform has been performed to reconstruct the CT images. The efficiency of whole process is important task. But due to software, hardware and other transmissions and mathematical problems the noise may appears in CT images. The reason of noise appear in CT image is also depend on the X-rays transmission. If the higher amount of X-rays are transmitted over the human body organs, then the quality of CT images are good but it may not good for affect human body organs. With low amount of CT images, human body organs may safe but noise is degraded to the quality of CT images. Hence, if noise can be suppressed from low dose CT images, it will good for the society.

Various research have been already done to reduce noise from the CT images, still it is a challenging task. To suppress noise from CT images, three major techniques are categorized: Projection based denoising, Iterative based denoising and Post-processing based denoising. In projection based denoising, the CT images are filtered when CT images are reconstructed through projected X-ray beams such as filtering of sinogram using bilateral filtering over the low dose CT images [1–3]. In iterative based denoising, CT images are reconstructed using an iterative approach such as iterative CT image reconstruction using shearlet transform [4, 5]. The major

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drawback of iterative reconstruction is high cost computation. In post-processing based denoising, CT images are denoised directly after obtained CT reconstructed images through X-ray computed tomography. Various techniques have been proposed to denoised CT images using post-processing methods. In post-processing, CT images are denoised broadly in two domains: spatial and transform domain. In spatial domain, pixels are directly denoised using mathematical optimization and computation. Linear and non-linear methods in spatial domain are very popular to denosied the CT images where non-linear methods are providing good results in compare of linear methods in terms of sharp and smooth images. Non-linear filters such as bilateral and non-local mean (NLM) filters are very helpful to provide edge preserving denoised CT images. Bilateral filter [6] is a non-iterative, local filtering method which provides edge preserved smoothing data but it is dependent on kernel radius. NLM [7] filter provides denoised images in terms of sharp edges based on self-similarity approach. But due to self-similarity concept, the computation cost is high.

In transform domain, wavelet transform is used where images are decomposed into low and high frequency subbands. The noise has a tendency that it affects over the edges or detail parts in most of the cases. Thresholding is one of the popular ways to denoised the images in transform domain. Before thresholding, a threshold value is estimated which helps to denoised the images. Soft and Hard thresholding are two popular methods for thresholding. In hard thresholding, a threshold value is estimated. Below the estimated threshold value, the wavelet coefficients are set as zero and rest of the values will be same. In soft thresholding, below the estimated threshold value, the wavelet coefficients are set as zero same as hard thresholding and rest of the wavelet coefficients are modified by subtracting the estimated threshold value. Both processes are good but soft threholding provides better outcomes in most of the cases [8–10]. VISUShrink [11], SUREShrink [12] and BayesShrink [13] are the popular thresholding methods for image denoising. In most of the cases, BayesShrink provides better outcomes in compare to VISUShrink and SUREShrink [14–18]. In transform domain, wavelet transform is one powerful tools [19–22] but it also has some limitations. To overcome that, many other transforms are used such as, wavelet packet transform, dual-tree complex wavelet transform, curvelet, tetrolet, framelet and so on.

In CT images, every small detail has their own significance and may be used for diagnosis purpose. With this consideration, a method noise concept is included with bilateral filtering. In this paper wavelet packet thresholding is performed so that maximum high frequency coefficients can be collected and thresholded. The main concept of this proposed scheme is to reduce noise and preserve the edges from the noisy CT images. Rest of the paper is organized as: Sect. 24.2 gives a small description of wavelet packet transform and bilateral filter. In Sect. 24.3, a brief description of proposed method has been defined. The result analysis and comparative results are discussed in Sect. 24.4. Finally, conclusions are defined in Sect. 24.5.

24.2 Wavelet Packet Transform

Wavelet transform is one of the major tools in the area of image and signal processing. The best part of wavelet that it divides the information into low and high frequencies. Further decompositions are possible as per the size of images. The extended version of wavelet transform is wavelet packet transform. Wavelet packet gives the information into low and high frequencies. The only difference between discrete wavelet transform (DWT) and wavelet packet transform (WPT) that WPT gives higher information in compare to DWT. WPT decompose both low and high frequency components while DWT decompose only low frequency components.

24.3 Proposed Methodology

CT images are generally corrupted with additive Gaussian noise. Hence noisy CT images are obtained via simulation methods. It can be expressed as:

$$X\,(m,n) = Y\,(m,n) + \eta\,(m,n) \tag{24.1}$$

Where, $\eta(m,n)$ is a noise coefficient, $Y(m,n)$ and $X(m,n)$ are noiseless and noisy images respectively.

The proposed algorithm has been designed using wavelet packet transform (WPT). WPT is using to obtain low and high frequency components. The low frequency components are filtered using Bilateral method. Similarly, high frequency components are denoised using thresholding.

The formulation of bilateral filter [6] is given below:

$$BF\,[I]_{\mathbf{p}} = \frac{1}{K} \sum_{\mathbf{q}\in S} G_{\sigma_s}\,(\|\mathbf{p}-\mathbf{q}\|)\;\; G_{\sigma_r}\left(|I_{\mathbf{p}} - I_{\mathbf{q}}|\right) \quad I_{\mathbf{q}} \tag{24.2}$$

Where, p and q are two different pixels, K is normalization constant, σ_S and σ_r are control the behavior of bilateral filtering.

It has two filter kernels as shown in Eq. (24.2). The first kernel is used to enhance the edges and works as edge stopping function. The other kernel is works as Gaussian filter which is used for suppressing the Gaussian noise.

To denosie high frequency components, Bayes shrinkage function is used. This function is used to suppress the Gaussian noise from CT images. The method used for estimating threshold value is defined via statistical methods.

The threshold λ can be selected as:

$$\lambda = \left(\frac{\sigma_\eta^2}{\sigma_Y}\right) \tag{24.3}$$

Where the noise variance can be estimated using robust median estimation method [15] as follows:

$$\sigma_{\eta}^{2} = \left[\frac{median\ \ (|X\,(m,n)\,|)}{0.6745}\right]^{2}, \tag{24.4}$$

Where, $X(m,n) \epsilon HH_L$, L represents respective level in wavelet decomposition. The standard deviation of noise less image (σ_Y) can be estimated as:

$$\sigma_{Y}^{2} = \max\left(\sigma_{X}^{2} - \sigma_{\eta}^{2}, \quad 0\right) \tag{24.5}$$

Where, $\sigma_X^2 = \frac{1}{N}\sum_{i=1}^{N} X_i^2$, and N represent patch size of an input image.

The thresholding function can be expressed as:

$$\hat{X} := \begin{cases} 0 & if\ |X| \leq \lambda \\ \text{sign}(X) & (|X| - \lambda)\ if\ |X| > \lambda \end{cases} \tag{24.6}$$

The proposed method can be expressed with the following major steps:

Step 1: Perform wavelet packet transform on input noisy CT image to obtain low and high frequency subbands.

Step 2: Perform bilateral method on the low frequency subbands using Eq. (24.2).

Step 3: Perform thresholding over high frequency subbands using following steps:

i. Estimate noise variance using Eq. (24.4)
ii. Apply thresholding on high frequency subbands using Eq. (24.6)

Step 4: Apply inverse WPT to obtain denoised image.

24.4 Experimental Results

In the experimental result evaluation, the proposed method is performed over the various standard CT images. The size of CT images are 512 × 512 with additive Gaussian noise. Experimental evaluation are tested with five different noise level σ ∈ [10, 15, 20, 25, 30, 35]. The CT images are obtained from public source database (https://eddie.via.cornell.edu/cgibin/datac/logon.cgi) which are shown in Fig. 24.1. There are six test CT images which are recognized here as CT1, CT2, CT3, CT4, CT5 and CT6, respectively. For result analysis, the noisy CT images are obtained with different noise level. In Fig. 24.2, noisy CT images are obtained with noise level 25. To execute proposed method, values of some parameters are used such as patch size is 10 × 10, σ_S is 1.2 and σ_r is 0.13.

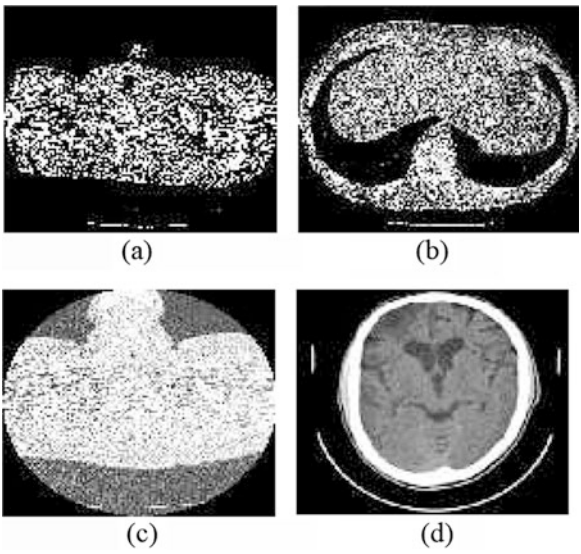

Fig. 24.1 Input test CT image dataset. (**a**) CT 1 image. (**b**) CT 2 image. (**c**) CT 3 image. (**d**) CT 4 image

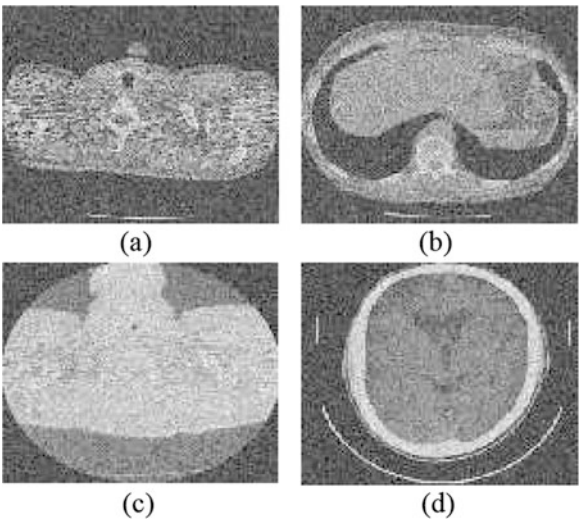

Fig. 24.2 Noisy CT image dataset ($\sigma = 25$). (**a**) CT 1 image. (**b**) CT 2 image. (**c**) CT 3 image. (**d**) CT 4 image

The existing methods for comparison are bilateral filtering [6], Surelet [23] and adaptive wavelet transform with Bayes shrinkage [13]. Figures 24.3, 24.4, 24.5 and 24.6 are showing the results of Bilateral filtering, Surelet, Wavelet based denoising using Bayes shrinkage and proposed method respectively. For comparative study and result analysis, some performance metrics are used to show the performance of methods. The performance metrics which are used, PSNR and IQI.

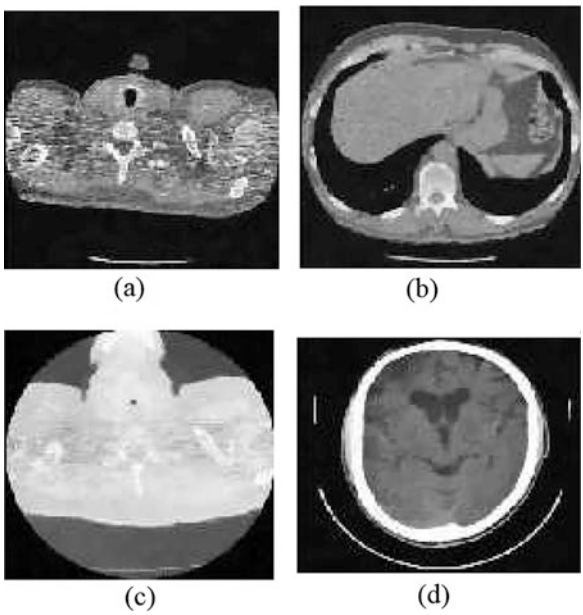

Fig. 24.3 Results of bilateral filtering. (**a**) CT 1 image. (**b**) CT 2 image. (**c**) CT 3 image. (**d**) CT 4 image

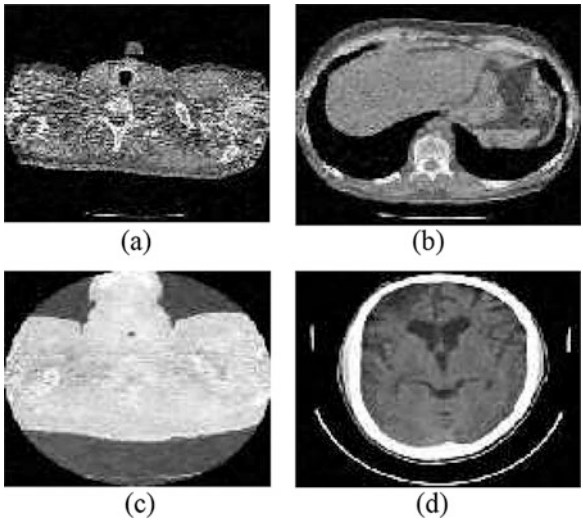

Fig. 24.4 Results of Surelet. (**a**) CT 1 image. (**b**) CT 2 image. (**c**) CT 3 image. (**d**) CT 4 image

Peak Signal-to-noise Ratio (PSNR) is one major factors to show the performance of methods. Increasing value of PSNR shows that method is good in compare to less PSNR value. The PSNR value can be measured as:

$$PSNR = 10\log_{10}\frac{255^2}{mse}\ \text{dB} \tag{24.7}$$

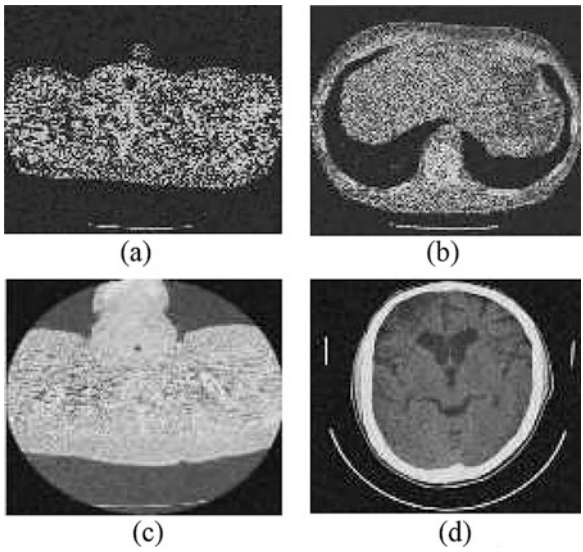

Fig. 24.5 Results of Bayes thresholding. (**a**) CT 1 image. (**b**) CT 2 image. (**c**) CT 3 image. (**d**) CT 4 image

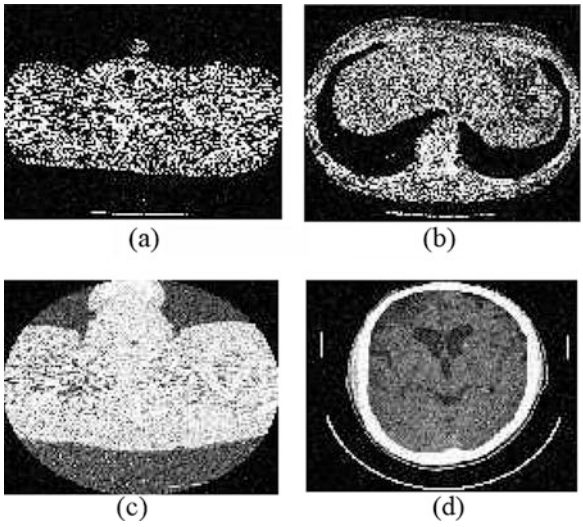

Fig. 24.6 Results of proposed scheme. (**a**) CT 1 image. (**b**) CT 2 image. (**c**) CT 3 image. (**d**) CT 4 image

Where $mse = \frac{1}{mn} \sum_{i=1}^{m} \sum_{j=1}^{n} [X(i, j) - W(i, j)]^2$

Image quality index (IQI) is other important metric which is used to show the results in terms of edge preservation. For input image (X) and denoised image (W), the IQI can be defined as:

$$IQI = \frac{4\sigma_{XW}\overline{X}\,\overline{W}}{\left(\sigma_X^2 + \sigma_W^2\right)\left[\left(\overline{X}\right)^2 + \left(\overline{W}\right)^2\right]} \tag{24.8}$$

Where, $\overline{X} = \frac{1}{N}\sum_{i=1}^{N} X_i$, $\overline{W} = \frac{1}{N}\sum_{i=1}^{N} W_i$, $\sigma_X^2 = \frac{1}{N-1}\sum_{i=1}^{N}\left(X_i - \overline{X}\right)^2$, $\sigma_W^2 = \frac{1}{N-1}\sum_{i=1}^{N}\left(W_i - \overline{W}\right)^2$ and $\sigma_{XW} = \frac{1}{N-1}\sum_{i=1}^{N}\left(X_i - \overline{X}\right)\left(W_i - \overline{W}\right)$.

The results of all existing methods and proposed method indicate that visually, the results of proposed scheme is better in terms of contrast, noise reduction and edge preservation. The values of PSNR and IQI are also indicates that most of the times the results of proposed scheme giving better outcomes.

From Table 24.1, it can be analyzed that proposed method gives minimum value of IQI for different noise level in most of the cases. Similarly, Table 24.2 also indicates that maximum PSNR value is achieved by proposed algorithm in most cases. Hence it can be concluded that proposed algorithm better results in terms noise suppression and edge preservation.

Table 24.1 IQI of denoised images

	σ	TV	Surelet	Bayes	Proposed
CT 1 image	10	0.993	0.9912	0.9924	0.9976
	15	0.9534	0.9856	0.9762	0.9865
	20	0.9312	0.9541	0.9365	0.9597
	25	0.8972	0.9165	0.9174	0.9248
	30	0.8903	0.8954	0.8832	0.8962
	35	0.8894	0.8762	0.8014	0.8747
CT 2 image	0	0.9817	0.9828	0.9751	0.9889
	15	0.9789	0.9794	0.9745	0.9831
	20	0.9421	0.9654	0.9241	0.9521
	25	0.8452	0.8684	0.8922	0.9047
	30	0.8364	0.8361	0.8632	0.8740
	35	0.8189	0.8314	0.8614	0.8694
CT 3 image	10	0.9874	0.9812	0.9914	0.9965
	15	0.9514	0.9614	0.9762	0.9893
	20	0.9423	0.9591	0.9432	0.9614
	25	0.9102	0.9241	0.9397	0.9235
	30	0.8964	0.8931	0.8942	0.9131
	35	0.8831	0.8894	0.8913	0.8941
CT 4 image	10	0.9871	0.9974	0.9954	0.9979
	15	0.9642	0.9831	0.9645	0.9846
	20	0.9409	0.9641	0.9469	0.9698
	25	0.9123	0.9352	0.9231	0.9411
	30	0.8991	0.8978	0.8945	0.9006
	35	0.8647	0.8649	0.8791	0.8771

Table 24.2 PSNR (in dB) of denoised images

	σ	TV	Surelet	Bayes	Proposed
CT 1 image	10	32.14	33.25	31.50	33.9
	15	30.95	31.45	29.96	31.44
	20	29.5	30.10	28.21	30.05
	25	27.98	29.68	28.01	29.85
	30	26.31	28.47	27.25	28.54
	35	25.26	26.19	25.31	26.88
CT 2 image	10	31.54	32.12	30.98	32.47
	15	30.87	30.64	29.42	31.05
	20	28.95	29.08	28.47	29.53
	25	28.48	28.64	27.26	28.96
	30	27.69	28.03	26.17	28.11
	35	25.83	26.96	25.34	26.97
CT 3 image	10	32.33	33.19	31.98	33.89
	15	31.29	31.25	30.67	31.87
	20	29.84	30.98	28.68	30.91
	25	27.15	29.27	28.34	29.31
	30	26.29	28.54	27.52	28.67
	35	24.36	26.65	24.64	26.73
CT 4 image	10	32.65	33.65	31.63	33.79
	15	31.35	31.24	29.26	31.35
	20	29.64	30.19	28.31	30.61
	25	27.45	29.34	28.72	29.36
	30	26.64	28.21	27.37	28.42
	35	25.39	26.94	25.61	26.61

24.5 Conclusions

CT images which are degraded with Gaussian noise are filtered with proposed method and some standard recent existing methods. The utilization of bilateral filter in proposed algorithm gives better results for providing better noise suppression and edge preservation. From results, it was observed that mostly results of proposed scheme are giving better outcomes in terms of noise suppression and edge preservation. The proposed scheme is effectively suppress the noise from CT images as well as also helpful to preserve the edges and structural details.

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An API for Development of User-Defined Scheduling Algorithms in Aneka PaaS Cloud Software: User Defined Schedulers in Aneka PaaS Cloud Software

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Abstract:

Cloud computing has been developed as one of the prominent paradigm for providing on demand resources to the end user based on signed service level agreement and pay as use model. Cloud computing provides resources using multitenant architecture where infrastructure is generated from multiple or single geographical distributed cloud datacenters. Scheduling of cloud application requests to cloud infrastructure is one of the main research area in cloud computing. Researchers have developed many scheduling applications for which they have used different simulators available in the market such as CloudSim. Performance of any scheduling algorithm will be different when applied to real time cloud environment as compared to simulation software. Aneka is one of the prominent PaaS software which allows users to develop cloud application using various programming models and underline infrastructure. In this chapter, a scheduling API is developed over the Aneka software platform which can be easily integrated with the Aneka software. Users can develop their own scheduling algorithms using this API and integrate it with Aneka software so that they can test their scheduling algorithm in real cloud environment. The proposed API provides all the required functionalities to integrate and schedule private, public or hybrid cloud with the Aneka software.

Keyword: Aneka, Cloud Computing, Scheduling API, Hybrid Cloud.

1. Introduction

Cloud computing has proved to be the most revolutionary technology of the last decade which resulted in many organizations moving toward cloud-based infrastructure [1]. From mobile applications to large data intensive applications are using cloud-based infrastructure for fulfilling their IT resource requirement. With more data generation, the need for cloud computing is increasing day by day for many emerging IT technologies such as Internet of Things and Big Data [2]. Cloud computing deployment models can be broadly classified into Public cloud, Private cloud and Hybrid cloud. Among all these models, hybrid cloud is gaining popularity with its features like infinite resources and cost benefits. Hybrid cloud utilizes public cloud resources if private cloud resources cannot complete the task with given Quality of Service (QoS) parameters. This makes hybrid cloud model a good candidate for many applications such as mobile devices, small industries, and other smart environments [3].

As cloud computing contains a colossal number of IT resources whether it is a private cloud or public cloud, it is difficult to test new algorithms for better and efficient scheduling. Many researchers use simulation tools to test and deploy different scheduling algorithms for different kind of applications in the cloud environment. A common used simulation tool is CloudSim [4] while other tools such as iFogSim [5] and IoTSim [6] are also gaining popularity for testing IoT based applications on cloud computing environments. But, results from even the most efficient simulation software always differ from actual results because many other aspects such as network, bandwidth also play an important role. Infrastructure as a Service (IaaS) provider such as Amazon EC2 [7], or Microsoft Azure [8] give access to underlying IT resources to the user. But these IaaS providers do not give rights to the end user for making any change in the scheduling policies for the application. There are many options in the market for PaaS where the end user can create individual tasks and submit them to the PaaS provider. Many PaaS providers do not provide access to underlying IT

infrastructure making it very difficult to change and test new scheduling policies [9]. Due to these constraints, research in the development of new scheduling policies is taking a big hit for real cloud computing environments.

Aneka [10] is a PaaS cloud provider developed in Microsoft .net for developing cloud computing infrastructure and applications using various programming models and available infrastructure. Aneka supports programming models such as Task, Thread and Map-Reduce while users can develop their own model. In Aneka, infrastructure can be developed using a cluster of multicore machines, private cloud and public cloud. Aneka contains inbuilt scheduling policies which are used to schedule jobs on private cloud created using multicore machines or using private cloud software such as OpenStack. Aneka provides dynamic provisioning feature which allows Aneka applications to use public cloud such as Amazon EC2 and Microsoft Azure when desired QoS cannot be achieved using the private cloud setup [11]. Aneka is one of its kind which gives the end user full freedom to develop applications in many languages and deploy it on any infrastructure available with them. It gives full access and right of underlying infrastructure to end user and well as full access to SDK for development of applications [12]. Aneka has many features but it is difficult for the end user to create their custom scheduling and provisioning policies.

In this chapter, we propose to develop an API for Aneka which allows end users to create and integrate their custom scheduling algorithms with Aneka. The user can develop their own applications in Aneka and then create a customized scheduling policy according to their application needs. Aneka also provides user with inbuilt sample applications such as Mandelbrot, Image Convolution or Blast to test their new scheduling algorithm. The proposed API bridges the gap between access to scheduling algorithms and using real cloud setup to test and create them.

The rest of the chapter has been organized as follows. Section 2 provides the introduction about the architecture of Aneka. Section 3 explains the proposed API with all classes. Section 4 provides sample codes and related discussion. Section 5 provides performance evaluation. Finally, Section 6 concludes the chapter and provides future directions.

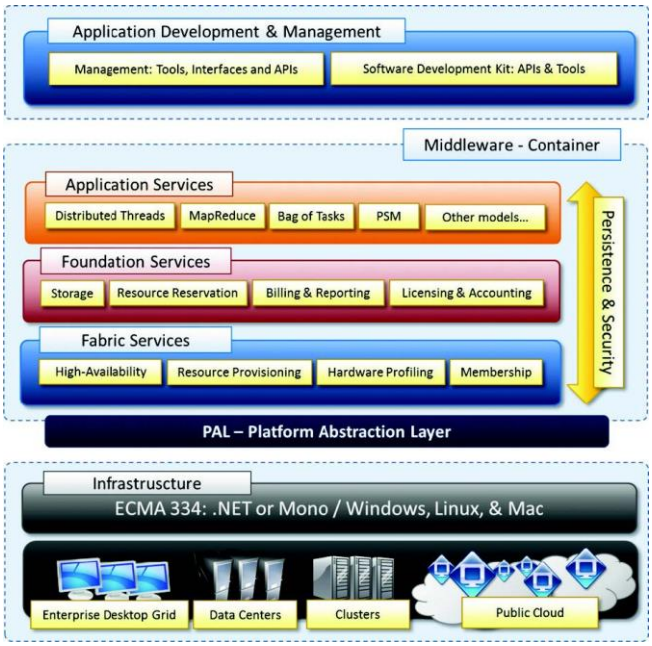

Figure 1. Overview of Aneka Architecture [11]

2. Aneka

Aneka is a PaaS cloud software that facilities the development and deployment of applications with underline support of .net framework. Figure 1 shows an overview of the architecture of Aneka. It contains three layers which are infrastructure, middleware and application development which allows the end user to change underline infrastructure and middleware to support rapid and customized development of cloud applications. The infrastructure of Aneka can be multicore machine, grid environment, cluster of machines, private cloud and public cloud. Public cloud is only required when scheduler decides that desired QoS cannot be achieved from other available resources. Middleware provides the support for programming models such as thread, task and Map-Reduce. It also provides the billing, accounting, resource reservation, hardware profiling and other

services. These service in Aneka can be plugged and unplugged as and when required from the Management console provided in the application development and management layer. Aneka also contains many components which are discussed below:

- **Aneka Master Container:** Aneka master is mainly responsible for the scheduling and monitoring of application tasks and resources in the Aneka. Aneka master also manages the billing and reporting services of all the worker nodes attached with an Aneka master. The end user's application sends the task to Aneka master which based on the availability of worker nodes further schedules these tasks. If any worker nodes fail without executing the task, master reschedules the task o another available worker node.
- **Aneka Worker Container:** Aneka worker is the component which basically deals with the execution of the tasks. It contains the executor for each type of programming models available with the Aneka. After completing any assigned task, it sends the result back to master for compiling and starts waiting for new tasks. Worker node is operating system independent, it can be run on Linux or Windows machines.
- **Aneka Daemon:** Aneka daemons are the basic services which need to be installed in all the machines before Aneka master and worker can be installed.
- **Management Studio:** Management studio is the interactive interface which end user uses to create and manage cloud environments created inside the Aneka cloud. The end user can easily add private and public cloud resources, manages all added resources, create bills, monitor added resources, add file repositories, and check current statistics of the Aneka cloud.
- **Aneka SDK:** Aneka also provides SDK for the development of applications which can be directly deployed on the Aneka cloud created using management studio. These SDKs contains programming language specific libraries and other tools.

3. Proposed API

Figure 2 shows the proposed API for Aneka cloud which acts as an independent interface which user can use to change the scheduling policies of Aneka. The user level scheduler is the new or proposed scheduler by the end user for its specific application or in general use. This user level scheduler is integrated with Aneka using the proposed scheduling API. This section explains different classes and interfaces used in the proposed API so that end user can easily write their own scheduling policies.

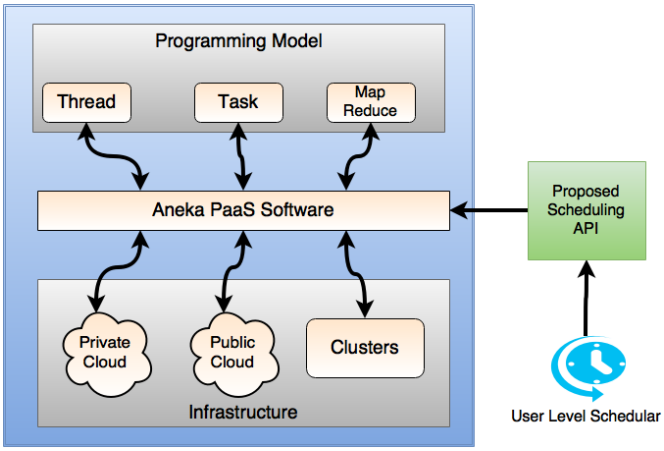

Figure 2. Framework for Scheduling API with Aneka PaaS Software

Aneka.Scheduling is the main project of proposed API which directly interacts with Aneka.Runtime project of Aneka to state which scheduling policy should be followed when any task arrives. Aneka.Runtime consults Aneka.Scheduling and based on the selected algorithm at the time of creation of Aneka master it schedules tasks on different worker nodes. Aneka.scheduling API contains six sub-projects out of which Aneka.Scheduling.Service and Aneka.Scheduling.Utils directly interacts with Aneka.Runtime project. These sub-projects are explained in details later in this chapter.

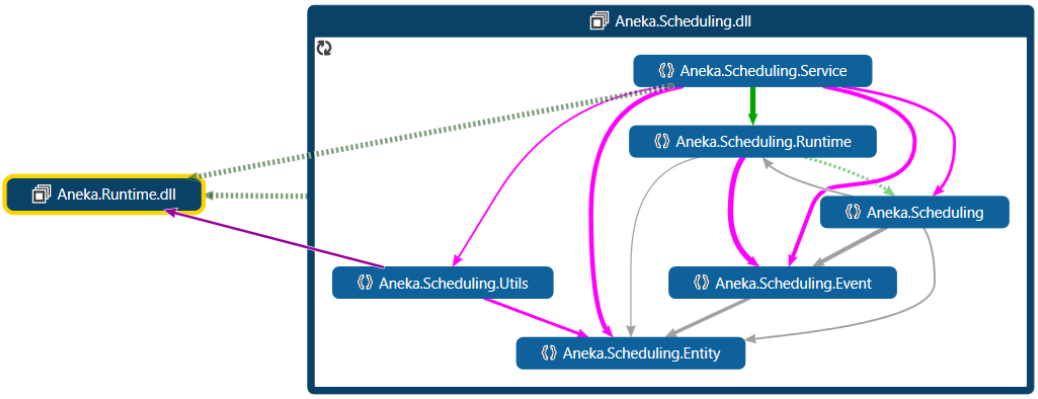

Figure 3: Code Map of proposed Aneka.Scheduling project in Aneka code

Aneka.Scheduling implements two interfaces which are ISchedulerContext and ISchedulerAlgorihtm as shown in Figure 4. Various events are associated with these interfaces which are triggered when there is a state change for the application or a task. Table 1 shows different event associated with Aneka.Scheduling.

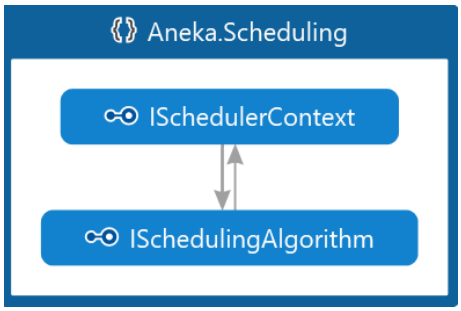

Figure 4 Interfaces implemented by Aneka.Scheduling Project

Table 1. Different Events associated with Aneka.Scheduling

S. No.	Event	Description
1.	SchedulerAlgorihtm	It selects the scheduling algorithm to use for scheduling tasks on worker nodes.
2.	ResourceDisconnected	Event when a resource is disconnected. For every task assigned to this Resource the TaskFailed event will also be fired.
3.	ResourceReconnected	Event when a resource is reconnected.
4.	ResourceProvisionProcessed	Event when a resource provisioning request is processed.
5.	ResourceProvisionRequested	Event when a resource provision request is triggered.
6.	ResourceReleaseRequested	Event when a resource release request is triggered.
7.	ResourcePoolsQueryRequested	This event is triggered when end user generates any resource pool related query. It is important event in case there are multiple pool in dynamic provisioning of Aneka cloud.
8.	TaskFinished	Event when a task is finished.
9.	TaskFailed	Event when a task is failed due the task failure. It is caused by something other than the resource disconnection
10.	TaskAborted	Event when a task is aborted due to the user action.
11.	TaskRequeued	Event when a task is requeued due the the user action

3.1 Aneka.Scheduling.Runtime

It contains two classes and one interface as shown in the code map in Figure 5. This is responsible for decision making during runtime of any scheduling algorithm such as timings, resources available, task completed etc. SchedulerContextBase class registers all context-based activity happening in the scheduler to their specific events. This class also generates the exception and records it in the logger file so that end user can analyse the errors generated.

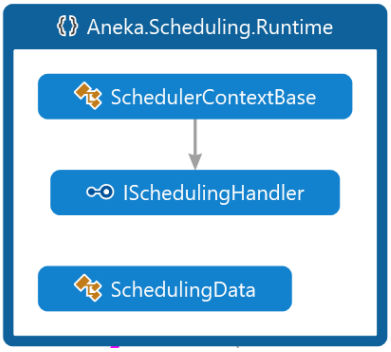

Figure 5 Classes and Interface of Aneka.Scheduling.Runtime

Major activities performed by this class are

- assign the value to the scheduling algorithm
- register the event handler for the forwarded assign work unit event from the scheduling algorithm
- hook the event handler for provision resources request
- hook the event handler for release resources request
- hook the event handler for a query for resource pools request
- register the scheduler context to the scheduling algorithm

Class SchedulingData extends the Aneka reporting data class which can capture the information about the scheduling data (mostly timing) of the specific task allocation. Various data collected by Scheduling data class are:

- **Queue Time:** A value representing the total waiting time of the task in seconds. This time is computed since the task is moved from queued to scheduled state.
- **Execution Time:** A value representing the total execution time of the task in seconds as seen by the scheduler service.
- **Task final State:** It provides the final state of the task submitted to the scheduler.

If the end user wants to add any new data point to the scheduling algorithm matrices, it can be easily added in this class. Interface ISchedulingHandler extends the IServiceNameAware interface of Aneka and provides a set of methods for the SchedulerService to specialize the activities of the scheduler. This interface allows separating all those management aspects that are common to several programming models, which reside in the SchedulerService class, from the specific aspects related to a given programming model, which reside in the component implementing this interface.

3.2 Aneka.Scheduling.Service

It contains two classes which are ScheulerService and IndependentSchedulingService as shown in code map in Figure 6. This is responsible for major scheduling responsibilities based on the selected algorithms.

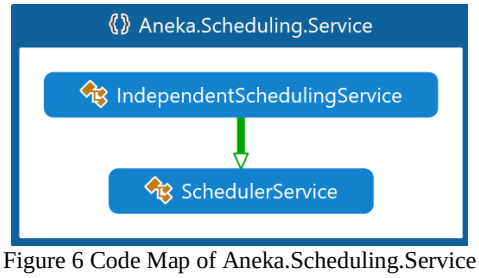

Figure 6 Code Map of Aneka.Scheduling.Service

Class SchedulerService specializes the ContextBase class of Aneka and implements the IService interface and IMembershipEventSink interface. It can be used as base application scheduler that needs to be further customized for handling the specific type of application according to the given programming model on which the application is based. The scheduled tasks directly performed by this scheduler are the interaction with the IApplicationStore interface to control the state of the

application. It provides template methods that can be implemented by inherited classes to perform the WorkUnit level scheduled tasks. The activity of this service is supported by an implementation of ISchedulingHandler interface that deals directly with the programming model related scheduledTasks at a WorkUnit level.

Class IndependentSchedulingService defines a scheduling service for scheduling independent work units. Models featuring independent work units can use and specialize this scheduler policy in this class. Various parameters used in this class are:

- List of resources is maintained in this class on which scheduling can be done.
- Reservation list is present in this class.
- Starts and stops the scheduling service. Activates the scheduling algorithm and registers the resources with it.
- Fetches the list of WorkUnit instances that are in state Queued from the application store and delegates them back to the SchedulerAlgorithm.

3.3 Aneka.Scheduling.Algorithm

It contains different algorithm currently available with Aneka, all available scheduling algorithms extends AlgorihtmBase class for their proper execution as shown in Figure 7. This also contains one NewUserDefined which end user will use to code their own scheduling policy. End users can even extend or change already existing algorithms for more optimization. Class AlgorithmBase is the implementation class for the ISchedulingAlgorithm interface. This class can be used as a template for creating specialized algorithms because it provides the basic features for integrating scheduling algorithms into the Aneka scheduling service. Different variables used in this class are listed in Table 2 and methods available with AlgorithmBase class are listed in Table 3.

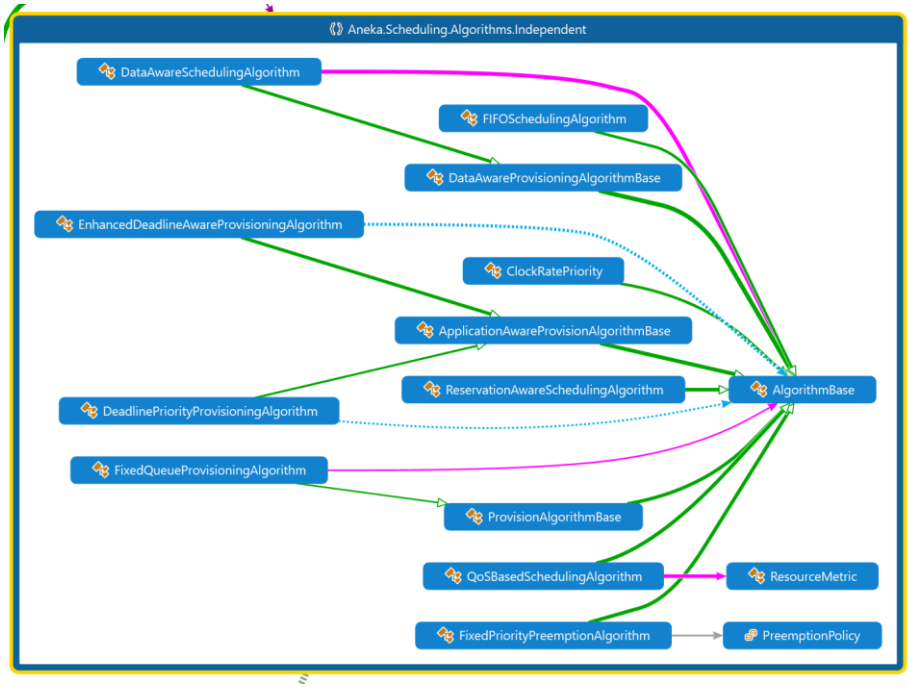

Figure 7 Code map of available scheduling algorithms

Table 2: Different variables/objects used in AlgorithmBase class

S. No.	Variable/Objects	Parent Class	Description
1.	rescheduledJobTimer	IDictionary	Dictionary mapping the each job reservationId to the timer used to reschedule them.
2.	bKeepRunning	N.A.	While this variable is true the scheduling loop will bKeep running.
3.	canSchedule	ManualResetEvent	Used to block the scheduling thread while there are no scheduledTasks or free resources.
4.	scheduler	ISchedulerContext	Holds a reference to the context that the scheduler is interacting with.
5.	SupportsProvisioning	N.A.	Whether the algorithm support dynamic provisioning or not

6.	canFireEvent	AutoResetEvent	Used to block the event thread while there are no events to fire.

Table 3: Methods Available in AlgorithmBase Class

S. No.	Method Name	Description
1.	Start	Start the scheduling loop for assigned tasks.
2.	Stop	Stop the scheduling thread.
3.	Schedule	This method is called repeatedly by the AlgorithBase class for making scheduling decisions.
4.	AddTasks	Used to add new task to the scheduling queue.
5.	GetNextTask	Used to get next task to schedule from the queue.
6.	TaskFailed	Method is called when any task fails. Reschedule policy is checked in this method for the failed task.
7.	TaskAborted	Method is called when user abort the assigned task.
8.	TaskFinished	This is called when task is finished successfully and should be reported to the user its output values.
9.	TaskRequeued	This method requeued the task if it is failed or aborted.
10.	SetScheduler	This method hooks up the event handler for events fired with the desired scheduler.
11.	StartScheduleTask	Start the process to schedule a given task to a given resource.
12.	AddFreeResource	This method will be called when a resource has a task removed and it is not free.
13.	HaveFreeResources	Return the value if there are free resource available that can be used.
14.	RemoveFreeResource	Will be called when adding a task to the resource fills the slot of that resource. Can be called if resource get disconnected.
15.	ResourceReconnected	Hooks the event when resource get reconnected and also updates the list of available resources.
16.	ResourceDisconnected	Called when the resource get disconnected and updates the list of available resources.

Let's take an example of FIFO strategy which is already implemented in the proposed API. It extends the AlgorithmBase class and provides an implementation of the First-In First-Out scheduling strategy. In this algorithm, the tasks are scheduled in their order of arrival. The Schedule function is changed in this implementation which checks that there is a task in the queue and a resource is also free. If both these conditions are true, then it schedules the first task in the queue to the first resource in the resource list. Similarly, other algorithms are proposed in the API and these algorithms are self-explained.

3.4 Aneka.Scheduling.Event

It provides all the events associated with the scheduling policies of Aneka. Proposed API provides the flexibility to end user to use already available events or create their own specific event. These events help scheduling policy designer to achieve desired performance and usability. These events are related to different components of Aneka which are listed in Table 4.

Table 4. Different type of events created in Aneka.Scheduling.Event

S. No.	**Event Type**	**Description**
1.	Task Events	These events are related to tasks such as task finished, task aborted etc.
2.	Scheduling Events	These events are related to scheduling such as algorithm selected etc.
4.	Resource Pool Query Events	These events are related adding, selecting and deleting specific resource pools.
5.	Resource Events	These events are related to resource addition, deletion and selection.

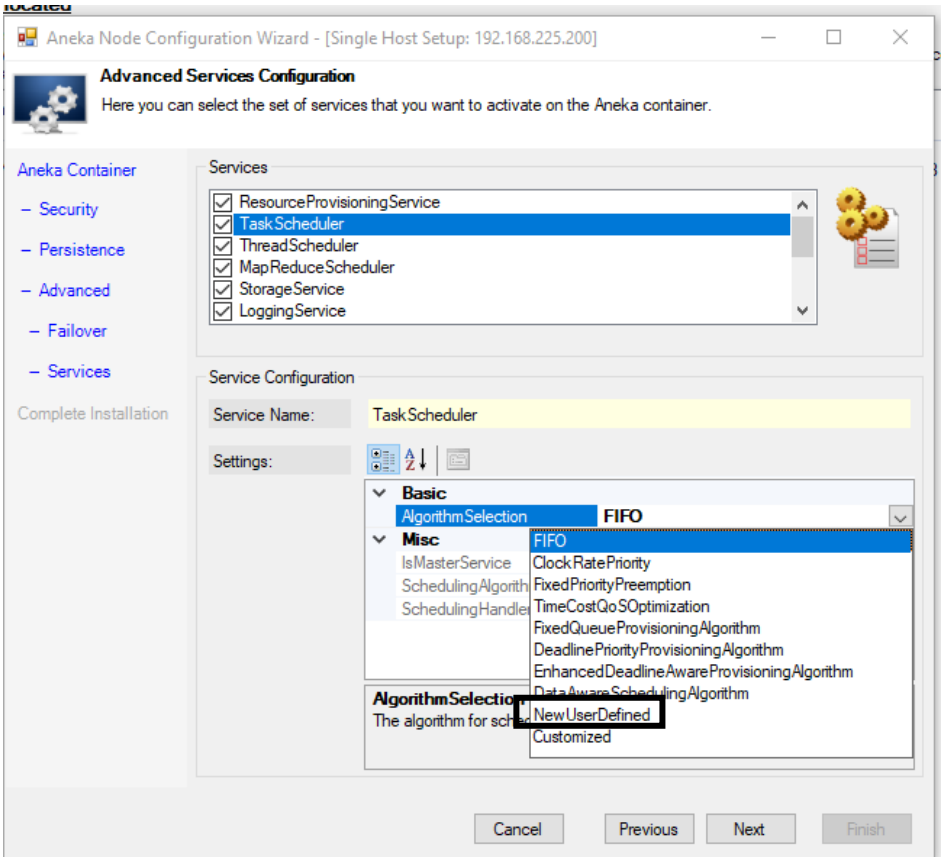

Figure 8 Interface in Management Studio to Select NewUserDefined Scheduling Algorithm

3.5 Selection of NewUserDefined from Management Studio

In this section step by step method to integrate the newly proposed scheduling policy is discussed. End user has to write new scheduling algorithm in NewUserDefined class of Aneka.Scheduling.Algorihtm. When Aneka master is being installed NewUserDefined should be chosen as shown in Figure 8. After this all the application running on Aneka if use dynamic provisioning will follow the scheduling policy desired in the proposed scheduling algorithm.

4. Developing New Scheduling Algorithms

Scheduling algorithms in Aneka define the logic with which tasks are allocated to resources from Aneka runtime. Developing new scheduling involves writing the code for the new algorithm and plug it into the existing scheduling services with minimal knowledge of the internals of the Aneka runtime. As we stated earlier this can be done by implementing methods of two interfaces — namely ISchedulerContext and ISchedulingAlgorithm — that represent the interface with the Aneka runtime and the scheduling algorithm respectively. These interfaces and bases classes are part of the Aneka.Scheduling library.

```
using Aneka.Provisioning;
using Aneka.Scheduling.Entity;
using Aneka.Scheduling.Event;

namespace Aneka.Scheduling
{
   public interface ISchedulerContext
   {
        bool SupportsProvisioning { get; }

        event EventHandler<SchedulingEventArgs> AssignTask;

        event EventHandler<ProvisionResourcesArgs> ProvisionResources;
```

```
        event EventHandler<ReleaseResourcesArgs> ReleaseResources;

        void Start();

        void Stop();

        void AddTasks(params Task[] tasks);

        void AddResources(params Resource[] resources);

        void SetScheduler(ISchedulerContext scheduler);
    }
}
```

Figure 9 *ISchedulingAlgorithm* interface

Figure 9 shows the ISchedulingAlgorithm interface that each scheduling algorithm has to implement. The algorithm provides a feedback to the Aneka runtime about its scheduling decisions through the events exposed by the interface. SupportsProvisioning is a boolean value that is set to true if the algorithm supports dynamic provisioning. AssignTask is trigred whenever a task is allocated to a resource. and ReleaseResources are events which are triggered when the scheduling algorithm issues a request for additional resources and reguest release of a provisioned resource, respectively. Start and Stop methods are called when the scheduling begins and ends. To add new tasks and new resources AddTasks and AddResources methods are called respectively. The algorithm works with the Aneka runtime and interfaces by means of the ISchedulerContext interface which is set in the SetScheduler method. Figure 10 shows ISchedulerContext interface.

```
using Aneka.Provisioning;
using Aneka.Scheduling.Entity;
using Aneka.Scheduling.Event;
using Aneka.Scheduling.Runtime;

namespace Aneka.Scheduling
{
    public interface ISchedulerContext
    {
        ISchedulingAlgorithm SchedulerAlgorithm { get; set; }

        ISchedulingHandler SchedulingHandler { get; set; }

        event EventHandler<ResourceEventArgs> ResourceDisconnected;

        event EventHandler<ResourceEventArgs> ResourceReConnected;

        event EventHandler<ProvisionEventArgs> ResourceProvisionProcessed;

        event EventHandler<ProvisionResourcesArgs> ResourceProvisionRequested;

        event EventHandler<ReleaseResourcesArgs> ResourceReleaseRequested;


        event EventHandler<TaskEventArgs> TaskFinished;

        event EventHandler<TaskEventArgs> TaskFailed;

        event EventHandler<TaskEventArgs> TaskAborted;

        event EventHandler<TaskEventArgs> TaskRequeued;
    }
}
```

Figure 9 *ISchedulingContext* interface

Only a subset of events and properties are of interest for the scheduling algorithm.

- *ResourceDisconnected* and *ResourceReconnected*: notify the scheduling algorithm that a resource has disconnected or reconnected from a temporary disconnection.
- *TaskAborted*, *TaskFinished*, *TaskFailed*, and *TaskRequeued*: notify the scheduling algorithm of the status of the tasks.
- *ResourceProvisionProcessed*: is the only event from dynamic provisioning infrastructure that is of interest for the scheduling algorithm. This event provides information about the outcome of a resource provisioning request made earlier by the scheduling algorithm.

4.1 Example 1: FIFO Scheduling Algorithm

As stated earlier. *AlgorithmBase* implements the *ISchedulingAlgorithm* interface and can be used as a template for creating specialized algorithms. Figure 11 provides *FIFOSchedulingAlgorithm* Class body to show by simply overriding a few methods of the *AlgorithmBase* Class First-In First-Out scheduling strategy can be implemented where the tasks are scheduled in their order of arrival.

```
using Aneka.Scheduling.Entity;
using Aneka.Scheduling.Event;
using Aneka;

namespace Aneka.Scheduling.Algorithms.Independent
{
public class FIFOSchedulingAlgorithm : AlgorithmBase
    {
     private List<Resource> _freeList = new List<Resource>();
     protected override bool HaveFreeResources()
        {
            return _freeList.Count > 0;
        }
     protected override void AddFreeResource(Resource r)
        {
            lock (this.synchLock)
            {
                int track = DebugUtil.EnterLock();
                if (r.IsConnected && r.FreeSlots > 0)
                {
                   _freeList.Remove(r);
                   _freeList.Add(r);
                }

                DebugUtil.ExitLock(track);
            }
        }
     protected override void RemoveFreeResource(Resource r)
        {
            lock (this.synchLock)
            {
                int track = DebugUtil.EnterLock();
                _freeList.Remove(r);

                DebugUtil.ExitLock(track);
            }
        }
     protected override void Schedule()
        {
            lock (this.synchLock)
            {
                int track = DebugUtil.EnterLock();

                if (_freeList.Count > 0 && TasksInQueue > 0)
                {
                   StartScheduleTask(_freeList.AsReadOnly(),GetNextTask());
                }
                else
                {
```

```
                    canSchedule.Reset();
                }

                DebugUtil.ExitLock(track);
            }
        }
    }
}
```

Figure 11 *FIFOSchedulingAlgorithm Class*

_freeList maintains the list of the currently available resources for scheduling tasks. *HaveFreeResources()* method returns a Boolean value indicating whether there are free resources that can be used. *AddFreeResource* is called when a resource has a task removed. Since the recourse might be already on the free list, we remove it first and we add it again to avoid duplicates. *RemoveFreeResource* is called when adding a task to a resource fills all the slots or will be called for other reasons e.g., a disconnected resource. *Schedule()* starts the scheduling algorithm. If there is a task in the queue and a free resource in the *_freeList* it calls the *StartScheduleTask* method by passing *_freeList* and the next task in the queue. Otherwise, it resets the *canSchedule* to block the scheduling thread until the task can be scheduled again by any other resource.

4.2 Example 2: Deadline Priority Provisioning Algorithm

A new scheduling algorithm can be designed in a way that supports dynamic provisioning of virtual resources by leveraging the resource provisioning service. These are all defined in the namespace *Aneka.Scheduling.Algorithm.Independent*, which can be found in the Aneka library. *ProvisioningAlgorithmBase* is this class provides an abstract base class for all dynamic provisioning algorithms. The algorithm provides a basic management of the provisioning request that has been issued. *ApplicationAwareProvisioningAlgorithm* is specialized for the scheduling a collection of tasks as a whole in order to ensure that some specific QoS parameters that are defined for the application are met. Developers can design their new scheduling algorithms and new strategies for triggering resource provisioning by extending one of these two classes or specializing the previous two algorithms.

For example, Figure 12 shows *DeadlinePriorityProvisioningAlgorithm* that extends *ApplicationAwareProvisionAlgorithmBase* class and leverages dynamic provisioning in order to schedule the execution of the tasks within the expected deadline. If the local resources are not enough to execute all the tasks in time, a request for additional resources is issued. The class overrides two main methods of the base class called *ShrinkRequired* and *GrowRequired* to request release or adding of resources from the provisioner respectively. Both methods use the private method called ExceedResourceCapacity to set a Boolean indicator called required.

```
namespace Aneka.Scheduling.Algorithms.Independent
{
    public class DeadlinePriorityProvisioningAlgorithm : ApplicationAwareProvisionAlgorithmBase
    {
        protected override bool ShrinkRequired(Aneka.Scheduling.Entity.Task task, QoS qos)
        {
            bool required = false;
            if (qos != null)
            {
                int currentResources = this.GetResourceCount(task.ApplicationId);
                if (qos.WorkRemaining<currentResources || qos.WorkCompleted==qos.TotalWork)
                {
                       required = true;
                }
                else
                {
                    required = this.ExceedResourceCapacity(qos, task.ApplicationId, false) == false &&
currentResources > 1;
                }
            }
            return required;
        }
        protected override bool GrowRequired(Aneka.Scheduling.Entity.Task task, QoS qos)
        {
            bool required = false;
            string applicationId = task.ApplicationId;
            if (qos != null)
            {
```

```
                required = this.ExceedResourceCapacity(qos, applicationId, true);
            }
            return required;
        }
}
```

Figure 12 *DeadlinePriorityProvisioningAlgorithm Class*

The *ExceedResourceCapacity* method checks whether the current allocation for the application is compliant with the requirements set for the corresponding application. A Boolean value *toGrow* indicates whether we need to check for additional resources to add when it is *true* or resources to release when it is *false*. *taskRemaining* keeps the total number of remaining tasks that must be executed. *taskResourceRatio* is then calculated based on the ratio of the number of remaining tasks to the number of current resources. Finally based on the indicative values of *AverageTaskExecutionTime* in the *requiredTime* is calculated and is compared to *timeRemaining* which indicates the time remaining to the deadline. *bRequired* value is then set accordingly to true when the required time is larger than the remaining time.

```
private bool ExceedResourceCapacity(QoS qos, string applicationId, bool toGrow)
        {
            bool bRequired = false;
            int currentResources = this.GetResourceCount(applicationId);
            if (currentResources > 0)
            {
                int taskRemaining = 0;
                if (toGrow == true)
                {
                    taskRemaining = qos.TotalWork - qos.ScheduledTasks;
                }
                else
                {
                    taskRemaining = qos.TotalWork - qos.WorkCompleted;
                }
                int taskResourceRatio = taskRemaining / currentResources;
                TimeSpan avgExecutionTimeForTask = qos.AverageTaskExecutionTime;
                TimeSpan timeRemaining = qos.TimeRemaining;
                double requiredTime = avgExecutionTimeForTask.TotalSeconds * taskResourceRatio;
                if (requiredTime > timeRemaining.TotalSeconds)
                {
                    bRequired = true;
                }
            }
            else
            {
                bRequired = true;
            }
            return bRequired;
        }
```

Figure 12 *ExceedResourceCapacity* method

5. Performance Evaluation

For the sake of performance evaluation, we built a small-scale experimental testbed and tested our previously proposed resource provisioning and scheduling algorithm called Data-aware [12]. We use our proposed API all to integrate Data-aware scheduling algorithm. For more details on the Data-aware algorithm and workload setup, please look at our paper in [12]. The testbed is a hybrid cloud environment constituting of two desktop machines (one master and one slave) residing at The University of Melbourne and dynamic resources provisioned from Microsoft Azure. Configurations of resources used in the experiment are shown in Table 5. Public cloud resources are dynamically provisioned from Microsoft Azure cloud when local resources are not able to meet application deadlines.

Table 5: Configuration of machines used in the experiments.

Machine	Type	CPU	Cores	Memory	OS
Master	Intel Core i7-4790	3.60 GHz	8	16GB	Windows 7
Worker	Intel Core i7-2600	3.40 GHz	8	8GB	Windows 7
Azure Instances	Standard DS1	2.4 GHz	1	3.5GB	Windows Server 2012

As an application, a Bag-of-Tasks for measuring a walkability index is used [12]. A walkability index is used to assess how walkable a given neighborhood is based on factors such as road

connectivity, gross dwelling density and the land use mix in the area. In our experiments, we use the walkability application to provide walkability indexes for 220 different neighborhoods in the city of Melbourne. The walkability application suits the purpose of our experiments since it is data-intensive and it can be broken into independent tasks, each computing a walkability index for a neighborhood. The test application contains 55 tasks, each calculating walkability indexes for four different neighborhoods of Melbourne city.

5.1 Experimental Results

We submit the walkability application to Aneka for execution with different deadlines, showing how the proposed algorithm behaves. All experiments are repeated for the other Aneka inbuilt scheduling algorithms, called *Default* and *Enhanced*. The Default scheduling algorithm makes an estimation of the expected completion time of the application with currently available resources, and if the expected completion time is later than the deadline defined in the Quality of Service parameters of the application, it requests extra resources from the public cloud to complete the application within given deadlines. The Enhanced algorithm is designed to utilize Amazon EC2 Spot Instance resources with an average higher deployment time but lower budget than the Default algorithm.

The execution time of the application without setting a deadline and only using private (local) resources takes 45.4 minutes. Figure 12 shows the results of the application execution under different deadlines. As shown by Figure 12, scheduling algorithms meet the deadline in all scenarios except in 3 cases, highlighted by "x" in the figure. Default and Enhanced algorithms violate the deadline constraint when the deadline is set to 35 minutes. The Default algorithm also misses the deadline when it is set to 40 minutes. The key reason is that these algorithms rely on only a single variable for measuring average runtime of tasks to allocate dynamic resources without considering data transfer time.

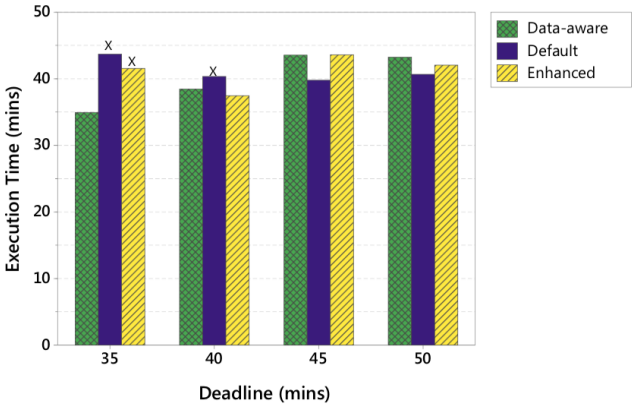

Figure 12 Execution time for Default, Enhanced, and Data-aware algorithms considering different application deadlines. The X symbol shows a violated deadline.

Experimental results demonstrate that the we can integrate new scheduling algorithm to Aneka Software using the proposed API. The results also show that the plugged-in scheduling algorithm works with qualitatively similar performance as the inbuilt scheduling algorithms and even outperforms them in some cases in terms of meeting deadline constraints.

6. Conclusion and Future Work

Aneka is one of the prominent PaaS cloud software available in the market which allows you to change and manage the underline infrastructure as well as write applications in any programming model. Aneka has many features the research community well demands the customization of Aneka scheduling algorithm for dynamic provisioning. In this chapter, an API is proposed which provides all necessary libraries to develop new Aneka scheduling algorithm. The new algorithm created from this API can be easily integrated with Aneka interface using Management Studio. The proposed API will help cloud computing researchers to develop their application in a real cloud and test them with their custom scheduling algorithm.

As part of the future work, we will focus on the creation of graphical user interface for addition of new scheduling APIs. This interactive interface will feature the designing of scheduling algorithms for new paradigms such as Internet of Things (IoT) and Fog Computing. The future work will also consist of development of APIs which are compatible with creation of multi-level scheduling

policies such as from IoT to Fog layer to Cloud computing layer. Using multi-layer scheduling policies users can design scheduling policies for latency sensitive applications running in Fog computing environments.

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Advances in Intelligent Systems and Computing 939

Ajith Abraham
Niketa Gandhi
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Innovations in Bio-Inspired Computing and Applications

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Preface

Welcome to the Proceedings of the ninth International Conference on Innovations in Bio-Inspired Computing and Applications (IBICA 2018) and seventh World Congress on Information and Communication Technologies (WICT 2018). Conferences are held at Toc H Institute of Science and Technology (TIST) during December 17–19, 2018. Last year, IBICA 2017 was held in Marrakech, Morocco, and WICT 2017 was held in New Delhi, India.

The aim of IBICA is to provide a platform for world research leaders and practitioners, to discuss the full spectrum of current theoretical developments, emerging technologies, and innovative applications of bio-inspired computing. Bio-inspired computing is currently one of the most exciting research areas, and it is continuously demonstrating exceptional strength in solving complex real-life problems. WICT 2018 provides an opportunity for the researchers from academia and industry to meet and discuss the latest solutions, scientific results, and methods in the usage and applications of ICT in the real world. Innovations in ICT allow us to transmit information quickly and widely, propelling the growth of new urban communities, linking distant places and diverse areas of endeavor in productive new ways, which a decade ago was unimaginable. Thus, the theme of this World Congress is "Innovating ICT For Social Revolutions."

IBICA–WICT 2018 brings together researchers, engineers, developers, and practitioners from academia and industry working in all interdisciplinary areas of intelligent systems, nature-inspired computing, big data analytics, real-world applications and to exchange and cross-fertilize their ideas. The themes of the contributions and scientific sessions range from theories to applications, reflecting a wide spectrum of the coverage of intelligent systems and computational intelligence areas. IBICA 2018 received submissions from 10 countries, and each paper was reviewed by at least five reviewers in a standard peer-review process. Based on the recommendation by five independent referees, finally 25 papers were accepted for the conference (acceptance rate of 37%). WICT 2018 received submissions from 12 countries, and each paper was reviewed by at least five reviewers in a standard peer-review process. Based on the recommendation by five independent referees, finally 25 papers were accepted for the conference (acceptance rate of 35%).

Many people have collaborated and worked hard to produce the successful IBICA–WICT 2018 conference. First, we would like to thank all the authors for submitting their papers to the conference, for their presentations and discussions during the conference. Our thanks go to program committee members and reviewers, who carried out the most difficult work by carefully evaluating the submitted papers. Our special thanks to Oscar Castillo, Tijuana Institute of Technology, Tijuana, Mexico; Florin Popentiu Vladicescu, University Politehnica of Bucharest, Romania; and Sheng-Lung Peng, National Dong Hwa University, Taiwan, for the exciting plenary talks. We express our sincere thanks to the session chairs and organizing committee chairs for helping us to formulate a rich technical program.

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Transfusion of Extended Vigenere Table and ASCII Conversion for Encryption Contrivance

Sakshi[1], Prateek Thakral[2(✉)], Karan Goyal[1], Tarun Kumar[1], and Deepak Garg[1]

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Abstract. In the field of cryptography, to make cryptosystem more secure an evaluation of modulus operations on integral values followed by ASCII value generation on plain text characters have been deeply explored in this research paper. On the basis of this an extended algorithm has been proposed. In this, the Encryption technique consists of an extended combination of Vigenere and Caesar cipher which is the main key feature of this algorithm and then decryption of text along with ASCII algorithm and substitution methodology has been done. The Algorithm is initiated on the basis of inspection of various research papers, furthermore, reviews have been made for proving this system more reliable. In the proposed algorithm modified Vigenere table and ASCII values are taken into consideration for decreasing the steps to reduce complexity and making a more secure way of cryptography.

Keywords: Computer security · ASCII value · Cryptography · Cryptology · Multiplicative cipher · Random key · Symmetric key

1 Introduction

Network security comprises various strategy and application that are taken to avoid and check unintended access, alteration, misuse, or refusal of a network and other network resources that are accessible [1]. With each passing year, the security dangers confronting computer systems have turned out to be all the more, in fact, modern, better sorted out and harder to recognize. A great part of the data imparted every day must be kept private. Data, for example, monetary reports, worker information and therapeutic records should be conveyed in a way that guarantees secrecy and honesty [2]. The issue of unsecured correspondence is exacerbated by the way that quite a bit of this data is sent over people in general Internet and might be handled by outsiders, as in email or texting Presently, cryptography is recognized as a part of computer science as well as of science and mathematics, and is connected closely with, computer security, information concept, and engineering. Encryption simply means to change the message, also known as plaintext, to make it unreadable to any user who is not an authorized user [2]. In other words, we can say the whole procedure of encryption is to discover a protected

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mechanism by means of which just the valid or the authorized user has the access to the message sent by the sender. Cryptography is termed as "Hidden Secrets" and is mainly deals with encrypting the data [3]. It is useful for inspecting those conventions, which are related to various perspectives in information security, for instance, verifying data, ordering of data, non-dissent and data uprightness. The authorization secures and sustains the interest of both the parties i.e. the person who is sending message as well the authorized receiver [4].

There are various security aspects for a cryptographic technique including Authentication, Confidentiality, Integrity, and Non-Repudiation [5]. Authentication is only a procedure of demonstrating one's personality. Furthermore, if privacy or secrecy is taken into the picture it is tied in with confirming that no one else can read the information except for the intended user. To confirm that the received message has not been altered at all from its original content, is keeping up the Integrity. Non-Repudiation describes a system that shows that message or information received is from a valid user [6].

2 Related Work

The current work done in this field can be analyzed in this section briefly by experiencing the proposed model and various algorithm proposed by the different authors.

Mathur [7] proposed an algorithm that performs modulus operation on the plain text message and the secret key by using ASCII based conversion mechanism. The minimum value of both is stored in separate arrays. A binary conversion of the minimum key value is performed and right shifting is done. The shifted encrypted key is added to the minimum value of plain text characters and the final cipher text is produced. Saraswat et al. [8] proposed an algorithm that brings the new version for the vigenere table having the 26 alphabets (A–Z) as well as the 10 numeric digits (0–9). The alphanumeric cross-section of the rows and columns of the table provides the intersection text on which advance version of Caesar cipher is performed to get the final cipher text. Krishna [9] proposed a new algorithm that is totally different from symmetric, asymmetric or hashing function. The algorithm changes the input plain text into small sized packets of constant length and then stored in a binary matrix. The binary matrix has the 8 bit equivalent of every plain text characters' ASCII value. It uses rotational mathematical method and conversion of radix on the text repeatedly. The encrypted text is rotated by the cyclic function. The final cipher text is in the form of unprintable characters below ASCII value 32.

Bhargava et al. [10] proposed a new algorithm that incorporates the features of transposition and substitution cipher mechanism. It uses Multiplicative cipher techniques and Rail fence cipher techniques. In multiplicative cipher technique a secret key is selected such that taking its product with any other character would give another changed character for every plain text character. The final cipher text is a sequence of special characters that is formed by performing the algorithm on plain text. Gupta et al. [11] proposed a symmetric key encryption algorithm that takes plain text and two different keys. A modified Vigenere table is used that consists characters from ASCII table and values ranging from 33–126. An intersection text is produced by plain text

and key 1 from the table. The Intersection text is then added with second key using modified Caesar cipher and modulo 26 arithmetic. It gives the final cipher text.

3 Proposed Algorithm

The algorithm that is being proposed here comes with the fusion of ASCII conversion and mathematical modification concept. Since the ASCII values are valid values for the numbers, characters, and other special symbols. The proposed algorithm will be coming up with the fulfillment of the shortcomings of the existing work and it will efficiently apply the ASCII values to produce the cipher text [12].

If we examine the ASCII table, we can draw conclusion that ASCII values from 33–126 depict the numeric values, alphabetical characters and special characters that are mostly used in day to day conversation while typing. These 94 characters are the printable characters that are available on every keyboard. In this algorithm the sender begins with the plain text message and a randomly generated key of length equivalent to the plain text.

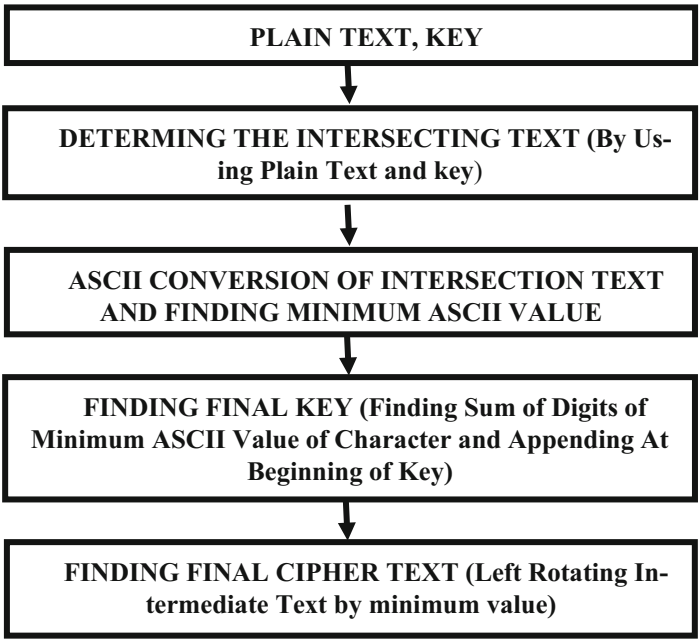

Fig. 1. Flowchart for the processing of the proposed algorithm

The entire operation can be understood by having gone through the proposed algorithm sequentially. The proposed algorithm can be viewed by the Fig. 1.

3.1 Step 1: Determining the Intersecting Text

This part is mainly affected by using the Vigenere table and is further extended to include the numeric values and the special characters. The below Fig. 1 presents the vigenere cipher table. The Vigenere cipher table contains only alphabets both in horizontal and vertical axis. The horizontal axis represents the plain text and the vertical axis represents the key. The intersection of these axis values i.e. the plain text character value and key character value gives the cipher text. The form of ordering used in the vigenere table will be used for ordering the characters for the table in the proposed algorithm (Fig. 2).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
B	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A
C	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B
D	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C
E	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D
F	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E
G	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F
H	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G
I	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H
J	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I
K	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J
L	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K
M	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L
N	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M
O	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N
P	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Q	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
R	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
S	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
T	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
U	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
V	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
W	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
X	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Y	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Z	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y

Fig. 2. Vigenere table

Similar to this vigenere table, a new and extended table i.e. the extended version of previous Table is designed that not only contains the alphabetical characters but also the numeric and special characters. For Table 1 the horizontal axis depicts the plain text and the vertical axis depicts the key. The Table 1 is a matrix of 94 rows and columns for which the records start with the character whose value start with the ASCII value 33 with character "!" and it moves on till character whose ASCII value is 126 with character "~" in both the horizontal and vertical axis. This table consist of all 94 printable characters that contains all the capital letters (A–Z), small letters (a–z), numeric values (0–9) and remaining are the special printable characters. The following Table 1 i.e. the extended vigenere table will be used for the proposed algorithm.

The determination of the intersection text can be understood by the next example. Let us take the plain text that needs to be sent be "ABC12#" and the key be "SA4$#*". Now we will see how Intersecting Text is calculated.

Table 1. The extended vigenere table

	!	“	#	$	%	&	‘	(	)	*	And up to ~
!	!	“	#	$	%	&	‘	(	)	*	
“	“	#	$	%	&	‘	(	)	*	+	
#	#	$	%	&	‘	(	)	*	+	,	
$	$	%	&	‘	(	)	*	+	,	-	
%	%	&	‘	(	)	*	+	,	-	.	
&	&	‘	(	)	*	+	,	-	.	/	
‘	‘	(	)	*	+	,	-	.	/	0	
(	(	)	*	+	,	-	.	/	0	1	
)	)	*	+	,	-	.	/	0	1	2	
*	*	+	,	-	.	/	0	1	2	3	
+	+	,	-	.	/	0	1	2	3	4	
,	,	-	.	/	0	1	2	3	4	5	
-	-	.	/	0	1	2	3	4	5	6	
.	.	/	0	1	2	3	4	5	6	7	
/	/	0	1	2	3	4	5	6	7	8	
0	0	1	2	3	4	5	6	7	8	9	
1	1	2	3	4	5	6	7	8	9	:	
2	2	3	4	5	6	7	8	9	:	;	
Up to till ~											

We can calculate Intersecting Text from table by finding the entry which is cross section point of plaint text character and key characters. Below gives the table showing the calculation of intersection text (Table 2).

Table 2. Working of proposed algorithm

Plain text	A	B	C	1	$	#
Key	S	A	4	$	#	*
Intersection text	S	B	V	4	&	,

Intersection text can also be calculated by using the mathematical formula. The formula for calculation intersection text is:

$$\text{I.T} = (\text{PT} - 33) + \text{K} \tag{1}$$

Where I.T = ASCII value of Intersection Text, PT = ASCII value of Plain Text, K = ASCII value of Key.

$$\begin{array}{l} \text{IF (I.T} > 126) \text{ THEN} \\ \{ \\ \text{I.T} = \text{I.T} - 94; \\ \\ \} \end{array} \tag{2}$$

This technique is applied so that the ASCII value of intersecting text is between the ranges of 33–126.

3.2 Step 2: Finding Minimum Value from the Intersection Text

In this step the ASCII values of the characters of the Intersection text are stored in an array and then sorted in ascending order. Now the smallest value among them is taken into consideration and stored in a separate variable (Table 3).

Table 3. Finding the minimum value from intersection text and sorting

Intersection text	S	B	V	4	&	,
ASCII value	115	98	86	52	38	44
Sorted ASCII values	38	44	52	86	98	115

Minimum (ASCII_VALUES) = 38, Store it in MIN. MIN = 38

Adding the digits of MIN recursively up to a single digit and store it in variable SUM.

SUM = 2.

3.3 Step 3: Final Cipher Text Determination

This step goes with determination of final cipher text. The ASCII values of the Intersection text are circularly sifted by the value of SUM (Table 4).

Table 4. Circular shifting

Intersection text	S	B	V	4	&	,
ASCII value	115	98	86	52	38	44
Circularly shifted ASCII values	86	52	38	44	115	98
Intermediate text	V	4	&	,	S	B

CIPHER TEXT: V4&,sb

The intermediate text obtained by the circular shift is the ultimate cipher text. Hence,

Plain Text	ABC1$#
Key	SA4$#*
Cipher Text	V4&,sb

4 Encryption and Decryption Algorithm

Encryption:
Input: Plain Text, Secret key. **Output**: Cipher Text

1. Begin: Read the Plain Text.
2. Generate a random Key equal to the length of Plain Text.
3. Determine the Intersecting text(I.T) – each character
4. Check the modified extended Vigenere table or
5. Calculate using formula
    a. I.T=Plain Input Text - 33+key
    b. If (I.T > 126)
    c. Then I.T = I.T - 94;
6. Take rotate= Smallest ASCII value from all characters of the Intersection Text.
    a. If (Rotate >9)
    b. Then Rotate=sum of all digits of Rotate.
7. Left Circular Shift the characters of Intersection text by the value of Rotate.
8. Append the value of rotate at the beginning of Intersection Text = Intermediate Text.
9. Final CIPHER TEXT = Intermediate Text.
10. End

Decryption:

1. Begin: Take the cipher Text.
2. Extract the rotate value from beginning of cipher text.
3. Right Circular Shift the characters of the Cipher Text by the value of rotate.
4. Find the Final Intersection Text (FIT)
    a) FIT = Cipher Text +33 – key
    b) If (FIT > = 126)
    c) Then FIT = FIT -94;
    d) If (FIT < = 33)
    e) Then FIT = FIT+94;
5. Convert the Final Intersection Text To Plain Text.
6. End

The implementation of the above algorithm can be in any language of our choice. A sample output screen of the encryption and decryption is given below (Fig. 3).

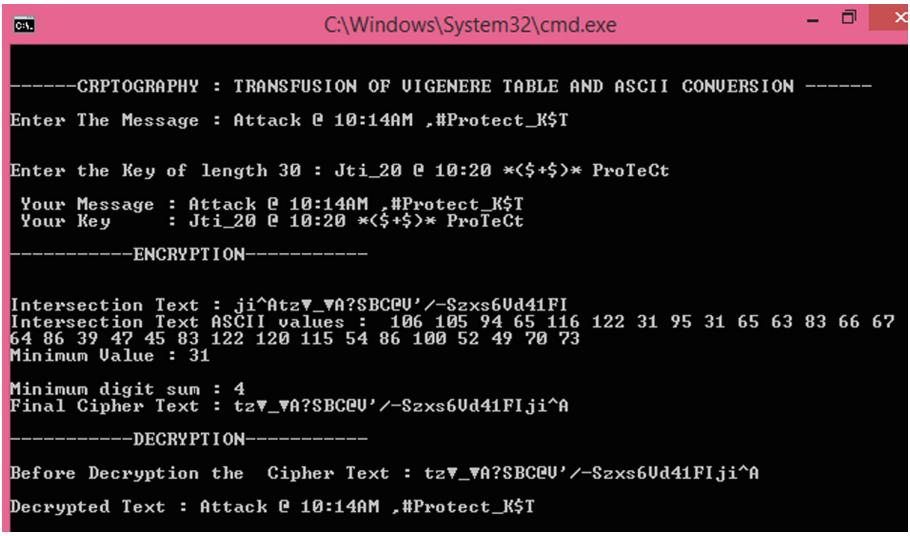

Fig. 3. Complete execution of the proposed algorithm

5 Comparative Analysis

While comparing the various existing and proposed algorithm till now, it has been found that the proposed algorithm is greatly secured in context of, uniqueness, security and it is more efficient for every printable characters of the plain text message. The encrypted text [13] produced by this algorithm takes very less execution time which is very high in the other existing papers.

The algorithm of Saraswat takes into consideration of only alphabetical and numeric characters whereas the proposed model works for every type of characters alphanumeric and special characters. This provides a range of security for the data. The algorithm execution time of Mathur increases with the length of character exponentially, whereas in the presented algorithm the execution time never exceeds the size of the smallest ASCII value in the intersection text. The work of Gupta works efficiently for all types of characters but the number of steps taken in the encryption is high and complex, the presented algorithm makes the encryption simpler and secure. Here is a comparison between the existing algorithm and proposed algorithm based on their execution time (in milliseconds) and size of the plain text and it can be referred from the graph that the proposed algorithm works far better than the existing algorithm (Fig. 4).

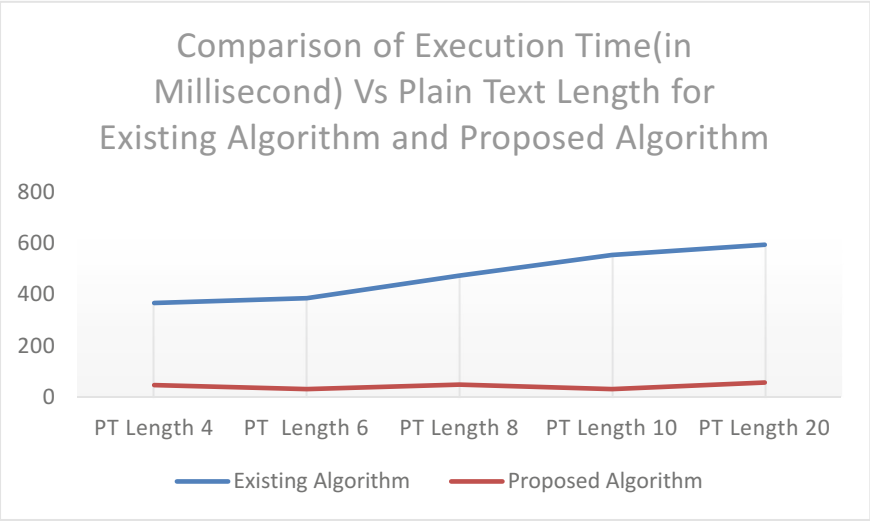

Fig. 4. Comparison graph of execution time (in Millisecond) vs plain text length for existing algorithm and proposed algorithm

6 Conclusion

In this research paper, we have introduced a more efficient and secure mechanism for the encryption of the plaint text. The algorithm addresses the major issue of security and privacy at the transmission phase of the data. The plain text throughout the process remains encrypted until the intended user provides the valid encryption key. From the previous section of the algorithm, we conclude that this new technique is robust and provides high level of security. The algorithm uses 4 steps to perform the encryption making it more secure. The range of characters that have been provided for encryption makes it tougher for cryptanalysis. Even the brute force attack will also take a large amount of time for decryption. The range of possibilities i.e. the 94 characters makes it tough to correctly reach to the plain text.

Even there are some limitations with the current system as the length of key and plain text must be same. The key security is also an issue. It's a belief that, this technique is a notable initiative towards the securing the data over network transmission. For future work our target would be to take a whole text file and then decrypt it with less time. Also to come up with more participation for data security of the cloud server such that we can secure the data storage over there.

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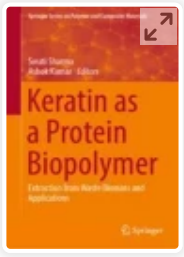

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About this book

This book provides information about the sources, structure, and properties of keratin as well as its applications. The extraction from different biomass sources (e.g. feathers, hairs, nails, horn, hoof, and claws) as well as the characterization methods of these extracted materials are explained. The development of bioproducts from keratins is challenging and limited since they are neither soluble in polar solvents nor in non-polar solvents. Therefore, the utilization of different microorganisms for the degradation of keratin is also discussed.

The main aim of this book is to highlight the unique

features of keratin and to update readers with the possible prospects to develop various value-added products from keratins. The book is highly interesting to researchers working in industry and academia on bioproducts, tissue engineering, biocomposites, biofilm, and biofibers.

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Keywords

Keratin **Extraction from waste biomass**

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Biofilms **Biofibers**

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Chapter 2
Keratin Production and Its Applications: Current and Future Perspective



Anshuman Shah, Shaily Tyagi, Ram Naresh Bharagava, Dalel Belhaj, Ashok Kumar, Gaurav Saxena, Ganesh Dattatraya Saratale and Sikandar I. Mulla

Abstract Keratin is a global class of biological material, which represents a group of cysteine-rich filament-forming proteins. They serve as a shielding layer for the epidermal appendages like nails, claws, beak, hair, wool, horns, and feathers. These proteins are further subdivided into two different class based on their secondary structure: α-keratin and β-keratin. Keratin is insoluble in hot or cold water; this unique property helps to prevent their digestion by proteolytic enzymes. Additionally, their complex hierarchical-like filament-matrix structure at nanoscale and the polypeptide chains create a robust wall for protection against heat stress,

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pathogen invasions (particularly through skin), mechanical damage, etc. In this review, we are trying to attempt a linear focus in the direction of structure, function, extraction of keratin, and its industrial applications.

Keywords Keratin · Keratin structure · Keratin production · Keratin application

1 Introduction

Natural elements like carbon, nitrogen, oxygen, sulfate, and phosphorous and also some proteins produced by bacteria including green fluorescent protein, etc., have superabundance impact on living system, and most of them are beneficially using in life science and molecular engineering. Virtually, all the biological materials are robustly consisting of biopolymers and some minerals. Such combination represents excellent properties and functionalities in many biomolecules (Wang et al. 2016a). In the early 1800s, there was no specific name of protein and was considered in the category of "albuminoids". Around 1849, one novel word "keratin" was appeared in the literatures that represent different properties and attract the scientist's attention for understanding the novel behavior of this hygroscopic protein. Keratin belongs to a very diverse family of fibrous protein. Keratinous material like horns, wools, nails, feathers, and hooves are the global class of biological co-products, which represent a group of cysteine-rich filament-forming proteins. Moreover, keratins are the protein that forms a shielding layer for the epidermal appendages and thereby imparting an important role in protection. The spacious arrangement of disulfide overpass significantly influences the keratin properties, in particular broad chemical and mechanical resistance. Keratin is insoluble in hot or cold water; this unique property helps to prevent their digestion with proteolytic enzymes such as pepsin, papain or trypsin (Bohacz 2017; Staron et al. 2011; Tesfaye et al. 2017).

Epithelial cells of cytoplasm are the richest compartment for keratinous structural protein, in which they were assembled into a network of 10–12 nm wide intermediate filament (Kim and Coulombe 2007). In human genome, almost 54 conserved genes encode keratin protein and these genes are further subdivided into type A and type B subgroupings of intermediate filament (IF)-encoding genes (Table 1) (Schweizer et al. 2006). There are 28 classes of type A and 26 classes of type B genes and each type of gene encode for a single polypeptide chain. Type A proteins are smaller and more acidic while type B protein is larger and more alkali than type A family (Schweizer et al. 2006). Type A and type B proteins interact together and form a heterodimer that promotes polymerization of keratin (Steinert et al. 1976; Fuchs and Cleveland 1998; Kim and Coulombe 2007). The arrangement of keratin is mediated by type A as well as type B genes and thus maintains the integrity of epithelial cell lines, but, on the other hand, their improper arrangement and misfolding may lead to severe epithelial disease such as epidermolysis bullosa

Table 1 Subgrouping of IF-encoding genes

Protein family	Size (kDa)	Pi
Type A	40–64	~4.7–6.1
Type B	52–70	~5.4–8.4

simplex (Coulombe and Lee 2012). In this review article, we briefly discuss the structure, function, source, and industrial application of keratin, and finally few important priorities as conclusion.

2 Structure and Classification of Keratin

Keratin is a global class of biological material, which represents a group of cysteine-rich filament-forming proteins. Keratin is the second most essential and abundant biopolymer that confronts in animals (Sharma and Gupta 2016; Sharma et al. 2016, 2017a, b, c, 2018). They serve as a shielding layer for the epidermal appendages like nails, claws, beak, hair, wool, horns, and feathers (Shavandi et al. 2017a, b). Their complex hierarchical structure like filament-matrix composition at nanolevel and polypeptide chains creates a robust wall for protection against heat stress, pathogen invasions (particularly through skin), mechanical damage, etc. (Kadir et al. 2017).

Keratins and keratinous materials are subdivided into two different classes of secondary structures of protein: alpha (α)-keratin and beta (β)-keratin (Shavandi et al. 2017b). On the basis of X-ray diffraction pattern, these proteins can also be classified as α-pattern of keratin, β-pattern of keratin, amorphous, and feather pattern of keratin (Fraser et al. 1972; Astbury and Woods 1934; Fraser and Parry 2011). The amorphous pattern elucidates the amorphous matrix component in α-keratinous tissue (Staron et al. 2011), while the feather pattern shows similarity to β-pattern (Fraser et al. 1972).

2.1 α- and β-Keratins

Keratin is made up of long polymerized chain of amino acids, and molecular weight of keratin in feather is about 10,500 Da (Staron et al. 2011). These α-helix and β-plated sheet structures arise due to the continuous folding of the backbone of the polypeptide chain due to hydrogen bonding between carboxyl and amino groups of the peptide chain. The structural configuration of α- and β-keratins is represented in Fig. 1 along with 3D structure of keratin protein.

In α-helical structure, polypeptide chain forms a hydrogen bond with the maximum possibilities of their interaction between carbonyl group of one amino acid and amino group of another amino acid. The diameter of α-helix structure is 7–10 nm, and their molecular mass is in the range of 40–68 kDa (Wang et al. 2016b, Alibardil et al.

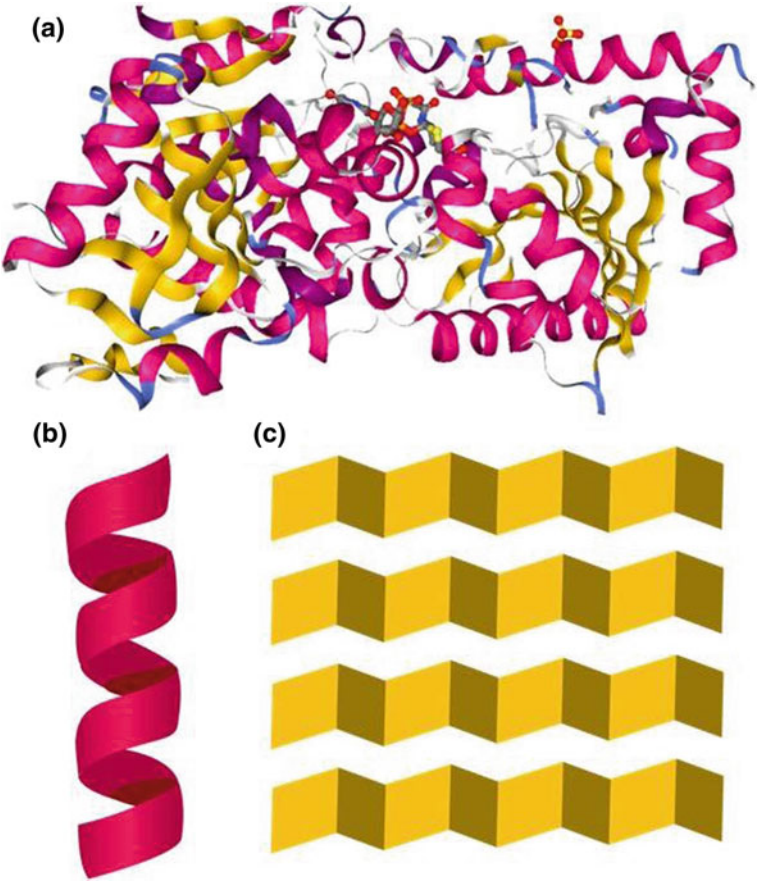

Fig. 1 **a** Schematic representation of 3D structure of keratin protein, **b** α-helix is formed by twisting of polypeptide chains into screw manner, and **c** β-sheet structure is the result of maximum extension and stretching of polypeptide chains

2006). α-Keratin is a most abundantly found in mammals. Such type of structure is organized as coiled coil and thereby participating in compact structural arrangement to elongate polypeptide chain (Crick 1952, 1953). On the other hand, β-structure carries intermolecular hydrogen bonding between carbonyl and amino group. The diameter of β-structure is about 3–4 nm and molecular mass is about 10–22 kDa (Table 2). These types of structure are most abundantly found in reptilian tissues, such as feathers, claws, and beaks of birds, etc. (Chen et al. 2012).

Table 2 Structure-based comparison and distribution of α- and β-keratins

Characterization	α-Keratin	β-Keratin
Bonding	Intramolecular hydrogen bonding	Intermolecular hydrogen bonding
Diameter (nm)	7–10	3–4
Structural features	Intermediate filament matrix	Amorphous matrix
Molecular mass (kDa)	40–68	10–22
Distribution	Wool, horns, hairs, nails, and hooves	Avian beaks, feathers, claws, reptilian epidermis, and claws
Stiffness	High	Lower than α-keratin

3 Sources of Keratin

Sources of keratin include wools, nails, hairs, hooves, feathers, reptilian scales, and avian (Fig. 2). Reptilian scales, feathers, and avian display almost similar keratin genes (Gregg et al. 1984), and it has been also proved that these feathers and scales are β-sheet based on transmission electron microscope (Filshie et al. 1964) and X-ray diffraction patterns (Astbury and Marwick 1932; Fraser and Parry 2008).

3.1 Feather, Beaks, Wool, and Hair

Since very early days, humans are very fascinated with understanding the concept of how birds can fly, and how birds (like duck) can protect their wings during swimming or rainy condition. You have been already noticed that the bird's wing does not get sloppy, easily during rain or rainy season. So, this is mainly considered keratin (β-form) protein may involve for providing mechanical support to the feather, and thereby prevents feather to get sloppy. To further understand this concept, Filshie and Gogers (1962) analyze feather under transmission electron micrographs, and their study reveals the filament-matrix structure with the β-keratin filaments. This structure was about 3 nm in diameter and embedded in an amorphous matrix.

The keratinous material is also present in rhamphotheca (outer surface layer) of bird beaks, and it allows the beaks to participate in a variety of functions, like feeding, social interactions, fighting, and grooming (Luester 2006). Usually, bird beaks fall into two categories: (1) long thin and (2) short/thick except in toucan beak, as it is both thick and long (Wang et al. 2016b). Wool and hair is the remarkable example of the hard-keratinous material. Wool is the excellent animal fiber, containing 82% keratinous protein. It is widely used in textile application and is scientifically important because of its mechanical and structural behavior (Feughelman 1997).

Hair is another widely used and studied fiber. Study on hair and wool revels that they both have common features except wool has large diameter. In many cases, hair plays an important role in terms of protection against dust and pathogens (hairs in nostril).

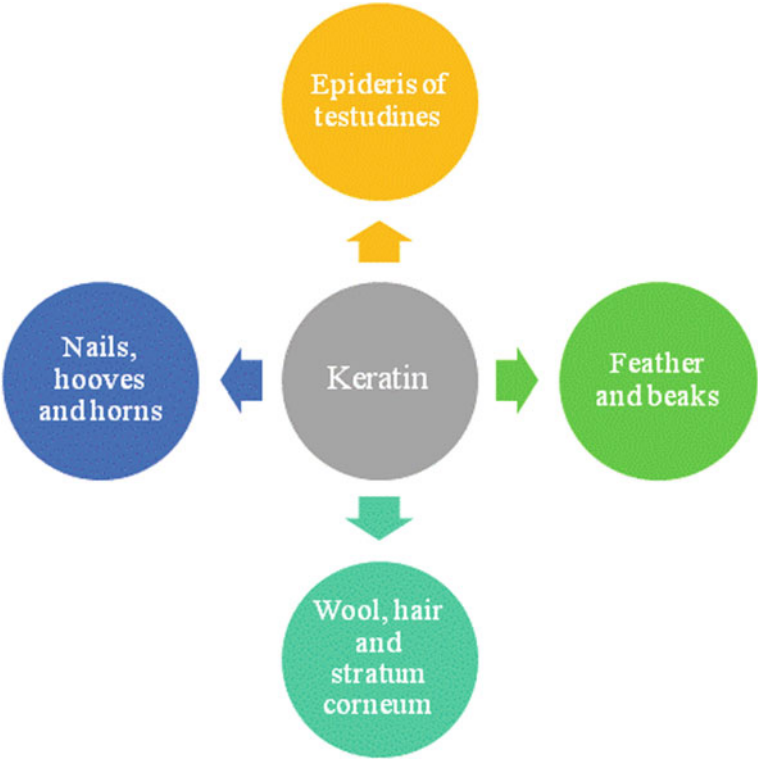

Fig. 2 Different sources of keratin

3.2 Stratum Corneum, Horns, and Hooves

Light and skin interaction regulates the optical visibility of the skin to human eye. Skin can absorb and reflect light in a diverse manner (Lee et al. 2018). Skin is also responsible for regulating the body's temperature, and it is actively participated in defense mechanism by acting as a barrier for pathogen(s). Mammalian skin is covered by outermost layer of stratum corneum, and the thickness of this layer is about 20–40 μm (Tomlinson et al. 2004). This layer act as defense layer from external attack (predators) and serve as diffusion barrier (Meyers et al. 2008).

Stratum corneum is composed of keratinocytes; these cells are embedded in an intracellular matrix that is highly rich in lipid content. Their cytoplasmic content is arranged in web-like pattern and robustly integrates at cell-to-cell junctions. Such interaction(s) in a diversely integrated manner maximize the mechanical support (Coulombe and Wong 2004).

Bovid animals like cattle, waterbuck, sheep, buffalo, and gazelle carry keratinous material in the form of horn. Horns act as a weapon, sometime(s) as shield to protect from predator and combat with other animals for their defense (Trim et al. 2011).

It may also involve for regulating body temperature (Geist 1966). These are highly tough, and can show resistance against opposite force, but cannot grow, once it gets broken (Tombolato et al. 2010). Hooves are the toughest keratinous materials and are still being an attractive topic for the research. Hoof wall is composed of flattened, keratinocytes. Hooves have a complex structure, and these complexities allow the hoof wall to absorb enough energy as the crack grows (Cook et al. 1964).

3.3 Epidermis of Testudines and Nails

The group "Testudines" usually represents the turtles, tortoises, and terrapins. Recent studies on Testudines indicate turtles are rich in both α- and β-keratins (Dalla Valle et al. 2013). The β-keratin/α-keratin ratio is higher in the carapace in hard-shelled turtle. This ratio provides an important factor for further study in the background of keratin.

Nails are the important source of α-keratin. In primates and few mammals, it covers the ends of the fingers and toes (as their ends have soft skin, so indirectly these proteins participate in protection). In cats, these protein forms curved claws and show α-type pattern during the analysis under X-ray diffraction pattern (Bear and Rugo 1951). Fingernails are one of the important features in primates (Hamrick 1998), as they can use their nails during fighting, scratching, and opening of some object.

4 Various Methods Used for the Keratin Production and Degradation

Poultry, meat, and leather processing industries generated every year large amount of keratin-containing wastes. Globally, every year, poultry processing industries generate around 8.5 million feather waste (Fellahi et al. 2014). Currently, these keratins-containing waster products are buried, dumped, and used as land filing, which generates problem in storage, ash disposal, and emission control (Agrahari and Wadhwa 2010). Here, we are trying to focus on some important methods for keratin production and degradation (Fig. 3).

4.1 Hydrolysis of α- and β-Keratins by Bacterial Cultures

The static extension of poultry industry facilitates a huge amount of wastes. Recycling of such waste(s) does not affect the environmental pollutant problems, but it also improves the rate of keratin production for various purposes. Poultry meat

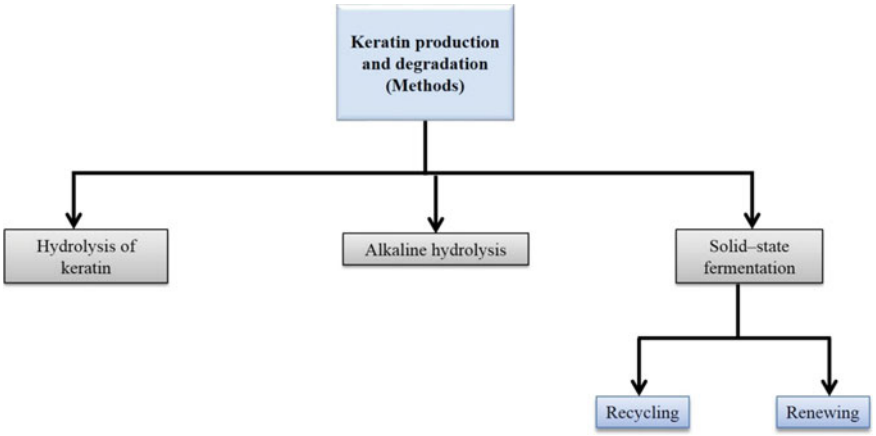

Fig. 3 Methods of keratin production

industries provide gigantic waste such as bones, feathers, and viscera. Bioconversion of such wastes into the useful material using a specific enzyme(s) is a fascinating paradigm. Presently, enzymes are widely used at broad spectrum for the conversion and production of poultry waste into feeding and fertilizers.

Keratin proteins separated from feather by several chemical modifications. Poultry (including birds) feathers contain around 90% keratin along with some important amino acids like cysteine, threonine, and arginine (Sinkiewicz et al. 2017; Tiwary and Gupta 2012).

Initially, protease (keratinases, EC 3.4.99.11)-producing microorganisms were isolated, screened and most potent protease-producing microorganisms were identified. The microbial enzyme (protease) attacks insoluble keratinous protein substrates and thereby releasing free amino ($–NH_2$) group containing molecules (Abdel-Naby et al. 2017; Bagewadi et al. 2018). In order to check the hydrolysis property of keratin components, different kinds of substrates like chicken feather, sheep wool, pea pods and more were used as substrate. Generally, after hydrolyzing, these substrates were further proceed by following chopping, washing, and then overnight incubation at 60 °C. Finally, freely released of amino acids were analyzed at 0–3 days of interval (Fellahi et al. 2014). The brief summary of keratin production is summarized in Fig. 4.

4.2 Production of Keratin Using Alkaline Hydrolysis

Keratin production and their extraction can also be done by alkaline hydrolysis. Extraction and production, these two processes mainly depend on two different complementary factors (1) chemicals, as it is important for extracting spe-

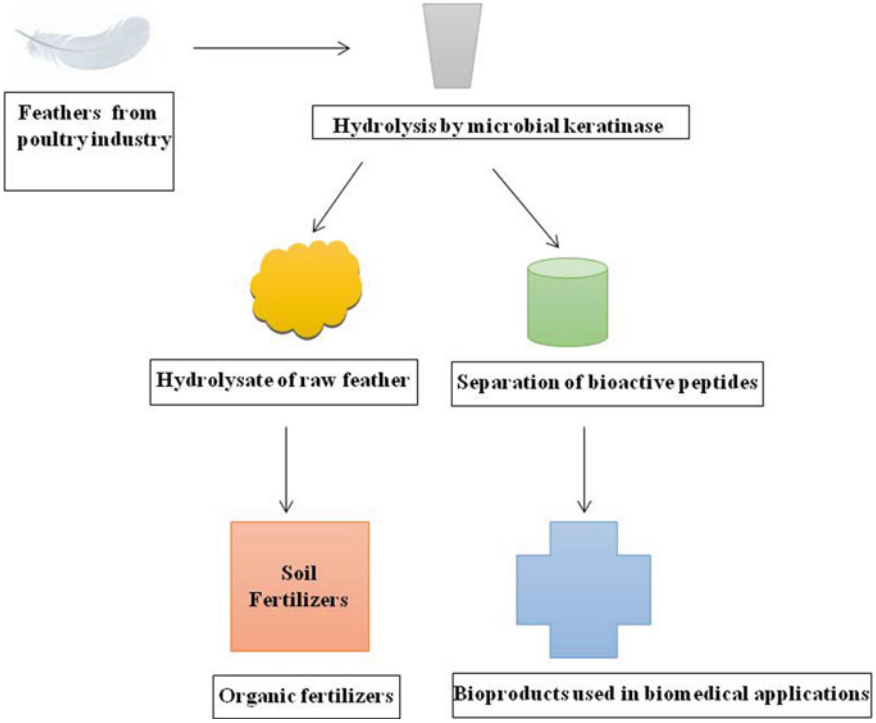

Fig. 4 Microbial keratinase activities for the conversion of wastes from poultry industry to useful by-products. Following hydrolysis, the hydrolysates can be used as organic fertilizers, and these hydrolysates can also be used in biomedical applications

cific cellular proteins from the cell, tissue or organ, and (2) optimal condition(s), as it is important, because, it provides all the ideal support for protein stability. For example, keratin from bird's feather can be obtained by alkaline hydrolysis method. During the process chemicals like ammonium sulfide or sodium sulfide can reduce disulfide group to thiol group. And also, by using β-mercaptoethanol, free –SH group can be partially modified. The process was carried out for 90 min at 45–80 °C. The obtained keratin molecular weight was approximately between 1 kDa and 11 kDa (U.S Patent 2007). Recently, Sinkiewicz et al. (2017) demonstrated the influence of thermochemical treatments using different reducing agents (2-mercaptoethanol, dithiothreitol, sodium m-bisulphite, and sodium bisulphite, as well as sodium hydroxide) on the production of keratin (in chicken feathers extract). 2-Mercaptoethanol and sodium bisulphite treatment yields about 84% and 82% of keratin. Additionally, sodium hydroxide (2.5%) was further improved the production of keratin up to 94% (Sinkiewicz et al. 2017).

4.3 Solid-State Fermentation (SSF) for Keratin Degradation

Keratinases are the enzymes having proteolytic activity for the keratin degradation (Bagewadi et al. 2018). Consumption and utilization of poultry animals as the food product tremendously increase the consequence of biowaste, and it is very difficult to degrade such wastes within the short period of time. Keratin and their keratinous component, carries numerous amino acids, and their decomposition in the form of feather does not only cause environmental problem but it also leads to loss of several important amino acids that can be used in making nutrient-rich food products.

Solid-state fermentation (SSF) is a booming industrial process in biotechnology and microbiology field; it is mainly used for recycling or renewing biological waste(s) at large scale. In this process, microorganism grows in aqueous-free environment or sometimes at very low water content (Saratale et al. 2014). Submerged fermentation is the analogue of solid-state fermentation in which all the natural conditions are optimized and they mimic the natural environment (Bagewadi et al. 2018; Soccol et al. 2017). Chitturi and Lakshmi (2016) demonstrate an attractive method for keratinase production using *Bacillus strains*. The beneficial trait of this research was indicated as an improved method for keratinase production, and the yield was increased from 283–367 KU/mL to 415–442 KU/mL (Chitturi and Lakshmi 2016). Not only bacterial cultures, but the keratinase enzyme can also produce from fungal culture(s) under optimal conditions (Bagewadi et al. 2018), as it has a great influence on the feather degradation. SSF is eco-friendly process, significantly contributing to minimize the bio-pollutants and to maximize the area for food industries (Bagewadi et al. 2018).

5 Industrial and Clinical Applications of Keratins

It is very difficult to degrade keratins and their disposal may lead to serious harmful impact on the environment. Therefore, research should be proceeding by focusing on keratin waste utilization (Bagewadi et al. 2018; Bohacz 2017; Karthikeyan et al. 2007). India has broad livestock populations, which display annually: 82 million goatskins, 30 million sheepskins, and 28 million buffalo hides (Karthikeyan et al. 2007). Around 8–10% of chicken weight is due to their feather and approximately millions of tons of feather are generated annually (Karthikeyan et al. 2007). Besides this, a large quantity of horns, hairs, hooves, and feathers are wasted every year (Onifade et al. 1998). From the past few years, these wastes are utilizing at industrial level to extract some important and insoluble (keratin) proteins. To get rid of this serious threat, there are various applications that can utilize these biowastes to convert them into beneficial form. Polyvinyl alcohol fibers that contain keratin were found to be an extensive industrial application, for example; they can be used as absorbents for toxic/hazardous substances like heavy metals ions as well as formaldehyde gas (Rouse and Van Dyke 2010).

5.1 Alkali and Hydrothermal Treatment

Hydrothermal treatment depends on high steam pressure of 10–15 psi with or without high temperature (80–140 °C) in the presence of acidic solutions (hydrochloric acid, sulfuric acid and more) (Eggum 1970) or alkali solution (sodium hydroxide, potassium hydroxide, sodium carbonate and more) (Gousterova et al. 2003; Papadopoulos et al. 1985). Combining acid or alkali treatment at the boiling temperature for about 2-3 h could open disulfide bridges of keratin and forms water-soluble polypeptides and oligopeptides or sometimes few amino acids. The crucial point of this process is the degradation of amino acids and polypeptide chains at high temperature that affects the nutritional improvement values.

5.2 Use of Keratin in Leather Industries

Keratin is a biopolymer having multifunctional properties, and these properties make (turn on the pathways of) keratinous material utilization at industrial level. Systematic optimization of the keratinous component form biological waste products, participate in recovery of natural resources and aids in maintaining pollution free environment (Niculescu et al. 2016).

Wool is the keratinous material having well-defined structure and mechanical properties (Wang et al. 2016b). Wool fiber contains approximately 82% of keratinous protein and high percentage of cysteine, around 17% along with small number of polysaccharides and lipid wax (Lewis and Rippon 2013). All these properties made keratin useful in leather industries (2007).

5.3 Keratin in Drug Delivery System

Drug delivery is a dynamic process which involves the process of administration of drugs, their absorption, and interaction with the target site. For many drug applications, drugs are designed in such a way that it should be able to provide maximum desired therapeutic effect or drug efficacy with less toxicity (Nelson et al. 2002; Parveen and Sahoo 2008). Drug delivery should be maintained in a controlled manner; if the condition for drug delivery is not maintained at high level, then it may cause serious complications, and even it may lead to the death of the person. Moreover, a diverse family of polymers have been identified in drug delivery purposes. Drug delivery already has been achieved by using synthetic and natural polymers. Synthetic polymers including polyphosphazenes, polyorthoesters, polyanhydrides, polyesters, and polyphosphoesters have found in broad application (Nair and Laurencin 2006), while natural polymers including collagen, cellulose, gelatin,

and alginates are broadly used because of their biocompatibility and biodegradability (Malafaya et al. 2007; Mano et al. 2007).

Over the last few years, keratin is widely used for the drug delivery system (DDS) in a controlled manner because of their stability, less reactivity, structural, and mechanical properties. Being natural polymer, keratins have advantage as it is rich in reactive chemical groups like amide, carboxyl, hydroxyl, as well as sulfhydryl, and hence, these properties enhance their activity to interact with biologically active molecules. One simplest way of incorporating drugs into keratin biomaterials is to dissolve or mix before processing into the keratin solution. Such protocols were designed for the synthesis of drug loaded keratin films (Fujii et al. 2004; Vasconcelos et al. 2010). For example, Li and co-workers developed a nano-based PEG-induced keratin method for drug delivery to treat cancer (Li et al. 2012).

5.4 Keratin in Surgery and Repairing

Keratins have complex bio-protectant and strong structural properties. They show similar properties to collagen like insolubility, high tensile strength, etc., and these properties illustrate the importance of keratin in surgery.

Partial and peripheral burns are the consequence of patient management with respect to multiple dressing. It is important to protect the skin from infection, wound, trauma, and external injuries to minimize the possibilities of major (supreme) damages in skin and thereby, promoting rapid epithelial cells proliferation (Loan et al. 2016). Skin is the outermost layer of the body that protects every living organism from serious threats and it also regulates homeostasis during unfavorable conditions. Loan and co-group reported that "keragel and keramatrix" (keratin-based products) can be used during damaging of dermis and epidermis layers (Loan et al. 2016).

Skin injury and their repairing possibilities can be enhanced by stimulating migration activity of keratinocytes at injured, damaged, and wounded site(s). These proliferation and migration rate of keratinocytes significantly promote basal membrane's protein expression including types IV and VII collagens (Tang et al. 2012) and show improvement in clinical trials such as skin surgery, leg ulcers (Hammond et al. 2010), and in epidermolysis bullosa (Than et al. 2013).

6 Conclusion and Important Aspects

Keratin depicts toughest and significant biological material; act as protective integument in mammals, primates, and in Testudines. Keratin has compact structural and robust mechanical properties which attracts life science researchers for the proper understanding of physical, chemical, and biological properties of keratin. For example, keratinous materials provide the toughest source for protection (nails over the skin, horn, and hooves in horse), feeding and interaction (outermost layer of beaks).

Research on keratin is directed toward the advancement of numerous biomaterials having keratin for practice in application of biomedical field. For example, in recent days, hair damage (caused by UV radiation from sunlight, pollution, and nutrient deficient food supplements) can be repaired by synthetic treatment of keratin. Although such treatment is temporary, still it is widely used in metropolitan area to minimize hair loss. Additionally, keratinous materials have diverse hierarchal structures and functions that can be useful for development or architecture of new structure for the human benefit. In spite of the fact that remarkable research has been conducted on keratin, still some area of research is unclear and insufficient. Here, we are now trying to put some important factors that may illustrate some beneficial points in keratin research:

- Although a significant amount of details is available for keratin, α- and β-keratinous material are not well understood, including their biosynthesis, molecular assembly, gene sequence, mechanical, and structural nature. This indicates and opens a new door in research for diverse investigation of keratinous material.
- Keratin has high mechanical and compact biological properties, this knowledge we can apply on synthesizing and assembly of new products with low molecular weight and high mechanical strength.
- To predict the novel structure and their function, it is essential to understand the morphological and structural configuration relationship.
- More studies required to understand the importance of keratin-based nanomaterials that may be useful for drug delivery and providing therapeutic response.

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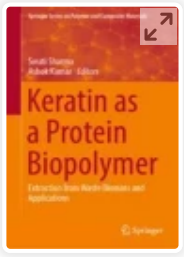

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Keratin as a Protein Biopolymer

Extraction from Waste Biomass and Applications

Editors: Swati Sharma, Ashok Kumar

Focuses on the extraction of keratin from waste biomass and their potential applications

Comprehensively discusses all data on keratin

Highlights the unique features of keratins and updates readers with the prospects to develop new value-added products

Part of the book series: Springer Series on Polymer and Composite Materials (SSPCM)

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About this book

This book provides information about the sources, structure, and properties of keratin as well as its applications. The extraction from different biomass sources (e.g. feathers, hairs, nails, horn, hoof, and claws) as well as the characterization methods of these extracted materials are explained. The development of bioproducts from keratins is challenging and limited since they are neither soluble in polar solvents nor in non-polar solvents. Therefore, the utilization of different microorganisms for the degradation of keratin is also discussed.

The main aim of this book is to highlight the unique

features of keratin and to update readers with the possible prospects to develop various value-added products from keratins. The book is highly interesting to researchers working in industry and academia on bioproducts, tissue engineering, biocomposites, biofilm, and biofibers.

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Keywords

Keratin **Extraction from waste biomass**

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Chapter 1
Keratin: An Introduction



Swati Sharma, Arun Gupta and Ashok Kumar

Abstract What is keratin? And why to use the keratin? Well known that protein is a part of every cell in living organism's body which plays many different roles to keep living things alive and healthy. The importance of protein for the growth and repair of muscles, bones, skin, tendons, ligaments, hair, eyes, and other tissues is proven since a very long time. Proteins also exist in the form of enzymes and hormones needed for metabolism, digestion, and other important processes. *Natural proteins* are purified from *natural* sources. Keratin is among the most copious proteins found associated with the body of reptiles, birds, and mammals. It is a structural constituent of nail, wool, feathers, and hoofs which offers strength to body and muscles. Nowadays, the keratin-rich waste biomass produced from poultry and meat industry imposes serious threat to environment and living beings. We need to explore various techniques and methods for the extractions and use of keratin from waste biomass. From the industrial point of view, keratin is a useful product in the medical, pharmaceutical, cosmetic, and biotechnological industries. Materials obtained from keratin may be converted into porous foam of different sponges, shapes, coatings, mats, microfibers, gels, and materials of high molecular weight. In this chapter, we briefly describe the various sources, properties, and structures of keratin.

Keywords Protein · Waste · Biomass · Medical · Pharmaceutical · Application Extraction

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1 Introduction

Growing need for sustainable and safe bio-based materials due to rising environmental concern has forced the use of available natural by-products as a substitution. By-products from different animal sources are recently being used for beneficial purposes such as drug delivery, medicines, cosmetics, and bioplastic.

Keratin is among the most abundant structural proteins (Coulombe and Omary 2002), and in animals together with collagen, it is the most important biopolymer (McKittrick et al. 2012). Keratinous materials, formed by specifically organized keratinized cells filled with mainly fibrous proteins (keratins), are natural polymeric composites that exhibit polypeptide chain structure, filament–matrix structure lamellar structure, and sandwich structure ranging from nanoscale to centimeter scale. Keratin is among the most copious proteins found associated with the body of reptiles, birds, and mammals. It is a structural constituent of nail, wool, feathers, and hoofs which offers strength to body and muscles (Reichl et al. 2011). They serve several functions, such as for predation and as armor, protection, and defense. Therefore, a thorough understanding of the relationships between the units that make up a functional keratinous material would expectantly provide useful knowledge in designing new materials. Keratin is chiefly found in epithelial cells in higher vertebrates (Korniłłowicz-Kowalska and Bohacz 2011). Keratins have high strength, stiffness, and insolubility in polar as well as nonpolar solvents. The stabilization is the result of intramolecular and intermolecular disulfide crosslinks, hydrogen bonding, and its crystallinity. These properties will differentiate it from other fibrous proteins like myofibrillar and collagen protein (Schrooyen et al. 2000). With increasing urbanization, food industries particularly the wool industry, slaughterhouse, and meat market produce million tons of keratin-containing biomass. The major producers including USA, Brazil, and China, report for more than 40 million tons annually. These proteins compose keratin by-products containing 15–18% nitrogen, 2–5% sulfur, 1.27% fat, 3.20% mineral elements, and 90% of proteins (Kunert 2000; Sangali and Brandelli 2000; Gessesse et al. 2003).

From past several years, keratin has been extracted from various sources such as horn, hoof, hair, beaks, shells, toenails, claws, fingernails, and feathers (Sharma and Gupta 2016; Sharma et al. 2017c). Keratin was used in medicine for the first time by Chinese herbalist Shi-Zen in sixteenth century. Hoffmeier, in 1905, first time extracted keratin from animal hoofs with the help of lime which further was used in making gels (Rouse and Van Dyke 2010). Keratins are cystine-rich proteins associated with intermediate filaments (IFs) which are cytoskeleton element having diameter of 8–10 nm (ARAI et al. 1983; Khosa et al. 2013). It is available in two forms α- and β-keratins. α-keratins are copiously found in the soft tissues such as sheep wool, hair, and skin. These are rich in cystine. β-keratins are present in hard tissue protein of nails, fish scales, bird feathers, and others. They are rich in glycine and alanine, poor in cystine, hydroxyproline, and proline (Gupta et al. 2012). Keratins are very much stable and insoluble in most of organic solvents. The presence of cystine

in ample amount has made the keratin more susceptible to hydrolytic and oxidation reactions (Schrooyen et al. 2000; Barone et al. 2006b; Endo et al. 2008).

Nowadays, a large amount of keratin by-products are unused which is probable hazard to the environment (Cavello et al. 2012; Park et al. 2013). Keratin waste is classified into three categories in regulation (EC) 1774/2002 of the European Parliament and Council of 3rd October 2002 laying down health rules concerning animal by-products which are not intended for human consumption but does not spread diseases to humans or animals (Korniłłowicz-Kowalska and Bohacz 2011). In the form of solid biomass, keratin is less prone to enzymatic hydrolysis due to high cross-linking by hydrogen bonding, disulfide bonds, and hydrophobic interactions (Korniłłowicz-Kowalska and Bohacz 2011).

Thus, use of keratin as a biopolymer requires its extraction from the biomass. In recent years, several attempts have been made for the extraction of keratin using chemical, mechanical, and enzymatic methods (Korol 2012; Jeong et al. 2010; Chaudhari et al. 2013; Fang et al. 2013). There are number of ways for extraction of keratin from the waste biomass including acidic hydrolysis (Breinl and Baudisch 1907; Earland and Knight 1956), alkaline hydrolysis (Tsuda and Nomura 2014; Song et al. 2013; Poole et al. 2008), enzymatic hydrolysis (Eslahi et al. 2013), ionic liquid hydrolysis (Idris et al. 2014; Wang and Cao 2012), and alkaline–enzymatic hydrolysis (Yin et al. 2007). Acidic hydrolysis provides very severe conditions which can destroy some useful amino acids during hydrolysis. Conversely, enzymatic hydrolysis provides less species alteration but with a slower process and is more expensive (Staroń et al. 2014), which makes its commercial use more difficult. On the other hand, ionic liquids are too costly and protein recovery is very low (Cevasco and Chiappe 2014) to be used for industrial purpose. Hence, research into simple, cheap, environmentally sustainable, and industrial applicable method to extract keratin seems justifiable.

Keratin is a useful product in the medical, pharmaceutical, cosmetic, and biotechnological industry. Materials obtained from keratin may be converted into porous foam of different sponges, shapes, coatings, mats, microfibers, gels, and materials of high molecular weight. Keratin is attracting the attention of the researchers due to its abundance. Keratin biomaterial is applied in the development of wound healing gels, tissue engineering, drug delivery, trauma and medical devices, biomedical, and cosmetic applications. One of the impending applications of purified keratin is to produce biomaterials in regeneration and tissue repair (Alsarra 2009; Ramshaw et al. 2009; Natarajan et al. 2012; Ramadass et al. 2013; Kumaran et al. 2016).

These are the polymers formed by various amino acids capable of promoting intra- and intermolecular bonds, allowing the resultant materials to have a large variation in their functional properties (Gupta and Perumal 2013). Feather keratin is a potential source of abundant, inexpensive, eco-friendly, and commercial biomaterial (Poole et al. 2009; Shi et al. 2014). Keratin word first emerged around 1850 and it illustrates the material which constitutes hard tissues such as animal horns and hoofs. The name was taken from the word "kera" which means horn. Keratin is an insoluble, highly stable structure, small proteins, and uniform in size. Feather keratin has a molecular weight of about 10 kDa (Fraser et al. 1972; ARAI et al. 1983; Ullah et al. 2011; Kamarudin et al. 2017). It is composed of α-helix, β-sheet structures as discussed

in further chapters. Also, the internal structure of every keratin has α-helices and β-sheets that support the protein. The elastic nature of keratin fiber is due to the interplay between α-helices and β-sheet configuration of the protein. Feathers consist of 50% of each fiber and quill by weight (Reddy and Yang 2007a). In a feather, fiber has a larger percentage of α-helix (41%) as compared to β-sheet (38%) and quill fraction consists of more β-sheet (50%) structure than α-helix (21%) (Barone et al. 2006a; Schmidt and Jayasundera 2004; Wallenberger and Weston 2003; Fraser et al. 1972). According to a previous study (Sun et al. 2009a), feather has 9.38% α-helix, 47.19% β-sheet, 32.25% β-turn, and 11.18% in random.

Keratin has about 7% cystine, which forms S–S bonds with other cystine molecules (ARAI et al. 1983) and forms cysteine by disulfide bridges. The presence of disulfide, hydrophobic, and hydrogen bond (Onifade et al. 1998; ARAI et al. 1983; Ullah et al. 2011; Cardamone 2010; Bulaj 2005) in keratin provides it strength, mechanical stability, rigidity, and resistance to degradation by proteolytic enzymes such as trypsin, pepsin, and papain (Yamamura et al. 2002; Agrahari and Wadhwa 2010; Paul et al. 2013) to keratin in the solid state. However, these cross-links are a hindrance to processing in the melt state (Barone et al. 2006b). The presence of reactive functional groups, especially peptide backbone, disulfide (–S–S) bridges, amino ($–NH_2$), and carboxylic acid (–COOH), makes it chemically reactive under favorable reaction conditions. During controlled reduction, protonation of keratin occurs. Thus, the keratin protein attains positive surface charge and becomes pseudo-cationic biopolymer.

Keratin is insoluble in polar and nonpolar solvents and has very low chemical reactivity. At low pH, high temperature and in presence of reducing agents the solubility of the keratin are increased. The biodegradability and nontoxic nature of keratin make it versatile biopolymer which can be modified and extended in various forms such as films, gel, beads, and nano/microparticles. The modified keratin has plenty of applications in food sciences, green chemistry, cosmetic industries, and pharmaceuticals.

2 Chemical Composition and Occurrence of Keratin

Keratin is the most important component of hair, wool, nails, hooves, claws, scales, horn, beaks, and feathers as shown in Table 1. These are least affected by chemical and physical environmental factors (Teresa and Justyna 2011). The keratin extracted is with 90–100 amino acids and 10.2–10.4 kDa molecular weight (Kamarudin et al. 2017; Barone and Schmidt 2005). Chemical structure of keratin showed α-helix, β-helix, or β-pleated sheet (Fraser et al. 1972; Lee and Baden 1975). Keratin has a high amount of cystine residues (7–15 mol% of amino acids) as compared to other which help to make intermolecular cross-links (Rouse and Van Dyke 2010). The amount of cysteine residues depends on the keratin source, which varies from 7% in feather to 15% in wool keratin (Fraser et al. 1972; ARAI et al. 1983).

Table 1 Distribution of α- and β-keratins

Types of keratin	Source organ
α-Keratin	Wool, quills, hair, horns, fingernails, hooves; stratum corneum
β-Keratin	Feathers, avian beaks and claws, reptilian claws and scales
	α- and β-keratin reptilia epidermis, pangolin scales

The high cystine content is the unusual characteristic of keratin which differentiates it from other structural proteins like elastin and collagen. Main amino acids present in keratin are cystine, proline, serine, and glycine (Fraser et al. 1972; Fraser and Parry 2003). In another study, γ-keratin was extracted which is nonstructural and associated with α- and β-sheets (Fraser et al. 1972; Hill et al. 2010). The sulfur content ratio plays an important role in keratin physical properties. Some researchers based upon sulfur content classified keratin as soft and hard forms (Rizvi and Khan 2008; Zoccola et al. 2009). Soft keratin has lower cystine content, week cross-linking, and smaller resistant to other chemicals found in the hair core and outer layer of epidermis (Fraser et al. 1972).

Hard keratin found in mammalian epidermal appendages, such as hairs, nails, horns, and in avian or reptilian tissues. In recent years, equine hoof (Douglas et al. 1996), bovine hoof, wool (Feughelman and Robinson 1971), and especially the sheep horn (Tombolato et al. 2010) are the attractive sources for keratin extraction.

3 Keratin Sources

Keratin biomass is derived from living organisms or from their body parts after death. The major livestock's of keratin includes sheepskins, goatskins, cattle hides, feathers, hairs, and buffalo hides as shown in Fig. 1. Skin and its appendages such as feathers, wool, nails, hooves, hair, scales, and stratum corneum are the richest sources of keratin (Kim 2007). It can be extracted from animal horns and hooves, wool, feathers, and human hairs (Fig. 1). Food industry produces million tons of keratin biomass. About 80% of human hair is formed of keratin only (Kaplin 1982; Wagner and Joekes 2005). It provides flexibility, strength, durability, and functionality to the hair in the form of different conformations (Velasco et al. 2009). Keratinous materials based on α- and β-keratins are discussed in Table 2.



Fig. 1 Main sources of keratin biomass

Table 2 Keratinous material based on the presence of α- and β-keratins

Keratinous materials based on α-keratin	Keratinous materials based on β-keratin	Keratinous materials based on α- and β-keratins
Stratum corneum	Feathers	Reptilian epidermis
Wool and hair	Beaks	Hard and soft epidermis of Testudines
Quills	Claws	Pangolin scales
Horns		
Hooves		
Nails		
Whale baleen		
Hagfish slime threads		
Whelk egg capsules		

4 Applications of the Keratin Protein

Keratin biomass is hydrolyzed by alkali, acid, or enzyme to extract keratin. The extracted keratin has various applications in various industries such as cosmetic, biomedical, and pharmaceutical industries. Furthermore, it does not have harmful effects and thus can be used for variety of cosmetics such as creams, shampoos, hair conditioners, and biomedical products. They have been used as a treatment of skin and human hair as reported before (Weigmann et al. 1990; Innoe 1992). Its existence in the hair cuticle and stratum corneum helps in preserving skin moisture while interacting with cosmetics. Its combination with other natural polymers such as chitosan, collagen, and silk fibroin was used as a component for cosmetic products (Sionkowska 2015). Keratin with high molecular weight is mostly used for skin care applications due to its individuality like film forming and hydrophilic. Keratin film or coating on skin provides smooth and soft sensation. Keratin-associated proteins from different sources were developed and applied as microscaffolds in medicine and cosmetics (Lipkowski et al. 2009). Proteins are useful ingredients for healthy skin and hair. There are studies which reported the role and efficacy of using protein in cosmetics; proteins can be obtained from simple and conjugated proteins (Secchi 2008). There are also studies which described the keratin derivatives and cationizing agent in the various cosmetics having specific functional groups (Matsunaga et al. 1983). Figure 2 shows the hair treatment cream formed using keratin extracted from chicken feathers. Other applications from different biomasses are discussed in Table 3.

Because the presence of high cross-linking by cystine formulation of micro- and nanoparticle from feathers is difficult, some researchers have prepared micro- and nanoparticles successfully from feather keratin. Keratin was converted into useful microparticles by treatment with ionic liquid, 1-butyl-3-methylimidazoliumchloride (Sun et al. 2009b). Treated feathers have low surface area but have higher ion sorption capacity than untreated feathers due to their hydrophilic nature. (Xu et al. 2014b) developed nanoparticles (50–130 nm) from feather keratin which showed good biocompatibility and stability essential for controlled drug release. Here, the chicken feather keratin nanoparticles were developed and used as a haemostatic agent which resulted in decrease in the bleeding time and blood loss in tail amputation and liver scratch rat models (Wang et al. 2016). In another study, quail feathers keratin incorporated into silver nanoparticles and formed the nanofibrous scaffold which gave 99.9% and 98% of the antibacterial activity against Gram-negative (*Escherichia coli*) and Gram-positive (*Staphylococcus aureus*) bacteria, respectively. Thus, it can be used for biomedical applications (Khajavi et al. 2016). As chitosan has good properties of biodegradation and biocompatibility, when they are mixed with keratin nanoparticles, they form scaffold. The biodegradation and protein adsorption of the scaffold had increased, and it was noncytotoxic to human osteoblastic cells. Thus, this scaffold can work as biomimetic substrate for bone tissue engineering applications (Saravanan et al. 2013). In one study, keratin nanopowder from chicken feather was produced by electrospraying which has a small particle size and has less crystallinity



Fig. 2 Hair treatment cream made by using keratin extracted from chicken feathers

than raw keratin (Rad et al. 2012). Water stable nanoparticles were developed from feather keratin. Figure 3 shows the keratin nanoparticles extracted from chicken feathers. Nanoparticles can be a good veterinary diagnostic, and it can penetrate

Table 3 Applications from different keratin biomasses

Sr. no.	Sources	Industrial application(s)	Reference(s)
1	Human hairs	Medicinal use	Zheng et al. (2005)
2	Hoof and horn's	Preparation of firefighting composition	Datta (1993)
3	Human hair and wool	To explore structural and biological properties of self-assembled keratins	Xu et al. (2014b)
4	Feathers	Development of protein fibers and 2D and 3D scaffolds for tissue engineering	Xu et al. (2014a), Rouse and Van Dyke (2010)
5	Chicken feathers	Keratin film for drug delivery system	Poole et al. (2009), Yin et al. (2013)
		Regenerated fibers	Xu et al. (2014a)
		Micro- and nanoparticles	Sun et al. (2009b)
		Graphene oxide and its derivative in biomaterials	Amieva et al. (2014)
		As a diet supplement for feeding ruminants	Coward-Kelly et al. (2006), Dalev (1994), Dalev et al. (1996), Dalev et al. (1997)
		Microporous material used as electrode material	Zhan and Wool (2011)
		Thermoplastic films	Reddy et al. (2013), Jin et al. (2011)
		Waste management using microorganisms for degradation	Vasileva-Tonkova et al. (2009), Syed et al. (2009), Grazziotin et al. (2006)
		Leather processing	Sastry et al. (1986), Sehgal et al. (1987), Karthikeyan et al. (2007)
		Handspun yarn	Reddy and Yang (2007b)
		Textile yarns	Reddy et al. (2014a, b), Yang and Reddy (2013)
		Keratinases in detergents formulation	Balakumar et al. (2013), Manivasagan et al. (2014), Rai et al. (2009)
		Flame retardant	Wang et al. (2014)
		Bio-composites or composite fabrication	Flores-Hernández et al. (2014), Spiridon et al. (2012), Huda and Yang (2008, 2009)
		Biofertilizer	Ichida et al. (2001), Kornillowicz-Kowalska and Bohacz (2010), Gurav and Jadhav (2013), Hadas and Kautsky (1994), Gousterova et al. (2012)

(continued)

Table 3 (continued)

Sr. no.	Sources	Industrial application(s)	Reference(s)
		Nanoparticle and microparticles for pharmaceutical application	Xu et al. (2014b), Sundaram et al. (2015), Yu et al. (2014), Sharma et al. (2017a, b)
		Keratin and graphene oxides within biomaterials	Amieva et al. (2014)
		Cement-bonded composites	Acda (2010)
		Keratin hydrogel	Wang et al. (2017), Barati et al. (2017), Priyaah et al. (2017)
		Tissue regenerative applications	Li et al. (2013), Saravanan et al. (2013), Kumar et al. (2017)
		Paper production	Tesfaye et al. (2017)
		Bioplastic	Sharma et al. (2018), Ramakrishnan et al. (2018)

easily into cells and organs due to their nano size. They are good for the drug delivery as compared to synthetic polymer and carbohydrates. Xu et al. (2014b) found that keratin nanoparticles have supportive function for the cell growth and stable in physiological environment for up to 7 days. The keratin nanoparticle shows anticancer properties. When keratin nanoparticles combine with chlorin e6, it resulted in greater cell death percentage (90%) as compared to free chlorin e6 on osteosarcoma (U2OS) and glioblastoma (U87) cells lines, and thus keratin nanoparticles are effective and promising delivery vehicles for photodynamic therapy applications (Aluigi et al. 2016). In one study, keratin-based drug-loaded nanoparticles were made and it was showing pH and glutathione dual-responsive behavior. Thus, from the results of the study conducted, it was concluded that keratin-based drug carriers had potential for drug delivery and cancer therapy in clinical medicine (Li et al. 2017).

Biocompatible composites were developed which can be used for high-performance dressing, to treat chronic ulcerous infected wounds by the combination of cellulose and keratin with the silver nanoparticles (Tran et al. 2016). Hair keratin nanoparticle had faster clotting time, and it significantly reduces blood loss and coagulation time which forms the viscosity gel on wound; hence, it has a great potential for haemostatic application (Luo et al. 2016). The soluble keratin would have applications in tissue regeneration, cell seeding, wound healing, and drug delivery (Yamini Satyawali 2013). Soluble keratin can be used to make 2D and 3D scaffolds, and protein fibers which further utilized for tissue engineering (Xu et al. 2014b). Due to self-congregation and polymerization property of keratin proteins has led to work as scaffolds for tissue engineering (Rouse and Van Dyke 2010).

When the partially oxidized keratin is added into water, it forms the hydrogel which can be used as an absorbent material, as a therapeutic for skin. The hydrogel can be used for the implantation. The keratin can be incorporated into films which are

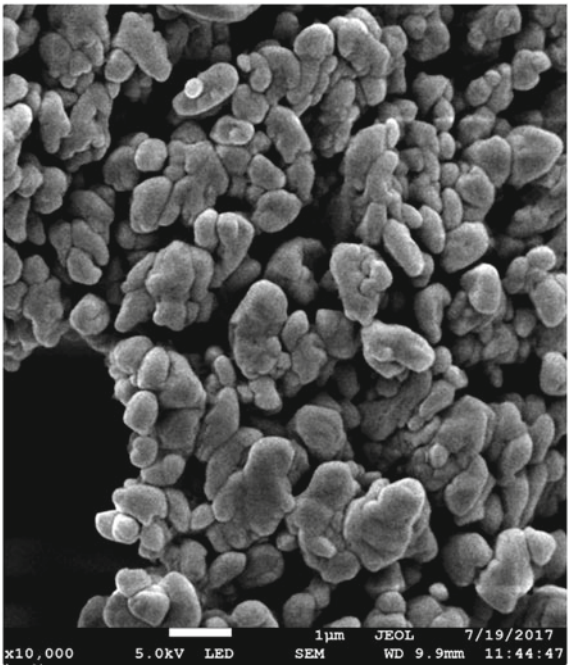

Fig. 3 Keratin nanoparticles extracted from chicken feathers

nonwoven, and these two materials are suitable for use in tissue engineering scaffolds (Blanchard et al. 2002). Keratin biomaterials have the potential to interact with cells and tissues but the composition, structure, and cell-instructive characteristics are not clear. Burnett et al. (2013) made keratin-based biomaterial, demonstrate self-assembly of cross-linked hydrogels, investigate a cell-specific interaction, and find the utilization in drug and cell delivery, tissue engineering, regenerative medicine, and trauma. The huge amount of waste biomass generated by animals as well as food industries can be used as raw material for the production of keratin at industrial level. The keratin waste biomass management by reconversion into industrially used products will save the ecosystem from large amount of sludge and boost up industries such as pharmaceutical and cosmetic industry economically.

5 Conclusion

To develop the strategies for efficient extraction of keratin from poultry biomass will prove to be very beneficial for sustainable management of huge waste. Researchers are working to develop various chemical, biological, and physical methods individually as well as in combined form for keratin extraction. The insoluble protein has many advantages in biomedical industry to develop products of pharmaceutical use,

in tissue engineering as well as in agriculture industry too. Recent advances in the sustainable management of poultry waste biomass, extraction techniques used by various researchers, and numerous applications of the extractions have been discussed in the subsequent chapters of this book.

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The book includes high-quality research papers presented at the International Conference on Innovative Computing and Communication (ICICC 2018), which was held at the Guru Nanak Institute of Management (GNIM), Delhi, India on 5–6 May 2018. Introducing the innovative works of scientists, professors, research scholars, students and industrial experts in the field of computing and communication, the book promotes the transformation of fundamental research into institutional and industrialized research and the

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An Optimization Technique for Unsupervised Automatic Extractive Bug Report Summarization



Ashima Kukkar and Rajni Mohana

Abstract Bug report summarization provides an outline of the present status of the bug to developers. The reason behind highlighting the solution of individual reported bug is to bring up the most appropriate solution and important data to resolve the bug. This technique basically limits the amount of time that the developer spent in a bug report maintenance activity. The previous researches show that till date the bug report summaries are not up to the developer expectations and they still have to study the whole bug report. So, in order to overcome this downside, bug report summarization method is proposed in light of collection of comments instead of single comment. The informative and phraseness feature are extracted from the bug reports to generate the all possible subsets of summary. These summary subsets are evaluated by Particle Swarm Optimization (PSO) to achieve the best subset. This approach is compared with the existing Bug Report Classifier (BRC) and Email Classifier (EC). For all approaches, the ROUGE score was calculated and compared with three human-generated summaries of 10 bug reports of Rastkar dataset. It was observed that the summary subset evaluated by PSO was more effective and generated less redundant, noise reduction summary and covered all the important points of bug reports due to its semantic base analysis.

Keywords Natural language processing · Feature weighting · Summarization Unsupervised · Bug report · Particle swarm optimization

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1 Introduction

Other profession individuals have a myth that the software development includes only programming element; in contrast, this line of work has strong element of system information management. The software organization requires the management and formulation of artifacts like designs, source code with documentation, specifications, and bug reports. These bug reports are stored into the software bug repositories. Software bug repositories have extreme information to perform the work on project. Tester's needs to understand the artifacts related to project for recording the issues mentioned by customers and tracks the resolution of bugs. To find the main issue of a bug, a meaningful and huge conversation could happen between developer and reporter by bug reports. So the bug reports have a large amount of reported conversation in the form of messages from multiple peoples and these messages might contain few lines or multiple passages of unstructured text. For example, Mozilla bug #564,243 has 237 sentences and Mozilla bug #491,925 has 91 sentences as comments. To resolve the bug, the developer has to analyze all the comments in bug reports. This process can be tedious, time-consuming, burden, and very frustrating for the tester or developer. Sometimes, the amount of information might be overwhelming and sometimes, this information leads to duplicate, deserted, and non-optimized searches, just because the previous bug reports of the project has been ignored. In [1], the researcher suggested the way to reduce the developer effort and process time, consumed to identify the factual bug report is to provide bug summary. The ideal process of bug summarization is to develop a manually abstract of resolved bug by assigned developer. This summary is used by other developers for better understanding of the bugs. However, the ideal method is very difficult to use in practice because it demands excessive human effort. Therefore, it is need of automatic bug report summarization. The factual summary will save the developer efforts and time and helps in generating up to date summaries of the project on demand. This paper is focused on four challenges. The first challenge is extractive bug report summarization that has huge amount of information as comments and large search space cause NP-complete problem. When working with extensive comments containing a lot of words, sentence selection and sentence scoring become a difficult job and also affect the accuracy and speed of summarization. The second challenge is to increase the ROUGE score by selecting effective semantic text. For example, if there are 20 text lines to summarize and the user wants 20% summarization, then a total of 2^5 subsets are possible of semantic structure; if checked one by one, then this problem goes to intractable. The third challenge is sparsity of data. For example, suppose that one query term is not in the document, then the probability of occurrence of that term is zero to the document. If the probability of query term would be multiplied with the probability of every term of document, then the document would not be retrieved. The fourth challenge is reduction of information. Some high important features are assigned higher weight and low important features are assigned low weight. Feature Selection (FS) provides various heuristics methods which led to non-exhaustive search and reduced high-dimensional space by selecting the features. This drops the

information and decreases the accuracy of summary by only selecting the higher weight features.

In such situations, the adoption of meta-heuristic, n-gram, and feature weighting (FW) methods is beneficial in accomplishing the optimal solution to resolve the problem in a productive way. Previously, there are two methods used for textual bug report summarization. First one is supervised learning-based method used by various researchers in [2–5]. The bottom line of this method is as follows: initially bug reports are manually summarized as training set, then text features are extracted from summarized bug reports, and statistical model are trained with these reports. Thereafter, this model is used to determine the features; further, these features are used to predict the manual summaries presented in training set. Later, the features are extracted from new bug report and its summary is predicted by using trained model. Second method is unsupervised learning-based method presented in [6–9]. The basic process of this method is as follows: In this, the centrality and diversity of the sentences are measured in a bug report to select the relevant sentences to put into the summary. In order to create effective, flexible bug report summary, reduce the time, effort of developer, and resolve above four challenges, we proposed an intelligent method for searching the effective semantic text by particle swarm optimization approach with concatenate scores of informativeness and phraseness methods for significant improvement in extractive bug report summarization.

Organization: This paper is divided into five sections: Sect. 2 presents an analysis by producing the summary of existing work related to this paper, Sect. 3 demonstrates the proposed system and algorithm in detail, and Sect. 4 explains the experiments and results thus exhibited along with an analysis of performance parameters. At last, the paper concludes and proposes the future work to be done in Sect. 5.

2 Related Work

Bug report summarization is the well-known research area in software industry, through the summarization dates back to 1958 when Luhn [10] generated the literature abstract. Text summarization process has been practiced in various domains like social media [11], videos [12], news articles [13], and audio [14]. From the past years, summarization process was also used by the incorporated world like Microsoft's Office Suite [15], Bug Triage Process [16], and IBM's Intelligent Miner for Text [17].

With the time, the summarization method is improved from simple term frequency methods to complex machine learning and natural language processing techniques.

Automatic bug report summarization is very difficult job; the vital challenge is how the sentences are picked to generate bug reports summary. To overcome this problem, the summarization methods are classified into supervised and unsupervised learning methods to select the appropriate sentences.

2.1 Supervised Learning Methods

In 2010, Rastkar et al. [1] used existing classifier like Email and Meeting Classifier (EMC), Bug Report Classifier (BRC), and Email Classifier (EC) to generate extractive summary. The human annotators generated the summary of 36 bug reports from (Mozilla, KDE, Eclipse, Gnome), and the bug report classifier performed better than other two classifiers by having <62% precision. Further in 2014, Murphy et al. extended the version of [18] by using the same classifier, to check whether the generated summaries helped in detecting the duplicates bugs. They performed task-based evaluation and found that summaries save the time as well as helped the developers in detecting the duplicates bug without the evidence of decreasing accuracy.

2.2 Unsupervised Learning Methods

The work by Mani et al. in 2012 [19] used four unsupervised learning methods to create the bug report summary. At first, noise reducer is developed to find out the inessential sentences from the reported bug reports after that Diverse Rank, Centroid, Grasshopper, and Maximum Marginal Relevance (MMR) approaches were applied on IBM DB2 bug report. These methods choose the sentences which were central to the bug reports. The author also compared this unsupervised summarization method to supervised method of [1] and found better results. Another work in 2012 by Lotufo et al. [20] modeled user reading process by three hypothetical model and applied heuristics using Markov chain and PageRank method to rank the sentences according to the probability of reading and generate summaries by choosing higher probability sentences. The precision of the model is improved up to 12% as compared to EC in [1] on Mozilla, Launchpad, Chrome and Debian projects. In 2016, Ferreira et al. [21] used Euclidean Distance (ED), Cosine Similarity (CS), PageRank, and Louvain community detection (LCD) algorithms to generate the summary from the comments instead of isolated sentences. It was observed that the ranking of the most appropriate sentences helped the developers in finding the relevant information as compared to manually generated summary of Angular, Bootstrap, and jQuery projects.

3 Proposed Summarization System

This section presents the proposed approach and proposed algorithm to generate the bug report summary.

3.1 Proposed Approach

The overall proposed system process is shown in Fig. 1; further, this is dived into summarization process by using particle swarm optimization. At first, the bug reports (free text) are taken as input, and this text is tokenized. It is then disintegrated into the sets of paragraphs, D = {PP1, PP2, PP3, …}. Every paragraph is break down into the number of sentences. P = {SS1, SS2, SS3, …}, each sentence contains many terms (features), S = {FF1, FF2, FF3, …}. The output of tokenization task is segregated words, paragraph, and sentences. It has three main tasks: stop word removal, rooting extraction, and synonym replacement. The output of this phase is normalized text. The weights of all terms are concatenated to calculate the score of the terms in our system to provide the effective summary. These terms scores are added to sentences to gain the sentence score. After preprocessing, the two features scoring methods are used based on informativeness and phraseness principles [22]: TF-IDF and N-gram method. The bigram, trigram features are extracted using Eqs. 4–7 to preserve the semantics to bug summary, which reduced the sparsity of the text [23]. The TF-IDF features are extracted using Eqs. 1–3 from the normalized data to reflect how much the term provided the information about a bug report [21]. The matrix is considered for every bigram and trigram term. The number of rows and column showed the n-gram words (W) number that are extracted from these bug reports and their probabilities (P). After all the terms are extracted from bug reports dataset, the probability of each term is calculated by Eq. 8. This probability score and TF-IDF score are concatenated to get the combined score of each term. Instead of feature selection (FS), the feature weighting (FW) method is adopted. FW is a generalization from of FS which involves much larger searching space and have more flexibility to assign the continuous relative weight over FS. So these term weights (score) are added to the sentences to gain the sentence score, and the subsets of summary are produced by sentences according to user input, and subset score is calculated for each subset. The subsets of summary are chosen by using Particle Swarm Optimization (PSO) algorithm [24] due to its selecting nature of optimizing searching. It has global and local optimization to find effective semantic text and sentence, which increased the rogue score. This subset act as particles and subset score act as initial position.

Suppose S_i is the produced summary according to user input and has n subsets, $S = \{s_1, s_2, s_3, \ldots, s_n\}$. These sentences have corresponding weights W_k, $W = \{W_1, W_2, W_3, \ldots, W_n\}$. By assigning weight to each sentence, WS is produced, $WS = \{W_1S_1, W_2S_2, W_3S_3, \ldots, W_nS_n\}$. PSO algorithm is described as follows: At first, initialize the each particle's position to subset score. The swarm is updated at every cycle with the best value based on Eqs. 9–10. The position best (pb_i) is taken as the fitness value of summary and the global best (gb) is taken as the fitness value found by swarm best of personal bests. The new fitness value is compared to previous value of pb_i. If new fitness value is surpassed, then the previous value of pb_i is updated to new pb_i value. If the pbi value has not changed for any particle, then new pb_i is compared with previous gb value. If the new pb_i is surpassed than the previous gb, the value of pb_i is selected as new gb. At each iteration, the gb presented the position

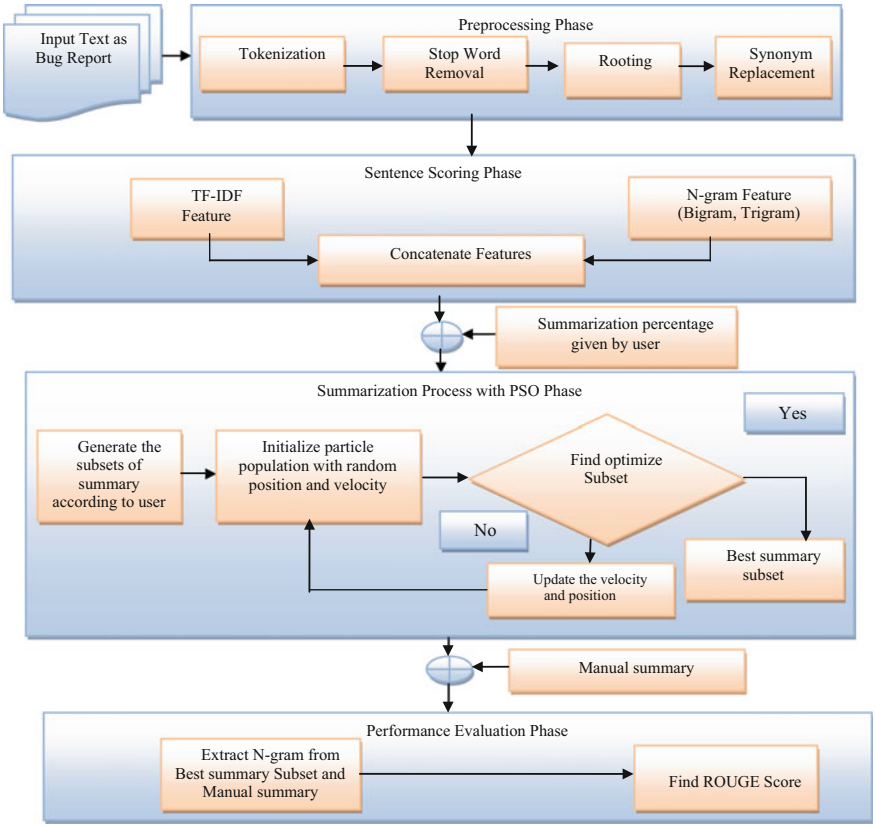

Fig. 1 Overall proposed system for bug report summarization

of the particle and showed a vector for best selected subset of the current bug report. The optimized summary is found after several iterations until the condition is not met. At last, ROUGE score [25] is calculated using Eq. 11.

3.2 Proposed Algorithm

Algorithm1: The summarization Process with PSO

Input: The XML files of bug reports
Output: ROUGE Score of optimized summary of bug reports

Step 1: Input text for preprocessing.
Step 2: Extract the TF-IDF Features
for (i = 1; i <=1;i++){

$$TF(t,D) = \frac{f_D(t)}{\min_{\omega \varepsilon D} f_D(\omega)} \quad (1)$$

$$IDF(t,D) = ln\left(\frac{|d|}{|\{D \epsilon D : t \epsilon D\}|}\right) \quad (2)$$

$$TFIDF(t,D,d) = tf(t,D) \cdot idf(t,d) \quad (3)$$

$F_D(t) :=$ frequency of term t in document D
$d :=$ Documment Corpus
}
i is number of feature.
Step 3: Extract the Bigram and Trigram Features

For bigram

$$P(Z_n|Z_0 \dots \dots \dots Z_{n-1}) \approx P(Z_n|Z_{n-1}) \quad (4)$$

$$P(Z_1^k) = \prod_{n=1}^{k} P(Z_n|Z_{n-1}) \quad (5)$$

For trigram

$$P(Z_n|Z_0 \dots \dots \dots Z_{n-1}) \approx P(Z_n|Z_{n-2}Z_{n-1}) \quad (6)$$

$$P(Z_1^k) = \prod_{n=1}^{k} P(Z_n|Z_{n-2}Z_{n-1}) \quad (7)$$

$P(Z_n)$:= Probability of word n^{th} Z in document d
$Z_{1,2,3\dots k}$= Word Sequence

Step 4: Concatenate both feature.

$$P_{total}(P_i) = TF - IDF(P_i) + bi - gram(P_i) + tri - gram(P_i) \quad (8)$$

Step 5: Make the subset of Summary produced by features and user input.

$$y = (\boldsymbol{x_1}, \boldsymbol{x_2}, \boldsymbol{x_3}, \dots \dots \dots \dots \dots \boldsymbol{2^n})$$

y:= is feature subset.
Step 6: Input these subset y in optimizer PSO as the particles form. Until an optimized subset is met, repeat the following:
Step 7: In PSO model for each particle j in S sentence , do for each dimension d in D do
//Initialize each particle's position and velocity to random values.

$$X_{j,d} = Rnd(x_{max}, x_{min})$$

$$sv_{j,d} = Rnd(-v_{max}/3, v_{max}/3)$$

end for
//Initialize particle's best position and velocity

$$sv_j(l+1) = sv_j(l) + \gamma 1_i(pb_j - x_j(l)) + \gamma 2_i(gb\text{-}x_j(l)) \quad (9)$$

New velocity

$$x_j(l+1) = x_j(l) + sv_j(l+1) \quad (10)$$

Where,

j	Particle Index
1	Discrete time Index
sv_j	Velocity of jth Particle
x_j	Current Position of jth Particle
pb_j	Personal Best Position of jth Particle
gb	Global Best Position
$\gamma 1_i \; and \gamma 2_i$	Random number Between the [0,1]applied to the jth Particle

Step6: Set the global best position to its initial position

$$\text{if} f(x_i) > f(pb_i)$$
$$pb_i = x_i$$

// update global best position

$$\text{if} f(pb_i) > f(gb)$$
$$gb = pb_i$$

else
end if
end for
Step 7: Optimize subset is given by PSO, find ROUGE score.
Step 8:Optimizer summary and Manual Summary Concatenate for extraction of N-gram features
Step 9: Find the Rouge Score by the following formula

$$\frac{\text{No\_of\_Overlapping\_Words}}{total\_words\_in\_refernce\_summary} \quad (11)$$

4 Experimental Result

In this paper, we used the benchmark Rastkar dataset [1, 18]. The ROUGE score is calculating based on three manual summaries of each bug report. Based on the above approach, two experiments are conducted to analyze the approach using ROUGE evaluation metric at 30% summary percentage given by user. If we decrease the summary percentage, then the important information is lost. If we increase the summary percentage, then unwanted data is included in the summary. In this experiment, the bug report summary is generated of every single bug report by using PSO optimization technique. The basic aim of this experiment is to overcome the four challenges which are discussed in the introduction section. This generated summary is compared with three human-generated summary [1, 18], and ROUGE score is calculated as demonstrated in Table 1.

It can be seen from Table 1. The range of ROUGE score based on PSO-generated summary of 10 bug reports was from 72 to 97%. The range of ROUGE score based on BRC and EC-generated summary of 10 bug reports was from 30 to 93% and 51 to 92%. The summary subsets evaluated by PSO were more effective and generated less redundant summary and covered all the important points of bug reports because PSO used n-gram approach for matching which is by default a semantic relation.

Table 1 Comparison of ROUGE score with manual summary using PSO, bug report classifier, and email classifier

Bug report no.	ROUGE score using PSO			ROUGE score using bug report classifier [1, 18]			ROUGE score using email classifier [1, 18]		
	Rouge-1	Rouge-2	Rouge-3	Rouge-1	Rouge-2	Rouge-3	Rouge-1	Rouge-2	Rouge-3
Bug 1	79.14	75.83	75.17	92.03	70.75	33.88	79.88	52.067	51.2
Bug 2	88.54	82.81	80.42	88.36	85.25	34.38	86.47	57.65	55.98
Bug 3	9.33	92.12	89.29	84.64	81.65	33.24	90.86	59.83	56.29
Bug 4	91.84	88.96	80.96	74.53	68.12	30.96	86.46	57.38	53.78
Bug 5	86.60	85.34	82.59	75.34	73.23	36.63	84.80	55.57	54.19
Bug 6	86.23	83.82	82.61	70.56	60.78	45.67	87.46	58.28	55.57
Bug 7	96.65	93.07	86.13	86.28	83.26	35.64	91.58	59.88	56.41
Bug 8	95.65	89.57	86.09	91.87	88.32	34.88	89.19	58.51	56.28
Bug 9	90.34	88.73	84.62	92.27	90.14	35.46	89.51	59.15	57.17
Bug 10	96.00	92.00	88.00	90.93	86.65	34.77	91.81	59.94	57.75

5 Conclusion

It can be concluded that the bug report summarization is very important task for bug triage process. The developer or user reported the report in BST after observing the unexpected behavior of software. With the passage of time, valuable information is accumulated of observed issues. These bug reports are not easy to read. They contained the free text as comments, discussions, and opinions about the bug fixing and bug resolving. So the reading task of these bug reports is time-consuming and tedious. To save the developer time and effort by not reading the entire bug report, need of an Extractive summary generation model of entire bug report. A novel approach is proposed to generate the bug report summary based on collection of comments. The PSO optimization technique is used to evaluate the appropriate summary subset. These subsets are generated by using informative and phraseness feature extraction methods. This method is compared with bug report classifier and email classifier. The summary subset evaluated by PSO was more effective and generated less redundant summary and covered all the important points of bug reports due to its semantic base analysis. In future work, some other optimized techniques will be applied with it to enhance the accuracy of the summarization.

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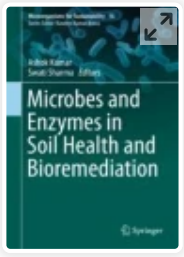

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Microbes and Enzymes in Soil Health and Bioremediation

Editors: Ashok Kumar, Swati Sharma

Presents the mechanism and various routes of bioremediation in the soil by microbes and their interaction with different genera

Provides details of microbes and their enzymes which are involved in various remediation pathways

Explains the bioremediation process of harmful chemical by single bacteria, enzymes or complex microbial communities

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About this book

Microbial enzymes play a vital role in maintaining soil health and removing pollutants from contaminated land. Soil microflora is closely associated with maintaining soil fertility, and the use of chemical pesticides, fertilizers and other volatile sprays in agriculture threatens the health ofthe microbial population in the soil. Every single particle of healthy soil contains millions of bacteria, which interact with the nutrients available, sustaining the nutrient cycle and making this microflora an essential component of life on earth. How do microbes help in the nutrient cycle? Either by intracellular digestion of macromolecules and converting these into smaller units in their metabolic pathways, or by secreting enzymes into the extracellular environment to facilitate the conversion of complex macromolecules into micro-molecules that can be easily absorbed by other living species. To meet demands for energy and food for the growing global population, it is important to protect agricultural land from contamination and maintain its productivity. Heavy metal ions from contaminated land canenter crops, fish or aquatic organismsvia contaminated water, and theseare then taken up by the human body, where they can accumulate and alter the normal microflora. The microbiological component of the soil is ahighly complex system and is still not fully understood. How do microbes survive in the changing physicochemical environment of soil?. This book helps readers understand the mechanism, various routes of

microbialsoil remediation, the interactionsof different genera, and how microbial enzymes support the sustainable restoration of healthy soil.

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Chapter 1
Let's Protect Our Earth: Environmental Challenges and Implications



Ashok Kumar, Tanvi Sharma, Sikandar I. Mulla, Hesam Kamyab, Deepak Pant, and Swati Sharma

Abstract Microbial enzymes play a vital role to maintain the soil health and removal of pollutants from the contaminated land. Soil microflora is closely associated to maintain the fertility of the soil. Use of chemical pesticides, fertilizers and other volatile sprays in the agricultural practices threatening the healthy microbial population in the soil. Every single particle of healthy soil is loaded with millions of bacteria which interact with the nutrients available in the surrounding and sustain the nutrient cycle, and this microflora is an essential component of life on earth. The rapid increase in the industrialization and urbanization polluted the water and air heavily which affected the microbial populations and their existence too. Some microbes have been evolved to breakdown the complex toxic pollutants entering the soil into non-harmful components and helping to maintain the soil fertility. Thus, it is urgently needed to identify these microorganisms and enzymes which are involved in restoring the remediation of toxic substances and restoration of microflora required for a normal life.

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1.1 Introduction

In recent years, an increase in population growth and rapid industrialization not only ameliorate the standard of life but also affected the quality of the environment. Due to the release of harmful pollutants into the ecosystem such as plastics, pharmaceutical ingredients, greenhouse gases, pesticides, and synthetic dyestuffs, every part of the earth has severely affected. These pollutants not merely caused the teratogenic, carcinogenic, mutagenic, and toxic effects on humans beings or organisms but also created a serious risk to the environment (Jacob et al. 2018; Liu et al. 2019). The heavy metal ions from the contaminated land enter in the crop products and edible vegetable fruits or in the fish or aquatic organism from contaminated water which ultimately reaches in the human body. The continuous flow of these poisonous substances or metal impurities allows them to accumulate inside the human body and alter the normal microflora. All microbial genera, bacteria, fungi, algae, nematode, and protozoa play a significant role in bioremediations and maintaining soil health. To meet the energy crisis and food demand with the growing population, it is very important to save the agricultural land from contamination and maintain productivity.

These pollutants are broadly dispersed everywhere in the environment because of various human activities and industrial processes (Bilal et al. 2019b; Rasheed et al. 2019). Numerous methods such as filtration, reverse osmosis, incineration, lagooning treatment, landfill deposition, and bioremediation using microbes and their enzymes have been applied to treat harmful pollutants (Bilal et al. 2019a; Kuppusamy et al. 2017). The major advantages of using microbial enzymes for the degradation of environmental pollutants are high efficiency, minimum by-products, no secondary pollution, economic feasibility, and environmentally safe (Garcia-Garcia et al. 2016).

Various bacterial genera were used in bioremediation that can convert pollutant into less toxic compounds: *Pseudomonas* sp., *Achromobacter* sp., *Burkholderia* sp., *Rhodococcus* sp., *Ralstonia* sp., *Alcaligenes* sp., *Sphingomonas* sp., *Dehalococcoides* sp., and *Comamonas* sp. that ultimately reduce pollutants (Lloyd et al. 2003). However, highly diverse and specific microorganisms present in nature efficiently remove the several pollutants. But microbial-based remediation is usually slow, as compared to the daily production of a huge amount of waste which causes the pollutants to accumulate in the environment. Nevertheless, molecular biology allows producing novel strains of the microorganism with desirable features for the bioremediation process, thus considerably improving the degradation capability of pollutants (Zhao et al. 2017). Microbes play a very important role in nutrient cycles by intracellular digestion of complex macromolecules and converting these into smaller

units in their metabolic activities. Secondly, the enzyme secreted in the extracellular environment facilitates the conversion of complex macromolecules into micromolecules which can be easily absorbed by other living species.

1.2 Major Environmental Challenges

1.2.1 Global Warming and Climate Change

Global warming is defined as the rise in earth temperature due to the increased level of carbon dioxide (CO_2) and other greenhouse gases (GHG). It is directly connected to the percentage of CO_2 present in the earth's atmosphere. The consequences of global warming are a rise in sea level, acidic oceans, increased air pollution, deviations in the cropping, and disease patterns. CO_2 is considered as the primary GHG that imparts to climate change, produced by the burning of fossil fuels such as coal, natural gas, and oil (He et al. 2018). A biological method like photosynthesis occurring in the plants convert CO_2 and water into organic compounds and maintains the equilibrium by fixing atmospheric CO_2 on the earth (Mondal et al. 2016). In the literature, many examples are already described for CO_2 conversion using microbes and their enzymes. Various algal species such as *Chlorella vulgaris*, *Nannochloropsis* sp., *Scenedesmus quadricauda*, *Chlamydomonas reinhardtii*, and *Nannochloris* sp. have been studied to sequester CO_2 (Eloka-Eboka and Inambao 2017). During photosynthesis, the RuBisCO enzyme in a photosynthetic organism is responsible for converting CO_2 into inorganic carbon. The major limitation of RuBisCO is a low affinity for CO_2 (Pavlik et al. 2017). However, CO_2 removal using biological methods is not suitable for region specific large-scale CO_2 sequestration such as industries outlets and polluted cities.

In a recent study, *Methylobacterium extorquens* formate dehydrogenase was reported for the conversion of CO_2 to formate (Jang et al. 2018). Carbonic anhydrase is an enzyme that is mostly used for conversion of CO_2 to bicarbonate (Sharma et al. 2018). Many bacterial species having CA enzyme are *Aeribacillus pallidus, Lactobacillus delbrueckii, Bacillus* sp., *Pseudomonas fragi, Serratia* sp., have been studied for conversion of CO_2 into calcium carbonate (Bose and Satyanarayana 2017; Li et al. 2015; Sharma et al. 2009; Srivastava et al. 2015; Sundaram and Thakur 2018). CO_2 sequestration using microbes offers a reduction of the major greenhouse gas CO_2 and, hence, ameliorates global warming.

1.2.2 Plastic Pollution on Earth

Synthetic plastics represent the main anthropogenic waste entering and accumulating into the environment. Indeed, plastic pollution is now considered a global environmental threat, together with ozone depletion, ocean acidification, and climate

changes (Barboza et al. 2018). Plastic is used in everyday life such as packaging material, clothes, water bottles, and carpets. Plastics such as polyethylene terephthalate (PET), polypropylene, and polyethylene present a serious risk to plant and animals growing in the marine ecosystem. The chemical bonds between the plastic monomer are stronger, so they are resistant to natural degradation.

While microplastics are plastic particles less than five millimeter, are of special concern due to their small size, high surface/volume ratio, long environmental persistence, and their ability to enter into the cells and cause adverse effects (Peixoto et al. 2019). The abiotic degradation of man-made plastic by temperature, oxygen, UV radiation, and physical stress (Gewert et al. 2015) slowly degrades plastic and generates microplastic which can spread into the environment by wind (Urbanek et al. 2018). Due to the agglomerations of plastics in the environment, microorganisms are evolving catabolic pathways and enzymes to partly degrade plastic (Yang et al. 2015).

In the literature biodegradation of polyethylene by different microbial strains such as *B. subtilis, Acinetobacter baumanni, Arthrobacter* sp., *Staphylococcus epidermidis and Flavobacterium* sp. was reported (Restrepo-Flórez et al. 2014; Vimala and Mathew 2016). A newly discovered bacteria *I. sakaiensis* enzyme PETase was reported that uses polyethylene terephthalate (PET) as a major energy and carbon source for growth and converts into nontoxic form (Yoshida et al. 2016). This enzyme thus offers a platform for further modification using directed evolution and protein engineering strategy to boost the efficiency of the enzyme, toward the persistent challenge of highly crystalline polymer degradation (Austin et al. 2018). Thermoset plastics such as polyester polyurethane and aliphatic polyester are simply attacked by microbes because of easily digestible ester and urethane bonds in their structures. Other enzymes secreted by microbes that show biodegradable activity include the esterases, lipases, dehydratases, depolymerases, cutinases, ureases, and proteinases (Dang et al. 2018; Masaki et al. 2005; Sood et al. 2016; Zheng et al. 2005). Nowadays bioplastic made from renewable natural resources has received a lot of attention and can be used to replace the plastic (Mostafa et al. 2018). However, bioplastic has not completely replaced the petroleum-based plastic due to various economic and manufacturing challenges.

1.2.3 Chemical Pesticides as a Pollutant on Earth

Currently, pesticides are applied in agricultural production to halt the growth of pests and associated diseases. The most commonly used pesticides include atrazine, lindane, chlordane, DDT, aldrin, cypermethrin, and heptachlor (Pereira et al. 2015). The rise in the use of pesticides/chemical fertilizers in agriculture practices has led to contamination of water, air, and land and adverse effect on human health

(Craig 2019; Li 2018). Although pesticides play a vital role in agriculture, these are recalcitrant to biodegradation and persist in the ecosystem for many years (Kumar et al. 2018; Nicolopoulou-Stamati et al. 2016).

Various microbial species such as *Arthobacter*, *Aspergillus*, *Chorella*, *Penicillium*, *Pseudomonas*, *and Flavobacterium* have shown a capability to degrade pesticides into a less toxic product by using enzymes (Kumar et al. 2018). Various enzymes have been isolated from microorganism such as diisopropyl fluorophosphatase, parathion hydrolase, phosphotriesterase, esterase, and paraoxonase, to study the pathways involved in the biotransformation of these xenobiotic compounds (Cycoń and Piotrowska-Seget 2016; Lu et al. 2013; Singh and Walker 2006; Zuo et al. 2015). These indigenous microbes have limited degradation efficiency, so at present several bacteria containing pesticide-degrading gene can be used for constructing genetically engineered bacteria (Hong et al. 2010). For environmental sustainability, the development of biological pesticides has become the key to safeguard the health of human and agricultural development.

1.2.4 Pharmaceutical Pollution and Increased Antimicrobial Resistance

The excessive use of antibiotics in animal and human medicine, as well as in agriculture, has not only led to their accumulation in the environment but also developed the broad range of highly antibiotic-resistant microorganisms (Almakki et al. 2019). Most bacteria develop resistance against commonly used antibiotics like methicillin-resistant *S. aureus, erythromycin-resistant Streptococcus, penicillin-resistant Pneumococcus, and tetracycline-resistant Shigella* (*Sengupta* et al. 2013; Ventola 2015). Wastewater effluents from pharmaceutical industry enter into the rivers, rich in antibiotics, steroids, hormones, and analgesic components, which have adversely affected the microbial ecology (Ding and He 2010). The continuous exposure of terrestrial and aquatic microorganisms to pharmaceuticals products has affected the genetic composition of microbial genera and developed the antimicrobial resistant genes.

However, biological methods for converting pharmaceutical pollutant into non-toxic forms are attractive because they are inexpensive and environment-friendly (Zur et al. 2018). Many bacterial and fungal strains such as *Klebsiella, Penicillium, Pseudomonas, Aspergillus, Sphingomonas* sp., *Bacillus, Enterobacter, Aeromonas, and Streptomyces* have been reported for biotransformation of pharmaceutical pollutant (Rana et al. 2017). Biotransformation results in the formation of the end product that is less toxic and more stable than the initial compound.

1.2.5 Heavy Metal Pollution on Earth

Heavy metals are metalloids that have density more than 5 g/cm^3 such as mercury, arsenic, and lead (Tchounwou et al. 2012). Heavy metals occur naturally in the earth's crust and anthropogenic activities such as smelting, mining, petroleum combustion, and burning of coal in power plant, and use of fertilizer increases its existence in the environment (He et al. 2005). In natural systems, heavy metals affect cellular organelles like endoplasmic reticulum, lysosome, cell membrane, nuclei, mitochondria, and various enzymes involved in detoxification, metabolism, and damage repair. Metal ions interact with nuclear proteins and DNA, causing conformational changes and DNA damage that leads to apoptosis or carcinogenesis (Wang and Shi 2001). Due to the persistence of metal in the terrestrial environment, heavy metal pollution poses a risk to animal, plant, and human health (Mishra 2017).

Heavy metal bioremediation by microorganism is emerging as an efficient technique. Different mechanisms used by microorganisms to tolerate the metal toxicity are extrusion, biotransformation, use of enzymes, and synthesis of metallothioneins and biosurfactants (Igiri et al. 2018; Ramasamy et al. 2007). *P. putida* is cadmium-tolerant strain and has the intracellular ability to sequester zinc, copper, and cadmium, by using cysteine-rich low molecular weight proteins (Higham et al. 1986). *Bacillus pumilus*, *Alcaligenes faecalis*, *Brevibacterium iodonium*, and *Pseudomonas aeruginosa* were reported for the removal of cadmium and lead (De et al. 2008). Microbial bioremediation is a cost-effective and eco-friendly technology for the clean-up of heavy metals.

1.3 Restoration of Soil Health Using Microbes

Soil respiration, microbial biomass, enzyme activities, and microbial diversity are the major biological indicators of soil health. Healthy soils are necessary for the integrity of terrestrial ecosystem or to recover from trouble, such as climate change, pest infestation, drought, pollution, and human exploitation including agriculture (Ellert et al. 1997). Moreover, with the continuous increase in the world's population, the demand for food production has increased (Fageria et al. 2008). But nowadays agricultural practices include the use of potentially dangerous chemical fertilizers that affects the soil and human health (Glick 2018). Protection of soil is therefore of high priority, and a thorough understanding of ecosystem processes is a critical factor in assuring that soil remains healthy. These enzymes catalyze many vital reactions necessary for the life processes of soil microorganisms and also help in the stabilization of soil structure. Although microorganisms are the primary source of soil enzymes, plants and animals also contribute to the soil enzyme pool. Soil enzymes respond rapidly to any changes in soil management practices and environmental conditions. Their activities are closely related to the physiochemical and biological properties of the soil. Hence, soil enzymes are used as sensors for

soil microbial status, for soil physiochemical conditions, and for the influence of soil treatments or climatic factors on soil fertility. Overall the microbe and enzyme profile in the soil must be stabilized in order to maintain the health of the soil, its fertility and to sustain agricultural growth. At present, the biogeochemical cycles in the agricultural ecosystem have been disturbed as a result of increased pollution and toxic level in the environment. The rate of organic content decomposition becomes lesser due to the extinction of various soil microflora. Therefore, it becomes necessary to find the suitable troubleshoot methods to prevent the increase in soil pollution to restore the decreased fertility of soil using biological approaches.

1.4 Conclusion

The soil microflora and enzyme quantity vary with external factors, physical and chemical conditions. Whichever may be the source of pollution either industries, fertilizers, pesticides, or urbanization and automobiles, each source has seriously damaged the microbial population and enzyme activity of the soil. This is also very complex to determine the exact level of microbial existence and enzyme activity in various geographical areas. Undoubtedly, molecular biology techniques, such as directed evolution and recombinant DNA technology, have revolutionized the speed of enzyme and microbe engineering which could be a milestone to restore the microbial population and enzyme activity in the soil. In this book chapter, we have given an overview of various types of pollutants which are affecting the soil or water bodies on the earth and how various microbes and enzymes are correlated with the existence or increasing level of this pollution.

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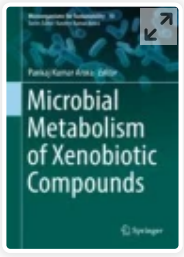

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About this book

Xenobiotic compounds including pesticides, nitrophenols, pyridine, polycyclic aromatic compounds and polychlorinated biphenyls are widely spread in environment due to anthropogenic activities. Most of them are highly toxic to living beings due to their mutagenic and carcinogenic properties. Therefore, the removal of these compounds from environment is an essential step for environmental sustainability. Microbial remediation has emerged as an effective technology for degradation of these xenobiotic compounds as microorganisms have unique ability to utilize these compounds as their sole source of carbon and energy. The primary goal of this book is to provide detailed information of microbial degradation of many xenobiotic compounds in various microorganisms.

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Xenobiotic Compounds **Bioremediation**

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Chapter 16
An Overview of Nitro Group-Containing Compounds and Herbicides Degradation in Microorganisms



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Abstract Basically, nitro functional group-containing chemicals have been used to synthesize various useful products like dyes, pesticides and solvents, and also military products and so on. Hence, many nitroaromatics (including nitrophenols) have been continuously released into the environment and appear in the soil and water. Some are known to be toxic due to their great impact on living systems (especially on health). Most such chemicals (nitroaromatic compounds) are listed as priority chemicals by the Environmental Protection Agency (EPA). The vast use of such chemicals and their toxic effects had led to the study of the degradation of nitro group-containing chemicals by microbes (an easily available and cost-effective treatment). In view of this, we discuss the degradation of a few nitro group-containing compounds and herbicide(s) by microorganisms from published literature, and we consider the future perspective.

Keywords 3,5-dinitro-*ortho*-cresol · 4-nitrophenol · Picric acid · Microorganisms · Degradation

16.1 Introduction

Over the last several decades, natural and manmade chemicals, including antimicrobial agents, antibiotics, personal care products, pesticides, herbicides, chlorinated aromatics and nitroaromatics, among others, have been used for various purposes in day-to-day life (Hoskeri et al. 2011, 2014; Megadi et al. 2010; Mulla et al. 2011a, b, 2016a, b; Tallur et al. 2015; Talwar et al. 2014). The long-term use of consumer products has released these chemicals to the environment, where they continually show up at levels from less than 1 nanogram to more than 1 microgram per litre (Mulla et al. 2012, 2014, 2016c, d, 2018). In recent years, several (including chloro and nitro group-containing aromatics) were found to be toxic to living beings—from humans to aquaculture organisms (Kovacic and Somanathan 2014; Edalli et al. 2018; Mulla et al. 2014, 2016c, d, 2017; Tallur et al. 2015). Various researchers from many countries have thus been prompted to investigate decontamination methods that would be effective on such chemicals (Arora et al. 2014, 2017; Burkul et al. 2015; Li and Yang 2018; Osin et al. 2018). Among the avenues considered, of the use of non-harmful biological mediators to detoxify toxic chemicals in wastewater treatment plants gained significantly more importance. In this chapter, we discuss some nitro group-containing compounds as used for degradation of toxic substances in microbes.

16.2 Uses of and Environmental Pollution by Nitro Group-Containing Compounds

In general, nitro group-containing chemicals go into the synthesis of certain useful products, for example, explosives, dyestuffs, insecticides, herbicides and rubbers (Arora et al. 2014; Douglas et al. 2011; Haizhen et al. 2009; Khalid et al. 2009; Spain 1995; Wan et al. 2007; Ye et al. 2004). In addition, they are also found in the preparation of products like medicines, fuels for vehicles, wall paints, solvents for polish, electronic batteries, coloured glass, etc. (Beard and Noe 1981; Dunlap 1982; Hirai 1999; Plunkett 1966; Windholz et al. 1976; Ware 1994).

On the other hand, most of nitro group-containing chemicals (including nitrophenols), are stable, but, some possess toxic properties (especially carcinogenicity) (Ju and Parales 2010; Kovacic and Somanathan 2014; Nishino et al. 2000; Padda et al. 2003; Purohit and Basu 2000). Hence, several (including nitrophenols) are included in the U.S. EPA list (Ju and Parales 2010). Some of these nitro group-containing chemicals have also been detected in food products. Likewise, mutagenic property-containing nitroaromatic compounds have been found in the atmosphere, especially by way of cigarette smoke and vehicle fuels (Kinouchi and Ohnishi 1983). Most of these have similar functional properties that make them beneficial for industrial use, on the one hand, while causing them to be harmful to the health of living systems. In general, the widespread use of nitroaromatics impacts the environment by contaminating soil and water (including groundwater) (Rieger and Knackmuss 1995; Ju and Parales 2010). Likewise, nitro functional group-containing insecticides are purposely applied to crops, leaving surrounding fields open to possible contamination. Additionally, inadequate management and/or loading practices by both manufacturers and customers results in their unintended injection into the environment (Mulla et al. 2014). For example, a Toxics Release Inventory report 2002 reported that nearly 11500 kg of 2,4-Dichloro-1-(4-nitrophenoxy)-benzene, 5100 kg of nitrobenzene and 1100 kg of 2,4-dinitrotoluene have been discharged into territory of United States (White and Claxton 2004). Ecological contamination from explosives manufacturers also occurs in Germany (Spain et al. 2000). The toxicological effects of nitro group-containing chemicals are well discussed in the literature (Kovacic and Somanathan 2014).

16.3 Biodegradation of Nitro Group-Containing Chemicals

Among multipurpose industrial organic compounds, nitro group-containing chemicals are among those most used in pesticides, pharmaceuticals, pigments, dyes, etc. (Haghighi-Podeh and Bhattacharya 1996). These chemicals may stay in the soil as

the by-products of insecticides like parathion, methyl-parathion and other more complex nitroaromatics (including herbicides) through hydrolysis. Hence, many researchers with the aim of detoxification of such chemicals have demonstrated that various organisms are able to utilize different types of nitrophenols as a growth substrate. Generally, the nitro group-containing chemical degradation process involved oxidation (monooxygenase and/or dioxygenase) and/or reduction (reductase) or Meisenheimer complex generation.

16.3.1 Microbial Degradation of Mononitrophenols

The bacterial culture *Pseudomonas putida* B2 utilizes both *ortho-* and *meta-*nitrophenol as a growth substrate and degrades both substrates by producing different pathways (Zeyer and Kearney 1984). In *Alcaligenes* sp. NyZ215 (Xiao et al. 2007) and *Pseudomonas putida* B2, enzyme monooxygenase initiates oxidative mechanism of 2-nitrophenol and is transformed to catechol with the elimination of nitrite ions. Catechol is further degraded by catechol 1,2-dioxygenase and finally enters into TCA cycle (Zeyer and Kearney 1984; Zeyer et al. 1986) (Fig. 16.1).

On the other hand, there are two different degradative pathways for 3-nitrophenol. However, both initiate with reduction of 3-nitrophenol to form 3-hydroxylaminophenol (Fig. 16.2).

During the degradation of 3-nitrophenol in *Pseudomonas putida* B2, the compound is initially transformed to 3-hydroxylaminophenol by reductase enzyme and subsequently transformed to 1,2,4-trihydroxybenzene with the release of ammonia (Meulenberg et al. 1996) (Fig. 16.2). In contrast, in *Ralstonia eutropha* JMP134, 3-nitrophenol is transformed to 3-hydroxylaminophenol through aminohydroquinone molecule (Fig. 16.2), and ammonia is released in the ring-cleavage pathway (Schenzle et al. 1997). Moreover, the enzymes involved during the degradation of 3-nitrophenol in strain JMP134 also help the bacterium to utilize 2-chloro-5-nitrophenol as the growth substrate (Schenzle et al. 1999).

On the other hand, various microbial strains are isolated and identified on the basis of their capacity to utilize 4-nitrophenol as a growth substrate. In most of cases it has been observed that 4-nitrophenol is degraded into either only 4-nitrocatechol by oxidative mechanism and/or further altered to 1,2,4-trihydroxybenzne with the release of nitrite (Fig. 16.3) in different genus bacteria like *Achromobacter xylosoxi-*

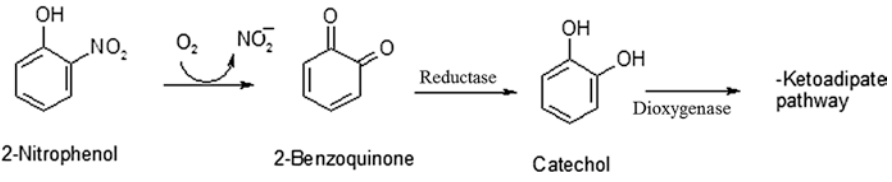

Fig. 16.1 Bacterial degradation of 2-nitrophenol

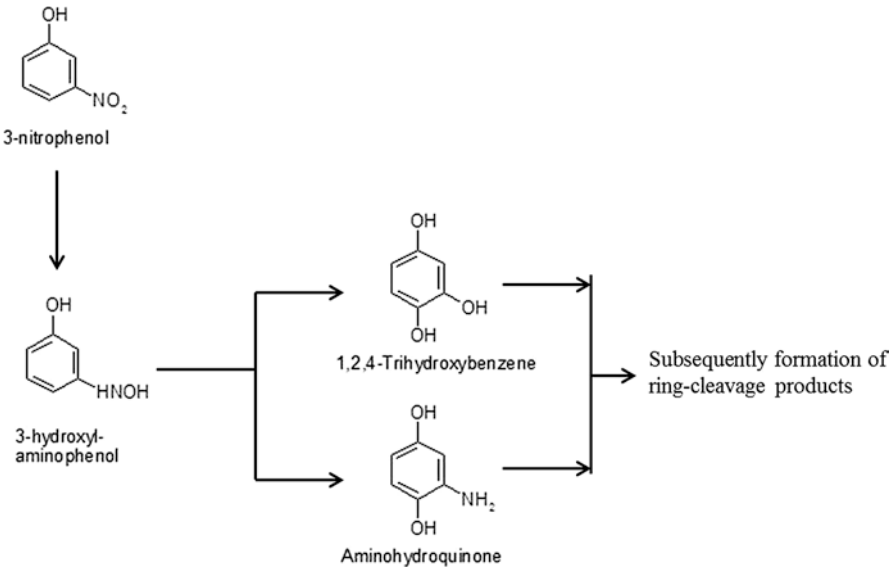

Fig. 16.2 Bacterial degradation of 3-nitrophenol

dans Ns, *Arthrobacter chlorophenolicus* A6, *Arthrobacter* sp. CN2, *Arthrobacter* sp. strain JS443, *Arthrobacter* sp. Y1, *Arthrobacter protophormiae* RKJ100, *Bacillus sphaericus* JS905, *Burkholderia cepacia* RKJ200, *Ralstonia* sp. SJ98, *Rhodococcus opacus* AS2, *Rhodococcus erythropolis* AS3, *Rhodococcus imtechensis* strain RKJ300, *Rhodococcus opacus* SAO101 and *Serratia* sp. strain DS001 (Arora et al. 2014; Gosh et al. 2010; Jain et al. 1994; Ju and Parales 2010; Kadiyala and Spain 1998; Kitagawa et al. 2004; Li et al. 2008; Pakala et al. 2007; Unell et al. 2008; Wang et al. 2016).

Kadiyala and Spain (1998) demonstrated that enzymes like oxygenase and flavoprotein reductase are involved in the first two oxidation steps of 4-nitrophenol to 2-hydroxyl-1,4-quinone by the release of nitrite in *Bacillus sphericus* JS905 (Fig. 16.3). However, bacterial strains like *Arthrobacter aurescens* TW17, *Arthrobacter* sp. YUP-3, *Pseudomonas putida* JS444, *Pseudomonas* sp. strain WBC-3, *Methylobacterium* sp. C1, *Moraxella* sp., *Rodococcus opacus* SAO101 and *Rodococcus* sp. PN1 (Hanne et al. 1993; Kitagawa et al. 2004; Nishino and Spain 1993; Spain and Gibson 1991; Takeo et al. 2008; Tian et al. 2018; Yue et al. 2018; Zhang et al. 2009) transformed 4-nitrophenol to benzoquinone with the help of enzyme monooxygenase. The by-product further converted to hydroquinone molecule (Spain and Gibson 1991) (Fig. 16.3). Furthermore, the pathways are similar at the ring cleavage, where hydroquinone and 1,2,4-trihydroxybenzene molecules individually transform into maleylacetate and finally enter into TCA cycle (Fig. 16.3). Hanne et al. (1993) studied the degradation of 4-nitrophenol by *Nocardia* sp. strain TW2 in the presence of different chemical inducers, and their results suggest that 1,2,4-trihydroxybenzene and hydroquinone pathways are expressed differ-

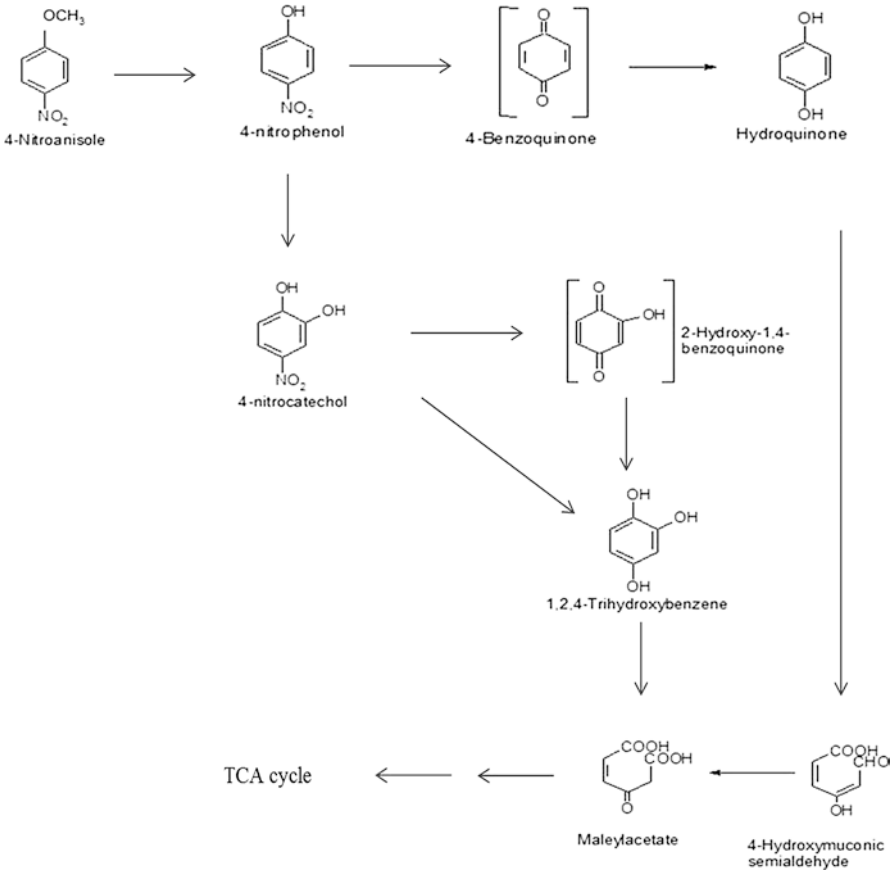

Fig. 16.3 Bacterial degradation of 4-nitrophenol and 4-nitroanisole

ently. Likewise, a similar process was also observed in both *Rhodococcus* strain PN1 and QAO101. Hence, an in-depth study of these bacterial strains is essential in order to know the exact mechanism of regulation of 4-nitrophenol catabolism. Yue et al. (2018) studied the bioaugmentation of *Methylobacterium* sp. C1 towards 4-nitrophenol removal, and their results suggest that *Methylobacterium* sp. C1 with other two bacterial cultures (*Bacillus megaterium* T1 and *Bacillus cereus* G5) biofilm were shown to be highly resistant as well as more efficient for the removal of 4-nitrophenol (up to 0.6 g/L). On the other hand, Min et al. (2017a) demonstrated by applying *Burkholderia* sp. strain SJ98 to artificially contaminated soil (4-nitrophenol, 3-methyl-4-nitrophenol and 2-chloro-4-nitrophenol), and their results suggest that the bacterial culture efficiently degrades all three compounds, thereby decreasing the concetration of nitrophenol, leading significantly to enhancement of several genera of rich microorganisms like *Nonomuraea*, *Kribbella* and *Saccharopolyspora*. Recently, Subashchandrabose et al. (2018) demonstrated 4-nitrophenol degradation by *Rhodococcus wratislaviensis* strain 9, and their results

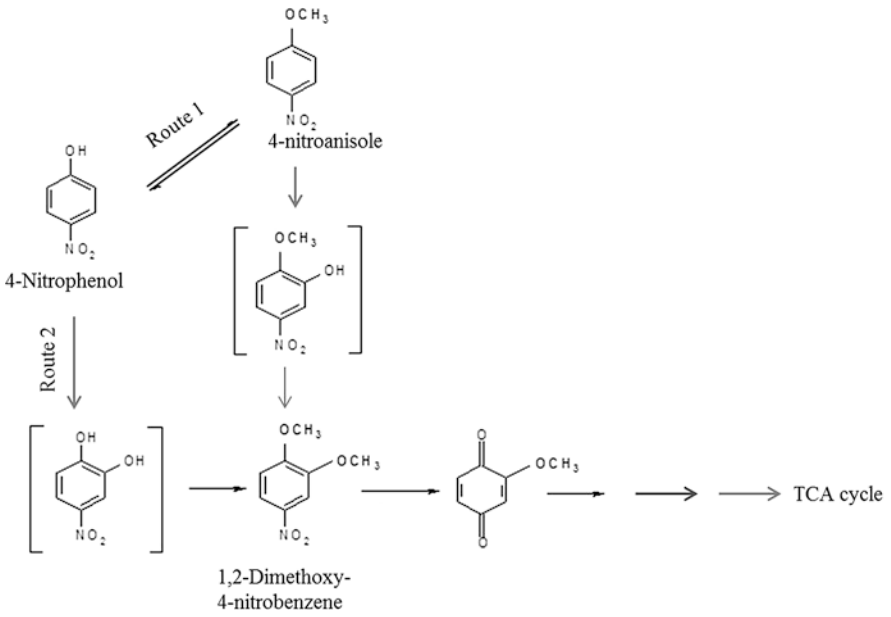

Fig. 16.4 Fungal degradation of 4-nitrophenol

showed the organism is able to degrade 900 μM of 4-nitrophenol within 14 h. Likewise, 4-nitroanisole degradation in two individual bacterial strains (AS2 and AS3) was studied, showing that 4-nitrophenol as a key intermediate occurs during degradation (Schäfer et al. 1996) (Fig. 16.3).

Teramoto et al. (2004) studied how the fungal culture *Phanerochaete chrysosporium* can utilize 4-nitrophenol as a sole source of carbon and energy. However, basically under ligninolytic conditions, 4-nitrophenol transforms to 1,2-dimethoxy-4-nitrobenzene (DMNB) through by-product formation of 4-nitroanisole by the fungus (Fig. 16.4).

16.3.2 Microbial Degradation of Di- and Trinitrophenol

Very few known microbes are able to utilize both dinitrophenols such as 2,4-dinitrophenol and 2,6-dinitrophenol and trinitrophenols like picric acid (2,4,6-trinitrophenol) as growth substrate. Ecker et al. (1992) demonstrated a bacterium is able to utilize 2,6-dinitrophenol as a growth substrate. Interestingly, in *Cupriavidus necator* JMP134, the degradative pathway of 2,6-dinitrophenol is different than the 3-nitrophenol degradation pathway.

In bacterial strain JMP134, degradation initiates with the oxidation step to transform 2,6-dinitrophenol to 4-nitro pyrogallol with the help of a dioxygenase enzyme that releases the first nitrite ion from the benzene ring. In the next step, the by-

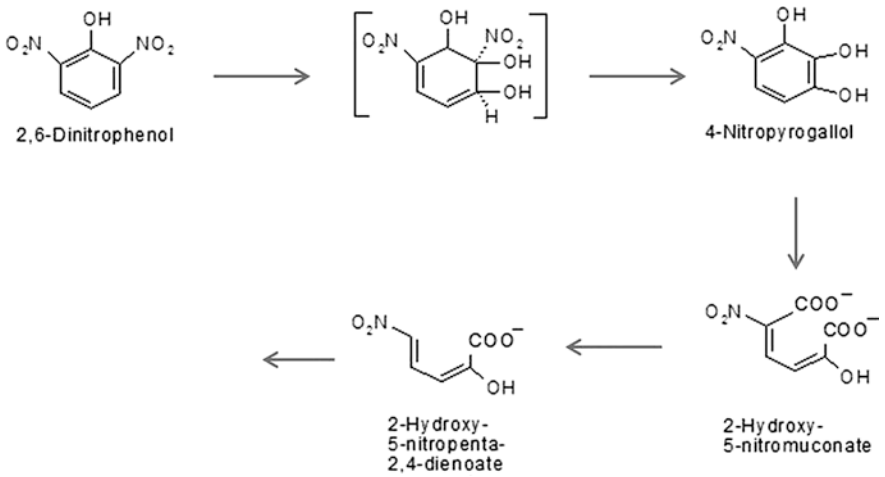

Fig. 16.5 Bacterial degradation of 2,6-dinitrophenol

product is further converted to 2-hydroxy-5-nitro muconate in a ring-cleavage and subsequently transforms to 2-hydroxy-5-nitropenta-2,4-dienoic acid by decarboxylation (Fig. 16.5). However, it was predicted that the other nitro radical present on the broken benzene ring might be released during subsequent steps. On the other hand, various genera of bacterial cultures like *Anabaena variabilis*, *Anabaena cylindrica*, *Burkhorderia* KU-46, *Haloanaerobiumpraevalens* DSM 2228, *Janthinobacterium* sp., *Nocardioides* sp. strain CB22–2, *Methanococcus* sp. B, *Nocardioides simplex* FJ2-1A, *Rhodococcus erythropolis* strain HL24–1, *Rhodococcus erythropolis* strain Hl24–2, *Rhodococcus imtechensis* strain RKJ300, *Rodococcus* sp. strain RB1, *Rhodococcus* sp. strain NJUST16 and *Sporohalobacter marismortui* ATCC 35420 (Behrend and Heesche-Wagner 1999; Blasco et al. 1999; Boopathy 1994; Gosh et al. 2010; Hess et al. 1993; Hirooka et al. 2006; Iwaki et al. 2007; Lenke and Knackmuss 1992; Oren et al. 1991; Rajan et al. 1996; Shen et al. 2009; Zin et al. 2018) utilize either 2,4-dinitrophenol and/or picric acid as a growth substrate. Initially, Knackmuss and research group studied the catabolic pathway of 2,4-dinitrophenol and picric acid in microorganism(s) (Ju and Parales 2010) (Fig. 16.6).

During the degradation process, a hydride-Meisenheimer complex is formed by the reduction of picric acid and produces 2,4-dinitrophenol with the release of a nitrite radical. Again, by hydride-Meisenheimer complex and reduction, hydrolytic cleavage of 2,4-dinitrophenol occurs, producing 4,6-dinitrohexanoate and finally entering into TCA cycle through various by-product formations. Yet, few of the responsible genes and enzymes of the degradative pathway have been determined with respect to their functional characterization and regulation mechanism (Arora et al. 2014; Ju and Parales 2010). Still, it is necessary to know the exact mechanism involved in catabolic regulation of 2,6-dinitrophenol, 2,4-dintrophenol and picric acid in different bacterial strains.

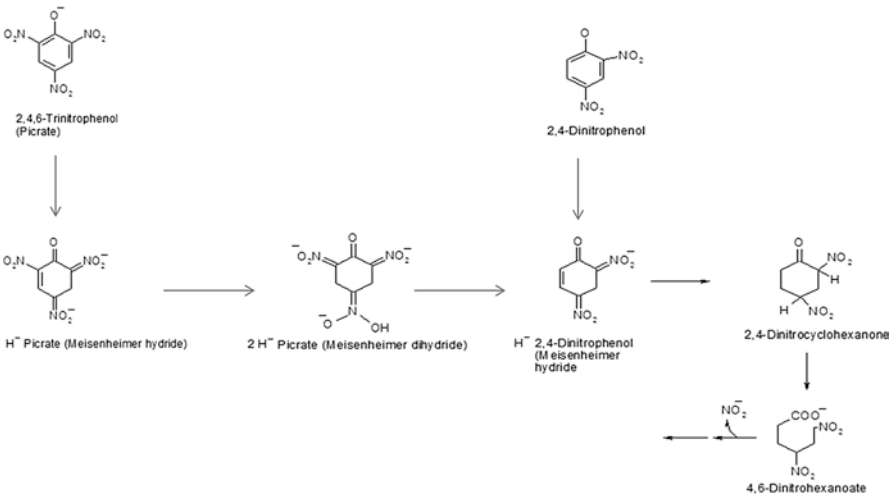

Fig. 16.6 Bacterial degradation of 2,4-dinitrophenol and picric acid

16.3.3 Microbial Degradation of Chloro and Nitro Group-Containing Chemicals

Very few microbes (*Arthrobacter nitrophenolicus* SJCon, *Burkholderia* sp. RKJ800, *Burkholderia* sp. strain SJ98, *Cupriavidus* sp. strain CNP-8 and *Rhodococcus imtechensis* RKJ300, etc.) are known to utilize 2-chloro-4-nitrophenol as a growth substrate (Arora et al. 2014, 2017; Min et al. 2018). A *Rhodococcus imtechensis* strain RKJ300 was isolated from pesticide-contaminated soil by enrichment with 4-nitrophenol as a growth substrate (Gosh et al. 2010). The organism also utilizes 2-chloro-4-nitrophenol as a growth substrate. In *Cupriavidus* sp. strain CNP-8 and *Rhodococcus imtechensis* strain RKJ300, the degradation of 2-chloro-4-nitrophenol initiates with oxidation to form chlorohydroquinone with the release of nitrite. In the next step, the metabolic by-product is dechlorinated and forms hydroquinone and subsequently converts to *gamma*-hydroxymuconic semialdyhyde and finally enters into TCA cycle (Fig. 16.7).

In *Arthrobacter nitrophenolicus* SJCon, 2-chloro-4-nitrophenol degraded to chlorohydroquinone and was further converted to maleylacetate by oxidation, which finally entered into TCA cycle. On the other hand, in *Burkholderia* sp. SJ98, 2-chloro-4-nitrophenol degraded into 4-nitrophenol with the release of chloride radicals, which was further sequentially converted into maleylacetate via 4-nitrocatechol and 1, 2, 4-benzenetriol and finally entered the TCA pathway (Fig. 16.7).

Schenzle et al. (1999) demonstrated that *Ralstonia eutropha* JMP134 (also known more recently as *Cupriavidus necator*) utilizes 2-chloro-5-nitrophenol as a growth substrate. Initially, 2-chloro-5-nitrophenol is reduced to 2-chloro-5-hydroxylaminophenol, then follows an enzymatic Bamberger rearrangement

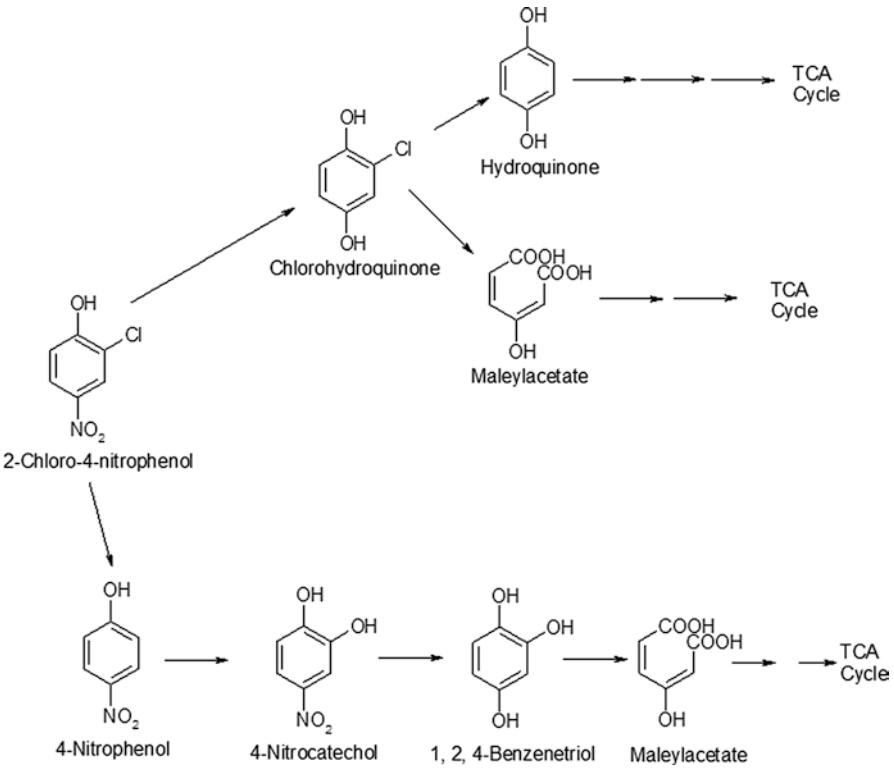

Fig. 16.7 Bacterial degradation of 2-chloro-4-nitrophenol

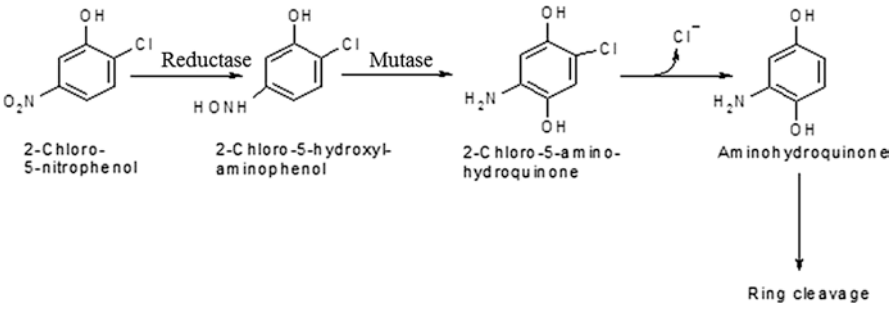

Fig. 16.8 Bacterial degradation of 2-chloro-5-nitrophenol

forming 2-amino-5-chlorohydroquinone, which is further converted to aminohydroquinone with the release of chlorine (Fig. 16.8). Similarly, in *Cupriavidus* sp. strain CNP-8, 2-chloro-5-nitrophenol degradation is initiated by reduction and finally enters into TCA cycle via sequential transformation to different by-products (Min et al. 2017b).

16.3.4 Microbial Degradation of Nitro Group-Containing Herbicides

Different genera of bacterial cultures like *Arthrobacter*-like organisms, *Corynebacterium simplex*, a *Pseudomonas*-like strain and two unidentified bacterial strains isolated from soil showed the ability to degrade a well-known herbicide 3,5-dinitro-*ortho*-cresol (Gundersen and Jensen 1956; Jensen and Gundesen 1955; Jesnen and Lautrup-Larsen 1967; Tabak et al. 1964). Interestingly, in all of these studies the only intermediate by-product detected was a nitrite radical. Tewfik and Evans (1966) reported concisely on a *Pseudomonas* sp. that metabolized 3,5-dinitro-*ortho*-cresol by a reduction process. During degradation, both nitro functional groups were reduced to amino groups, which were further oxidatively deaminated to form 2,3,5-trihydroxytoluene before entering into the ring-cleavage pathway (Fig. 16.9). On the other hand, in *Arthrobacter simplex*, 3,5-dinitro-*ortho*-cresol initially was converted to 3-methyl-5-nitrocatechol and subsequently transformed to 2,3,5- trihydroxytoluene and finally entered into TCA cycle via ring fission (Tewfik and Evans 1966) (Fig. 16.9).

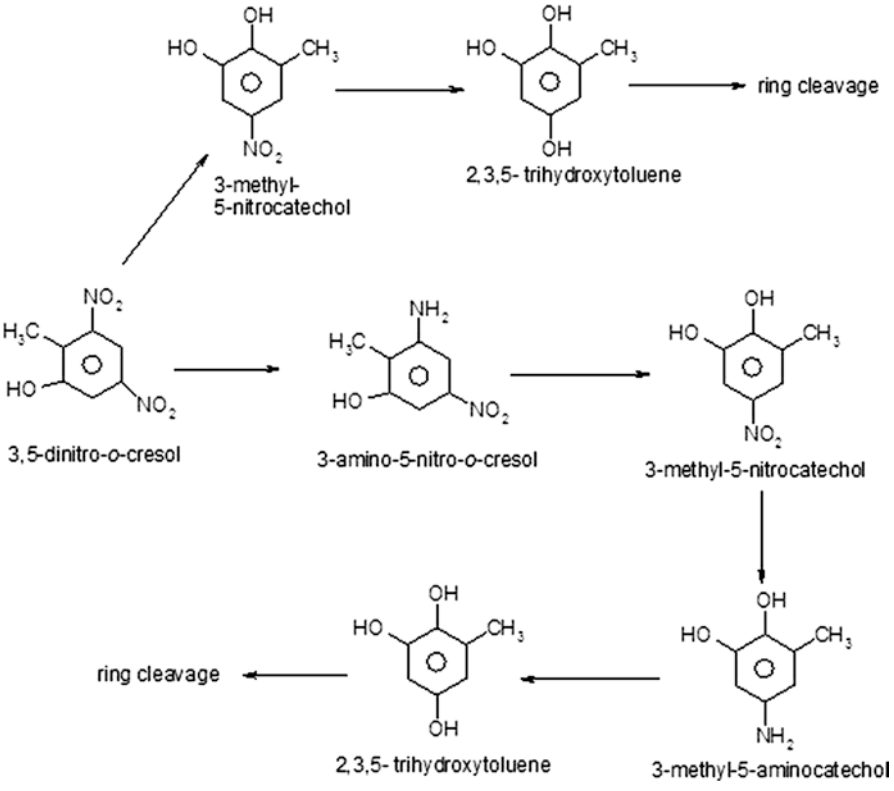

Fig. 16.9 Bacterial degradation of 3,5-dinitro-*ortho*-cresol

Meanwhile, the same research group also found that in the *Corynebacterium simplex* strain (reported earlier by Gundersen and Jensen 1956), 3,5-dinitro-*ortho*-cresol is degraded by essentially the same metabolic route; however, apart from that, reduced by-products probably were not formed as no nitroreductase activity could be confirmed in this organism (Fig. 16.9). Likewise, degradation of the other herbicide, 2-sec-butyl-4,6-dinitrophenol (dinoseb) by bacterial isolates was studied and reported (Stevens et al. 1991). However, the isolates in this case were unable to degrade the herbicide without a co-substrate. But, when the medium contained glucose/ammonium chloride with dinoseb under unshaken conditions, the medium turned a bright red colour, indicating formation of by-product(s). Various transformed products were detected and identified by GC-MS (Stevens et al. 1991). Similarly, Kaake et al. (1995) demonstrated a dinoseb degradation mechanism by bacterial cultures under reducing conditions, and they proposed a degradative pathway for dinoseb on the basis of reduction of nitro groups (attached on the benzene ring of dinoseb) with the formation of amino groups, which subsequently were replaced with hydroxyl groups.

16.4 Conclusions and Perspectives

The information reviewed in the present chapter represents the immense effort undertaken in the investigation to carry out the detoxification of nitro group-containing chemicals and herbicides. In recent times, the topic of biodegradation of such chemicals in biological living systems has emerged in the scientific community. The applications of microbes (individual pure and mixed cultures) towards catabolism of nitro group-containing chemicals and herbicides are being used now, especially in wastewater treatment plants, because, the method is freely available and cost-effective. Degradation mechanisms (especially genomic profile and enzymatic characterization) of several nitro group-containing chemicals have been comprehensively investigated in microbes (especially in bacteria). However, a few key questions still need to be clarified, among others: What is the behaviour of microbes towards a shock load of such chemicals? Can these microbes remediate such chemicals under various environmental conditions? Can a pure culture co-operate with other organism(s) (especially in a bioaugmentation process) during the degradation of such chemicals? The present substantial information for understanding the mechanisms of microbial degradation of nitro group-containing chemicals will help future studies.

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Mobile Solutions and Their Usefulness in Everyday Life

Editors: Sara Paiva

Features practical, tested applications of technological mobility solutions for visual impaired people

Presents topics such as obstacle detection systems, urban mobility, smart home services, and ambient assisted living

Includes a number of application examples in education, health, electronics, tourism, and transportation

Part of the book series: EAI/Springer Innovations in Communication and Computing (EAISICC)

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About this book

This book provides an insight into recent technological trends and innovations in solutions and platforms to improve mobility of visually impaired people. The authors' goal is to help to contribute to the social and societal inclusion of the visually impaired. The book's topics include, but are not limited to, obstacle detection systems, indoor and outdoor navigation, transportation sustainability systems, and hardware/devices to aid visually impaired people. The book has a strong focus on practical applications tested in a real environment. Applications include city halls, municipalities, and companies that must keep up to date with recent trends in platforms, methodologies and technologies to promote urban mobility. Also discuss are broader

realms including education, health, electronics, tourism, and transportation. Contributors include a variety of researchers and practitioners around the world.

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Sara Paiva has a Ph.D. in Computer Science and is an invited professor at Instituto Politécnico de Viana do

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Chapter 7
A PHR-Based System for Monitoring Diabetes in Mobile Environment



Yugal Kumar, Geeta Yadav, Pradeep Kumar Singh, and Punkhari Arora

Abstract Currently, people are more concerned about their health and diseases. Therefore, their interests in health and diseases have increased tremendously in the last decade. Till date, medical industries developed several programs and services to promote the health-related issues such as awareness programs regarding HIV, diabetes, dengue, overweight, etc. Due to increased concern for ubiquitous health services, it incorporates the advantage of information technology which can lead to design a preventive management system for various types of disease and health conditions. Further, the technological advancement is also favorable to the management of chronic diseases. In this work, a personal health record (PHR)-based decision support model is proposed for monitoring diabetes using mobile environment. In order to facilitate the people, a graphical user interface is incorporated into the PHR-based model for analyzing their lifestyles.

7.1 Introduction

In the world, more than 40 million people die of various noncommunicable diseases like cancer, cardiovascular diseases, diabetes, heart failure, chronic obstructive diseases, etc. [1]. The majority of people belong to low- and middle-income countries. But, these diseases are also responsible for mortality in high-income countries. This can be prevented by adopting healthy behaviors and also decrease the mortality rate worldwide. A study on smoking habits presents that the risk oflung

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cancer is reduced up to half for a person who has stopped smoking since the last 10 years in comparison to those who continued smoking [2]. From this study, it is observed that the risk of cardiovascular disease is similar to the risks of a person who has stopped smoking since the last 15 years and a person who never smoked. The risk of HIV can be reduced by adopting safe sexual practices and awareness about this disease [3]. In high- and middle-income countries, most people suffer with overweight problem due to unhealthy eating habits and lack of exercise and it can lead to the risk of diabetes. Further, it is reported that the risk of onset of retinopathy and nephropathy can increase due to diabetes, and these risks can be reduced up to half and two-third levels, respectively, by controlling diabetes [4, 5]. The main function of healthcare services is to inspire and support the people to adopt healthy behaviors and self-manage the chronic diseases [6]. But, the main obstacle regarding this is the way through which information can be propagated. The main sources to propagate the information are consultations, existing service infrastructure, and through traditional media, but these sources can be used in a limited way. Due to advancement in mobile telephone technology, the numbers of mobile users are increasing day by day. A variety of mobile phones and mobile service providers are available in the market. The invention and advancement in mobile phones changes the traditional communication system and entertainment industry and also affects the life of people [7]. The dependency of human beings on the mobile phone is increasing day by day, especially of the youth. The mobile technology includes a variety of mobile phones such as personal digital assistants (PDAs) and PDA phones (BlackBerry and Palm Pilot), smartphones (iPhone), enterprise digital assistants (EDAs), etc. These devices have a variety of services and functions such as SMS, MMS, WWW, multimedia access, and application software. These features and functions of mobile technologies also encourage the scientists and researchers to explore the capability of mobile phones for providing individual-level support to patients in the healthcare domain [8]. Few examples are to send a text message to avoid smoking habits, awareness message regarding HIV, weight loss programs' message, diabetic disease-related message, asthma patients access information regarding exacerbation of asthma, etc. Due to incremental growth and deployment of mobile devices into private devices such as smartphones, tablets, pads, etc., large numbers of applications regarding medical treatment are available on mobile application stores and half of applications are related to daily health tips and disease information [9–13]. The trend of self-healthcare can increase exponentially to meet the demand of patients.

7.1.1 Objective of the Chapter

This chapter proposes a personal health record (PHR)-based health index mobile service using a decision support model. This PHR can enable medical staff to inquire and manage health- and medical-related information of patients. Further, this information can analyze information in different situations and extracts pattern

of behaviors of patients which are not explored. The aim of the PHR-based decision support system is to improve the lifestyle of patients and also to overcome the risk of chronic diseases. In addition to it, a user interface is developed for the users such that it can communicate in the optimized mobile environment. This decision support system is available for users at all times and provides the status of their health. The objectives of the proposed chapter are as follows:

- To design a PHR-based diabetes monitoring system to monitor the health of users
- To develop the user interface for the proposed monitoring system
- To incorporate the proposed model into mobile environment
- To analyze the information of the patients and give suggestions

7.2 Related Works

This section describes the related work in the direction of e-health monitoring system and usability of mobile phones to monitor the health of mobile users.

7.2.1 E-Health Model

Recently, the applicability of mobile devices has increased rapidly in health services. In the present era, the growth of mobile users is exponential, and it can act as an important tool regarding health communication. It is also a good medium for the low literacy and low-income populations to get information regarding health issues. The aim of the e-health is to monitor the health of the individual person. It includes a variety of fields such as monitoring individual bio-signals, area of telemedicine, analyzing signals, and customized health and medical services [9, 10]. In bio-signal monitoring, several sensors are combined together to obtain the sample output using some predefined procedure [12]. It also provides a graphical user interface to enter the information through patients. These types of monitoring systems are available in the market, which transmit the information regarding heart rate, blood pressure (BP), and body temperature of patients. Some of applications that can be used in this process are wireless communication terminals, Bluetooth, near-field communication (NFC), wireless local area networks (WLANs), and service providers are delivering processed healthcare information to users. On the other side, telemedicine is a remote treatment process carried through video conferencing and analyzes the collected PHRs for rehabilitation training. The aim of the e-health model is to mine the gathered information and predict the occurrence of disease. Due to the increase in interest of mobile phones in healthcare, several applications have been developed to monitor the health of mobile users.

7.2.2 PHR-Based Health Management

The personal health record can be defined as to store and manage the health record of a person throughout their life [13, 14]. Due to technological revolution, it is possible to measure the activity related to PHR data, such as amount of exercise, blood pressure, diabetes index, and so on. Hence, the demand of customized health management services is increased in present scenario due to the availability of health-related data. Further, it is also conceivable to cure the chronic diseases via PHR. The PHR of individuals can be used for continuous health management and health promotion activities. The other reason is that such type of health management can improve the health of persons [13, 15, 16]. For, continuous individual health management, it is necessary that personal health record of a person can be collected continually and, in this direction, mobile phones are the appropriate medium to collect that health data. Further, the more the PHR data are collected, the greater the usefulness and utilization, and patient-oriented environment is developed rather than hospital-oriented environment. In addition, patients can obtain accurate health information due to the various types of information integrated with PHR. This can lead to the prevention of disease and controlling the health of an individual. In literature, it is noticed that large numbers of health-based monitoring and management systems are reported. Some of these are listed as. Zhu et al. [17] have proposed a cardiac monitoring system to label the electrocardiogram (ECG) data. The proposed system integrates the mobile end of the system with a back-end annotation system for reviewing and scoring the quality of an ECG signal. In the proposed system, crowdsourcing methodology has been used to determine the ECG annotations from a set of experts including doctors, trainees, and automated algorithms. It is observed that the proposed system gives diagnosis accuracy equivalent to experts with reduced cost. Benharref and Serhani have proposed Service Oriented Architecture (SOA) and cloud-based framework for e-health monitoring [18]. The aim of the proposed framework is to collect real-time data from patients, provide nonintrusive monitoring, and provide medical and lifestyle management activities. In this framework, the mobile technologies are incorporated to collect and communicate data from a patient. The effectiveness and usability of the proposed framework are investigated using a case study, and it is observed that the proposed framework provides promising results. Xu et al. have developed an m-Health monitoring system based on cloud computing platform (Cloud-MHMS) and mobile network for implementing pervasive health monitoring [19]. In the proposed system, data storage, data processing, and data analysis processes are carried out using cloud storage and multiple tenants' access control layer, healthcare data annotation layer, and healthcare data analysis layer. Further, it is observed that the usability of the proposed monitoring system is tested on antimicrobial drug usage. It is reported that the proposed system provides better results for personal health care analysis. To determine the impact of the lifestyle and environmental parameters on the seminal quality and fertility rate, especially in man, a seminal quality prediction model is presented in [20]. To determine symptom trajectories of depression, a mobile-

based monitoring system is presented in [21]. The proposed mobile-based system is used to classify the depression severity. The performance of the proposed system is evaluated on 344 primary care patients with depression. The depression symptoms are measured weekly through interactive voice response (IVR) calls using the patient health questionnaire. Further, it is noticed that multivariate linear regression is applied to predict the trajectories. To efficiently and accurately determine the light exposure, mood, and activity levels of individual people, McNamara and Ngai have designed a personal mobile sensing system [22]. The proposed system explores the technologies embedded into smartphones. The functionality and performance of the proposed system is evaluated through various users up to a time period of 2 years. The authors claimed that the proposed system can estimate accurate light exposure and also predicted well both personal light exposure and general seasonal trends. A rule-based classification system has been designed for the diagnosis of different types of liver disease [23]. In this work, a rule base is constructed for effective diagnosis and prediction of liver diseases. The rule base consists of 20 rules to classify the liver disease. It is noticed that the proposed rule-based system provides better results in terms of classification of liver diseases. Hossain has developed an elderly monitoring system to continuously monitor the health of older adults and support them with various services like emergency detection and alarm, information and media service access, and interaction and communication [24]. The performance of the proposed system is evaluated using ten elder adults of the age group of 60–70 years. It is reported that the proposed system gives better results in terms of efficiency, effectiveness, and user satisfaction. Santos et al. [25] have proposed IoT-based mobile gateway for mobile health (m-Health) scenarios. The proposed gateway is applied to collect the information of patient-like location, heart rate, and possible fall detection. The objective of the proposed system is to forward the collected information to a caretaker, and it will manage a set of actions and alarms appropriately. It is observed that the proposed mobile gateway act as an effective communication channel. The usability and applicability of the different predictions and monitoring systems have been presented in [26]. For earlier prediction and diagnosis of dengue disease, a PSO-ANN-based diagnostic model is reported in [27]. In the proposed model, PSO is applied to optimize the parameters of the ANN. The results report that the proposed model effectively predicts the occurrence of the dengue disease. A systematic review on the diabetic personal health record is reported in [28]. A diabetes electronic health record for effective diabetes management is presented in [29]. Some diagnostic systems for predicting diseases using machine learning approaches are described in [20, 23, 30].

7.3 PHR-Based Diabetic Monitoring System

This section describes the proposed PHR-based diabetes monitoring system. A PHR can be described as a software tool which permits the patient to enter the desired information regarding the disease and provides the possible solution for

the disease. Further, patients can manage their health information using the PHR system and can access the medical information anytime round the clock. This system also associates the patient's information with the medical institutes, hospitals, consultation, doctor's appointments, etc. and can be accessed easily whatever is needed. As the medical awareness among people is increasing day by day, such types of systems are in demand and can also improve the lifestyle of people. But, the effectiveness and utilization of these systems are highly dependent on the medical data; as more and more medical data are gathered, these systems can be utilized effectively. Further, the aim of the PHR system is to covert the hospital-centered medical environment into the patient-centered one. Hence, in this work, a PHR-based diabetes monitoring system is developed for effective management and diagnosis of the diabetes disease. Diabetes is one of the metabolic diseases that can occur due to nonconversion of glucose into energy by body cells. It can be classified into two types such as type-1 diabetes and type-2 diabetes. It is reported that only 10% patients of the total diabetes population suffer from type-1 diabetes and rest of them suffer from type-2 diabetes. In type-1 diabetes, insulin is not produced by the human body, and for the treatment of this type of diabetes, insulin can be given to the patients. Type-2 diabetes can occur due to genetic factors, stress, obesity, and lack of exercise. The effects of type-1 diabetes are quite complicated, such as they are responsible for heart disease, limb disease, blindness, kidney failure, etc. while lifestyle factors are more responsible for type-2 diabetes. Highly obese and overweight people have more chances for type-2 diabetes. It is observed that type-2 diabetes can be controlled by changing lifestyle, weight loss, diet control, and exercise. In this work, a Personal Health Record (PHR)-based model is proposed for accurate diagnosis and effective management of diabetes. Further, this model will help and make the people aware regarding diabetes. Figure 7.1 illustrates the proposed PHR-based diabetes monitoring system. The proposed system is divided into three phases, such as, user information, PHR-based diabetic monitoring system, and clinical information. To identify the people with diabetes, some diagnosis standard is considered for the prescreening of diabetes. The descriptions of these standards are mentioned in Table 7.1. The diagnosis standards considered for the prescreening of diabetes are body mass index (BMI), blood pressure (BP), cholesterol levels, history of heart disease, sedentary lifestyle, prenatal history, and age. Further, blood pressure is divided into three categories, such as, healthy BP, early high BP, and high BP. Similarly, cholesterol level is also categorized into three classes, such as, low-density lipoproteins (LDL), high-density lipoproteins (HDL), and triglycerides. Tables 7.2 and 7.3 give information regarding the categories of blood pressure and cholesterol-level diagnosis standards. The above-mentioned diagnosis standards are applied to diagnose whether a person has diabetes or not. Further, diabetes is classified into two types, such as, Type-1 and Type-2. Tables 7.4 and 7.5 present the diagnosis standard to identify the patients affected with either Type-1 diabetes or Type-2 diabetes. In case of Type-1 diabetes, it is recommended that some insulin dose will be considered for the patients. But for Type-2 diabetes, it is suggested that patients can take a healthy diet as well as go for daily workouts.

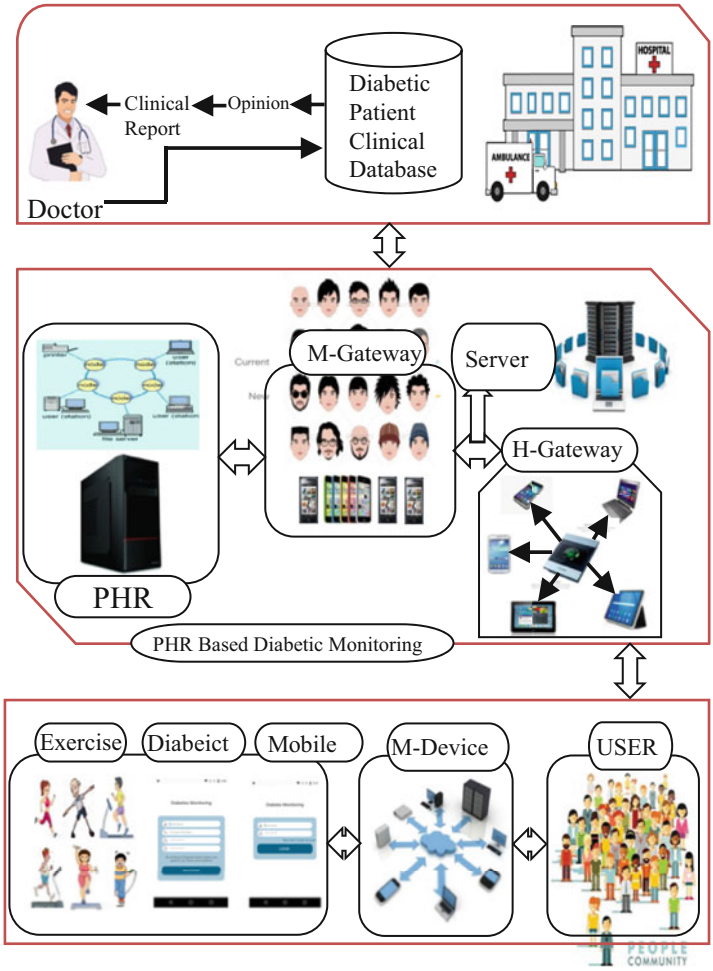

Fig. 7.1 Proposed PHR-based diabetes monitoring system

Table 7.1 Diagnostic standard for classification of prediabetic screening

Sr. no.	Diagnosis standard	Range
1	Body Mass Index (BMI)	Higher than 25 kg/m^2
2	Blood pressure	Higher than 120/80 mmHg
3	Cholesterol level	Higher/Lower
4	History of heart disease	Yes/No
5	Sedentary lifestyle	Yes/No
6	Prenatal history	Yes/No
7	Age	More than 40 years

Table 7.2 Classification of the cholesterol diagnostic standard

Standard	Classification	Range
Cholesterol	LDL	Higher than 100 mg/dl
	HDL	Less than 40 mg/dl
	Triglycerides	Higher than 150 mg.dl

Table 7.3 Classification of the blood pressure diagnostic standard

Standard	Classification	Range
Blood pressure	Healthy BP	120/80 mmHg
	Early high BP	In between 120/80–140/90 mmHg
	High BP	Higher than 140/90 mmHg

Table 7.4 Classification of type-1 diabetes

Diabetes classification	Standard diagnosis	Range
Type-1	Random blood sugar test	Higher than 6.4 mg/dl
	Fasting blood sugar test	Higher than 126 mg/dl
	Glycated hemoglobin	Higher than 6.4

Table 7.5 Classification of type-2 diabetes

Diabetes classification	Standard diagnosis	Range
Type-2	Two-hour postprandial test	Higher than 7.0 mmol/L
	Oral glucose tolerance test	More than 200 mg/dL

7.4 Implementation Details, Results, and Discussion

In this work, a mobile-based application is developed to monitor the diabetes. In the proposed system, a user can enter the medical details regarding diabetes through a mobile application; then, this information is analyzed using the PHR-based system. This analyzed information is used for monitoring the diabetes-affected person through a mobile app. The main task of the proposed app is to classify the person as normal, prediabetic, having type-1 diabetes, and type-2 diabetes. Further, this app also provides some suggestions to overcome the diabetes like life health index, exercise therapy, health information, and dietary nutrient information. The proposed system considers the body mass index (BMI), blood pressure (BP), cholesterol levels, history of heart disease, sedentary lifestyle, prenatal history, age, and some clinical features for effective diagnosis of the diabetes. The proposed PHR-based diabetes monitoring system is developed using Android Studio 1.1.0in environment on window-based operation system having Intel(R) Xeon(R) processor, CPU E5–1620 v2, 3.7 GHz, and 8 GB RAM. The process of identification of diabetes is mentioned in Fig. 7.2. Figure 7.3 illustrates the login screen of the proposed

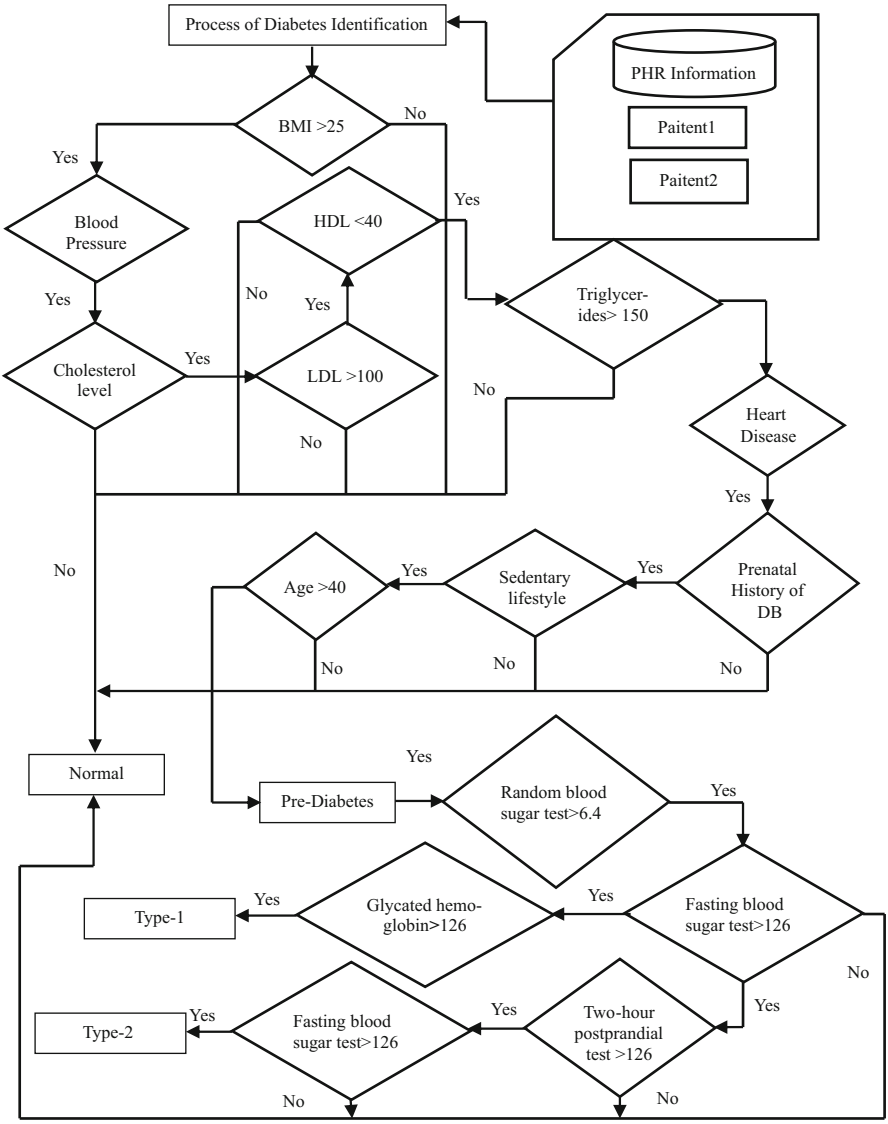

Fig. 7.2 Diabetes identification rule base process

diabetes monitoring app. If the user is already registered with the app, then it will login into the system using the user name (refer Figs. 7.4 and 7.5). Otherwise, users can initially register with the app using create account option. Figure 7.4 shows the user registration process interface of the proposed app. After registration process, an account of user is created and unique user name and password is given to every user for further processing. Figure 7.5 shows the interface of the pre

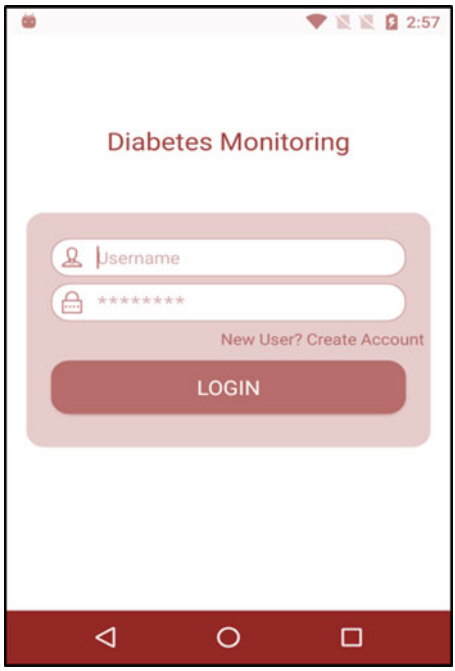

Fig. 7.3 LOGIN screen

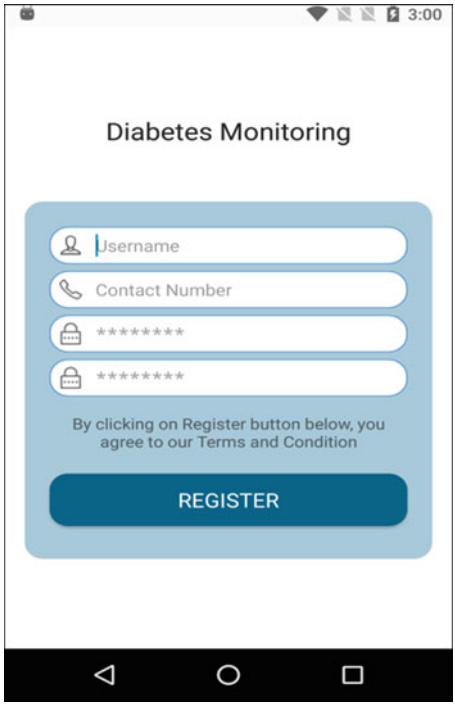

Fig. 7.4 Registration interface

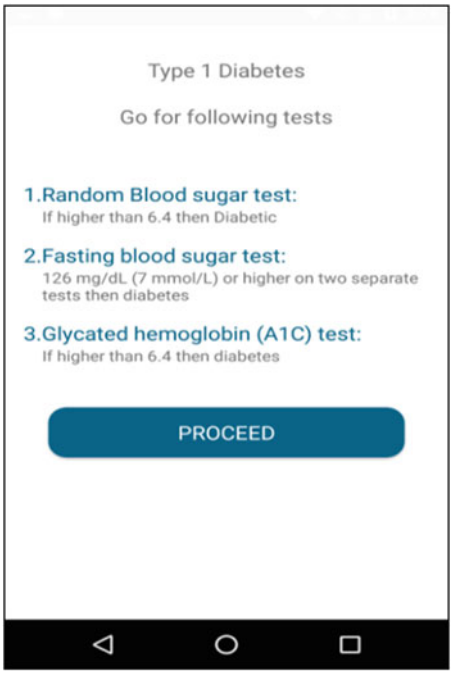

Fig. 7.5 Prediabetic screening interface

diabetes screening. This interface requires information like BMI, BP, cholesterol level, heart disease history, life style information, and parental history of diabetes for successful diagnosis of a person either pre-diabetic or normal. If a person has high BP, high BMI score and also having parental history of diabetes, then the person has maximum chance of pre-diabetes and further, it is suggested that to control the BP and BMI to reduce the chance of pre-diabetes.

Figure 7.6 describes the nonclinical parameters for diagnosing and monitoring type-1 diabetes. These parameters include excessive thirst, high level of urination, weight loss, tiredness, and blurring of vision. If such symptoms occur, then definitely the possibility of diabetes exists, and it is recommended that the person undergoes some clinical tests. Figure 7.7 illustrates the diagnostic tests which are used for the confirmation of diabetes.

These tests include random blood sugar test, fasting blood sugar test, and glycated hemoglobin test. These tests clearly notify the presence of type-1 diabetes. Figure 7.8 shows the list of suggestions that can be taken after diagnosis of the diabetes. It is suggested that in case of type-1 diabetes, the patient should take the insulin dose as per recommendation. Further, it is advisable that the patient should go for regular monitoring of the diabetes and also improve eating habits. The nonclinical parameters for diagnosing and monitoring type-2 diabetes are reported in Fig. 7.9. These parameters include being unwell, eating too much, and ineffective diabetes medication. Further, it is suggested that if these symptoms occur, then some clinical tests are recommended for identifying the presence of diabetes. These

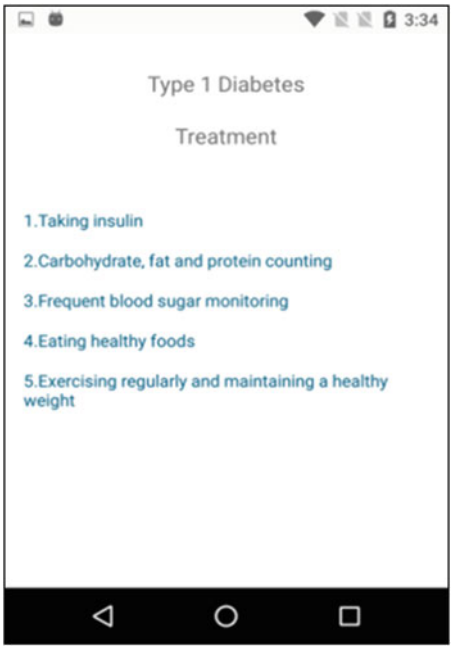

Fig. 7.6 Nonclinical symptoms of type-1 diabetes

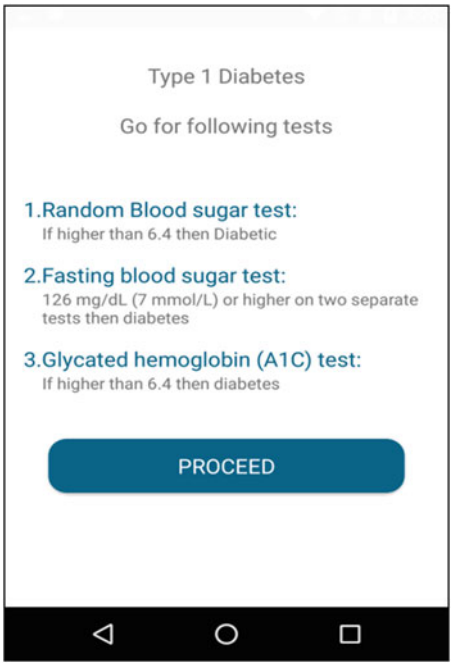

Fig. 7.7 Clinical symptoms of type-1 diabetes



Fig. 7.8 Lifestyle improvements to reduce type-1 diabetes

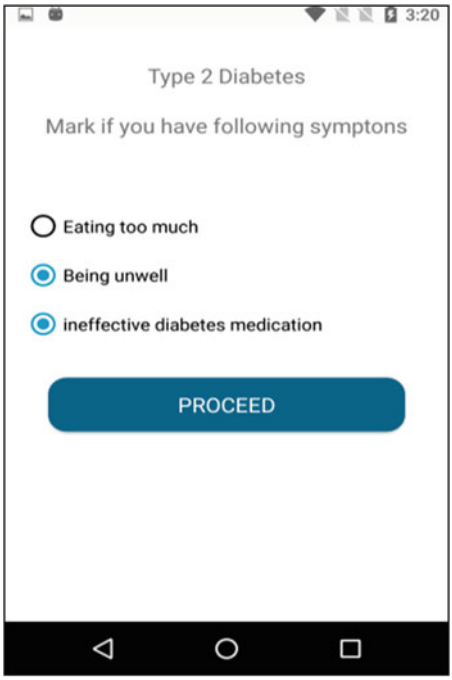

Fig. 7.9 Non-clinical symptoms of type-2 diabetes

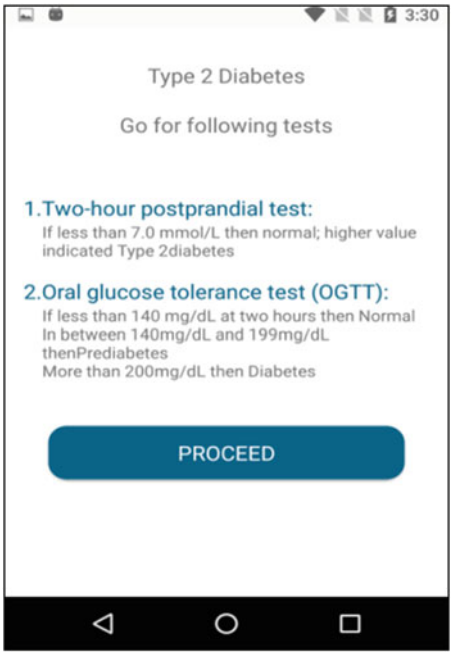

Fig. 7.10 Clinical symptoms of type-2 diabetes



Fig. 7.11 Lifestyle improvements

tests are 2 h postpyramidal tests and oral glucose tolerance test (OGTT) which are described in Fig. 7.10. If the results of these tests are positive, then the patient is affected with type-2 diabetes. Figure 7.11 illustrates the precaution taken in case of type-2 diabetes. In most cases, type-2 diabetes is reduced by adopting habits such as

healthy eating, daily exercise, reducing the intake of Bailey fat, and so on. In some cases, the insulin dose is also given to maintain the sugar level in the body. Further, it is advised that the patient should go for the regular monitoring of diabetes and control the sugar level by adopting healthy habits.

7.5 Conclusions

Currently, people are more concerned and conscious regarding their health. Moreover, large numbers of medical services and devices have been developed to automate the medical facilities. The concept of M@M, IoT, and smart health has become widely popular among human beings, and people want to collect more and more information on health issues. Further, it is noticed that chronic diseases increase due to eating habits, obesity, lack of exercise, late-night sleep, excessive smoking and drinking, unmanaged lifestyle, etc. Hence, due to advancement in medical technology and increased convergence, it is possible that the patient can control himself to avoid some chronic diseases like diabetes and obesity by using the PHR platform. In this paper, the PHR-based diabetes monitoring system is proposed that performs the real-time monitoring of the diabetes user. In this system, the real-time data are collected through mobile phones, and these mobile phones are connected with the PHR server for monitoring and diagnosis of diabetes of the individual user. Further, the PHR server is connected with the hospitals in case of emergency service and also for consultation with doctors.

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11

OMIC Technologies in Bioethanol Production: An Indian Context

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Abstract

Swift depletion coupled with hazardous effects of nonrenewable energy sources (such as petrol, coal, and diesel) on the environment has inspired all governments around the globe to participate in identification, development, and commercialization of the technology to produce environment-friendly renewable fuels. In this context, recent studies on bioethanol have reflected its viability to be one such energy source due to its production by renewable and sustainable biomass with comparatively less emissions than fossil fuels. Meanwhile, advancement in next-generation sequencing technology and genetic engineering has provided an opportunity to not only inspect into omics data but also to produce hyper-productive strains for efficient degradation of lignocelluloses material at the industry level. This chapter talks about the availability of omics data for microorganism strains and biomass required for bioethanol production in India (third largest energy consumer, second most populated, and counted among the fastest developing countries).

Keywords: Agricultural bioinformatics, biofuel, genome and proteome data, future trends

11.1 Introduction

Natural fossil fuels like natural gas, coal, petroleum, and diesel have been a primary source for the world's economy. However, the over consumption of fossil fuels has not only resulted in depletion of these nonrenewable

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resources but also played a major role in the increase of greenhouse gases (GHGs), global warming, and climate change. These limitations accompanied by an increase in the world's energy requirement have made an emphasis to search for alternate energy sources with the following characteristics: renewable, efficient, sustainable, and cost effective with negative or less emission of GHGs [1]. Fuels generated from plant biomass can be considered as substitute of fossil fuels, termed as biofuel. Although, biofuel is similar to hydrocarbons with respect to emission, it can be more environment-friendly if the production and distribution of biofuel are taken care of.

The very first advantage that biofuels hold over conventional fuels is that they are biological molecules and hence biodegradable. This means that they will not persist in the environment for long durations and would not make an area uninhabitable. Secondly, biofuel production can be manipulated to eliminate sulfur to reduce the net impact of acid rain. Further, the limitations imposed by GHG on use of fossil fuels can be easily overcome by the use of biofuel. Lastly, biofuel production would decrease the energy dependence, i.e., countries having land resources to grow biofuel feedstock could produce their own energy and would no longer be dependent on fossil fuels that are limited to few geographical locations in the world.

The production of biofuel has changed over the course of time and biofuel can be broadly classified into three generations, namely, the first, second, and third generations. First-generation biofuel is made using feedstock that is also consumed as human food like sugar, vegetable oil, and/or starch. However, the food vs. fuel debate paved the path for second-generation biofuel, where only sustainable feedstock is considered for biofuel productions, which are either a non-food crop or plant products that are no longer useful for consumption. Since the second-generation biofuel feedstock covers a wider range from forestry to agriculture and waste material enriched in lignocellulosic content that is difficult to extract, it involves advanced conversion technologies. Therefore, the quality of second-generation biofuel is majorly driven by the production routes opted by the industry generally having the following sequence: pretreatment, hydrolysis, fermentation, distillation, and purification of bioethanol.

Moreover, the outcomes of recent advancement and experimentation on algae-based biofuel production in terms of diversity and quantity with lower resource inputs as compared to that of second-generation biofuel production have given more impetus toward the usage of algae for biofuel production. Besides the diversity of carbon sources they can use and quantity they can produce, the simplified path to genetically manipulate them to produce any kind of biofuel is most remarkable. Hence, algae-based biofuel production marks the third generation. However, they require more understanding and further scientific research.

Bioethanol is a biofuel that can be easily produced by renewable and sustainable plant resources that it can be extensively used for transportation with a possibility of minimized particulate production in compression–ignition engines [47]. In Europe and in the United States, bioethanol has been used since the 1900s but was hampered due to its high production cost. However, after the oil crisis in the 1970s, production of bioethanol was resumed with renewed interest. Although bioethanol has lower energy content than petrol (68%), its cleaner combustion and reduction of CO_2 emission level (by 80%) enable it to be a viable alternate source of energy. Also, studies conducted in the past couple of decades have also shown that replacement of fossil fuels by ethanol-based fuels has resulted a drastic reduction in net average of GHGs by 71% for cellulosic ethanol and 31% for bioethanol [2].

Therefore, the scenario presented by second- and third-generation biofuel (mainly bioethanol) production provides an ample area where even a small improvement or discovery could give a huge impetus toward the efficient production of bioethanol. The major areas that need scientific attention are raw materials, organisms that can produce enzymes being used in pretreatment process, and availability of omics data for further research. Hence, the chapter focuses on the availability of omics data and biomass found specifically in India for bioethanol production and the bacterial organism indigenous to India having cellulolytic enzymes.

11.2 Indian Scenario

Bioethanol in India is generally derived from molasses (by-product of sugar production process). However, with the increase in the energy demand of India and its population, it is impossible that molasses alone would be sustainable for bioethanol production. Besides, the debate on first-generation biofuels as they are derived from food crops has raised questions about net energy, water utilization, and net GHG balance. These criticisms have led to increased interest in second-generation biofuels [3]. In India, more than half of its land is used for agriculture. Also, it is the world's first largest producer of rice (https://www.worldatlas.com/articles/the-countries-producing-the-most-rice-in-the-world.html) and the second largest producer of sugarcane (https://www.worldatlas.com/articles/top-sugarcane-producing-countries.html), wheat (https://www.worldatlas.com/articles/top-wheat-producing-countries.html), and sorghum (https://www.worldatlas.com/articles/top-sorghum-producing-countries-in-the-world.html). This leads to production of massive amounts of crop residues that could be used for second-generation biofuel

production. Most of these crop residues are burned by farmers that leads to air pollution. Specifically, this event has been seen in the northern states of India. Agricultural waste has not been given much attention and usually ends being composted or grazed by animals. Agricultural waste, such as rice husk, has been traditionally being burned in the states of Haryana, Punjab, UP, and Rajasthan. This burning is not only an inefficient method of eliminating biomass; it also leads to increased levels of particulate matter in the northern parts of India. In November 2015, the state of Delhi reported the highest particulate matter between the ranges 368–122, much higher than the safe limits (http://www.dailypioneer.com/todays-newspaper/delhi-gasps-for-fresh-air-as-particulate-matter-soars-by-350.html and https://www.nature.com/news/new-delhi-car-ban-yields-trove-of-pollution-data-1.19385). The lack of a supply-chain mechanism of utilizing the biomass left after harvesting is a plausible reason as to why the farmers resort to burning. Thus, industries that can utilize the agricultural waste are a potential area of development that needs attention. Moreover, sustainably produced second-generation biofuel can potentially promote rural development and improve economic conditions in developing regions.

There are two essential requirements for successful production of bioethanol in a developing country like India: availability of second-generation plants and crop residues that are sustainable, and identification of native strains of microorganisms (preferably bacteria) that produce cellulases. The latter is most important as characterization and further manipulation of catalysts via protein engineering could lead to preparing and commercialization of enzymatic cocktails. While enzymatic cocktails are available from companies such as Novozymes, there is a lack of enzymatic cocktail of Indian origin that in our opinion has the ability to revolutionize bioethanol production in India.

11.3 Cellulolytic Enzymes Producing Bacterial Strains Isolated from India

An impediment toward the conversion of plant biomass into bioethanol is the enzymatic hydrolysis of lignocellulosic material. It is a process whereby lignocellulosic content from plant biomass is converted into fermentable sugars (Figure 11.1) through the use of enzymes like cellulases and xylanases. However, production of these enzymes at industrial scale by bacterial and fungal strains involves relatively high cost, and hence

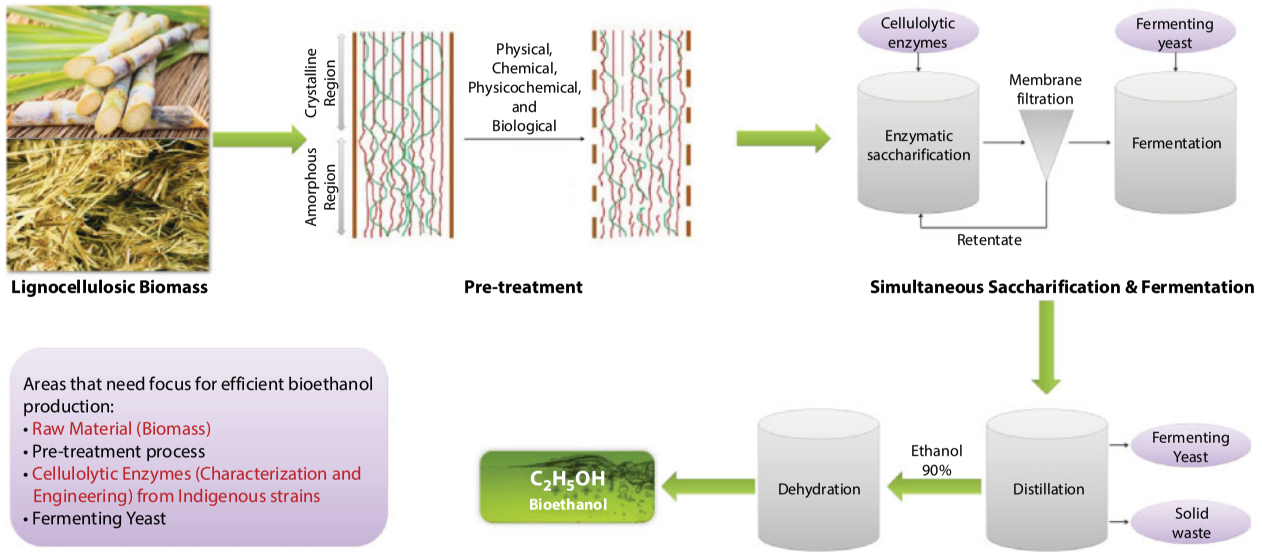

Figure 11.1 Schematic diagrams explaining the bioethanol production from second-generation biomass. Conversion of second-generation sustainable biomass (described in the text) to bioethanol involves multiple steps, where pretreatment renders the cellulose fibers to be exposed and to detach from other recalcitrant polymers (hemicelluloses and lignin). Further saccharification and fermentation followed by distillation delivers the bioethanol that can be blended with gasoline/petrol. However, certain areas require focused attention, with respect to India, such as procurement of biomass and preparing an enzymatic cocktail, which involves complete characterization and protein engineering of cellulases identified from strains isolated in India.

identification of new and active enzymes besides improvement in the efficiency of already known enzymes is one of the major areas of research in bioethanol production.

Cellulases working synergistically with xylanases are the most common enzymes produced by fungal and bacterial strains. But enzymes like amylase, holocellulase, and pectinase not only increase the range of plant biomass that can be degraded but also reduce the cost if they can be produced by only one organism. The greater interest lies in the enzymes produced from thermophiles ranging from 50°C to 90°C as it can be used for harsh industrial process. Moreover, at the industrial scale, it is important to produce copious amount of cellulases, and hence omics study of organisms that can be easily engineered genetically besides having higher growth rate plays a crucial role (bacteria). Here, we give an overview of various promising microorganism strains indigenous to India for bioethanol production. Table 11.1 provides a list of bacterial organisms that can produce the plant biomass-degrading cellulolytic enzymes (such as endo/exoglucanases, cellobiohydrolases, β-glucosidases, and others) with its genome availability.

11.3.1 *Bacillus* Genus of Lignocellulolytic Degrading Enzymes

Bacillus, a genus of gram-positive and rod-shaped bacteria, has around 20 different species (Table 11.1) capable of producing lignocellulolytic degrading enzymes isolated from India. Many of these have the ability to grow at varying pH and temperature making them attractive for industrial purpose of cellulase production.

Among the 20 strains listed, two strains of *Bacillus cereus* and *Bacillus amyloliquefaciens*, respectively, can produce a variety of enzymes like β-glucosidase, cellulase, pectinase, xylanase, and β-1,4-endoglucanase for hydrolysis of plant biomass and have been extensively studied.

11.3.2 *Bhargavaea cecembensis*

Gram-positive, nonmotile, nonspore forming, and rod-shaped bacteria isolated from the Indian Ocean are reported about their cellulase-producing capability [4]. Named after the late Indian scientist, PM Bhargava, the strain of *Bhargavaea cecembensis* was isolated from the hot spring of Manikaran (India). This thermophillic organism is potentially a source of cellulase that can be scaled up for industrial-scale production.

Table 11.1 List of microorganism strains and enzymes isolated reported to be indigenous to India and are proposed to be industrially important for bioethanol production.

Enzyme	Name	Genome	Strain	Reference
Cellulase	*Agrobacterium larrymoorei*	Present	A1	[24]
Amylase, cellulase, xylanse	*Alkalibacterium* sp.	Absent	JN645863	[11]
Endoglucanase, exoglucanase, xylanase	*Amycolatopsis* sp.	Absent	GDS	[25]
Cellulase, xylanase	*Aneurinibacillus aneurinilyticus*	Present	DBT87, DBT15	[26]
Cellulase, β-glucosidase, pectinase, xylanase, β-1,4-endoglucanase	*Bacillus amyloliquefaciens*	Present	IARI-SP-2 KF240848, IARI-R-25	[27, 28]
Cellulase	*Bacillus aquimaris*	Present	NT1	[29]
Cellulase, β-glucosidase, xylanase	*Bacillus baekryungensis*	Absent	IARI-ABL-36	[28]
Cellulase	*Bacillus brevis*	Present	VS-1	[30]
Cellulase	*Bacillus cellulasensis*	Present	NIO-1130T HQ858013	[31]
Amylase, cellulase, pectinase, xylanase, β-glucosidase, β-1,4-endoglucanase	*Bacillus cereus*	Present	JX312575, JN411376, IARI-SP-7 KF240853, DBT14, IARI-L-73	[26–28, 32]

(*Continued*)

Table 11.1 List of microorganism strains and enzymes isolated reported to be indigenous to India and are proposed to be industrially important for bioethanol production. (*Continued*)

Enzyme	Name	Genome	Strain	Reference
Amylase, β-glucosidase, pectinase	*Bacillus firmus*	Present	JN411422, IARI-L-21	[28, 32]
Amylase, cellulase, pectinase, xylanase, β-glucosidase	*Bacillus flexus*	Present	JN645852, IARI-ABL-37	[11, 28]
Amylase, β-glucosidase, pectinase, β-1,4-endoglucanase	*Bacillus licheniformis*	Present	JX312587, IARI-SP-3 KF240849, IARI-ABL-38	[27, 28, 32]
Amylase, cellulase, pectinase, xylanase, β-glucosidase	*Bacillus marisflavi*	Present	IARI-ABL-39	[28]
β-1,4-Endoglucanase	*Bacillus megaterium*	Present	JF343146, IARI-SP-9 KF240855	[27]
Amylase, β-glucosidase, pectinase	*Bacillus mojavensis*	Present	IARI-ABL-40	[28]
β-Glucosidase, pectinase	*Bacillus muralis*	Present	IARI-L-74	[28]
β-1,4-Endoglucanase	*Bacillus mycoides*	Present	JN411283, IARI-SP-8 KF240854	[27, 32]
β-1,4-Endoglucanase	*Bacillus oceanisediminis*	Present	IARI-SP-10 KF240856	[32]

(*Continued*)

Table 11.1 List of microorganism strains and enzymes isolated reported to be indigenous to India and are proposed to be industrially important for bioethanol production. (*Continued*)

Enzyme	Name	Genome	Strain	Reference
Cellulase, β-glucosidase	*Bacillus pumilus*	Present	JN411426, NAIMCC-B01415, IARI-SP-5 KF240851, IARI-L-54	[28, 32, 33]
Amylase, cellulase, xylanase	*Bacillus selenatarsenatis*	Present	JN645858	[11]
β-1,4-Endoglucanase	*Bacillus* sp.	Absent	SV1, 313SI, IARI-SP-4 KF240850	[27, 34, 35]
Amylase, xylanase, β-glucosidase, pectinase	*Bacillus subtilis*	Present	JF343233, JN411353, LFS3, IARI-SP-1 KF240847, IARI-L-69	[27, 28, 32, 36]
β-1,4-Endoglucanase	*Bacillus thuringiensis*	Present	IARI-SP-6 KF240852	[27]
Cellulase	*Bhargavaea cecembensis*	Present	JX312640	[4]
Cellulase	*Cellulomonas cellulans*	Present		[37]
Xylanase	*Cellulosimicrobium cellulans*	Present	CKMX1	[38]
Cellulase	*Citrobacter freundii*	Present		[39]

(*Continued*)

Table 11.1 List of microorganism strains and enzymes isolated reported to be indigenous to India and are proposed to be industrially important for bioethanol production. (*Continued*)

Enzyme	Name	Genome	Strain	Reference
Amylase, cellulase, β-glucosidase, pectinase	*Desemzia incerta*	Present	IARI-L-46	[28]
Amylase, β-glucosidase, pectinase, xylanase	*Exiguobacterium antarcticum*	Present	IARI-L-70	[28]
Amylase, cellulase, β-glucosidase, pectinase, xylanase	*Exiguobacterium indicum*	Present	IARI-R-137	[28]
Amylase, β-glucosidase, pectinase	*Exiguobacterium undae*	Present	IARI-L-116	[28]
Amylase, cellulase, xylanase	*Halobacillus trueperi*	Present	JN645845	[11]
Amylase, cellulase, xylanase	*Halomonas caseinilytica*	Present	JN645870	[11]
Amylase, cellulase, xylanase	*Halomonas muralis*	Present	JN645872	[11]
Amylase, β-glucosidase	*Jeotgalicoccus halotolerans*	Absent	IARI-ABR-5	[28]
Cellulase	*Marinobacter* sp.	Absent	MSI032	[40]
Cellulase	*Paenibacillus barcinonensis*	Absent	MG7	[41]
Cellulase, endoglucanase	*Paenibacillus pabuli*	Present	JF343230	[32]

(*Continued*)

Table 11.1 List of microorganism strains and enzymes isolated reported to be indigenous to India and are proposed to be industrially important for bioethanol production. (*Continued*)

Enzyme	Name	Genome	Strain	Reference
Amylase, cellulase, β-glucosidase	*Paenibacillus* sp.	Present	IHBB 10380, IHB B 3415	[42, 43]
Amylase, cellulase, β-glucosidase, pectinase, xylanase	*Paenibacillus terrae*	Present	JF343212, IARI-L-127	[28, 32]
Amylase, β-glucosidase, pectinase	*Paenibacillus xylanexedens*	Present	IARI-L-76	[28]
Amylase, cellulase, xylanase	*Planococcus antarcticus*	Present	IARI-ABL-9	[28]
β-Glucosidase, pectinase	*Planococcus donghaensis*	Present	IARI-L-39	[28]
Amylase, β-glucosidase, pectinase	*Planococcus kocurii*	Present	IARI-ABL-3	[28]
Amylase, cellulase, β-glucosidase, pectinase, xylanase	*Pontibacillus* sp.	Absent	IARI-ABL-41	[28]
Cellulase	*Pseudomonas fluorescens*	Present		[44]
Amylase, cellulase, xylanase	*Salicola marasensis*	Absent	JN645869	[11]
Amylase, cellulase, xylanase	*Sediminibacillus halophilus*	Present	JN645856	[11]
Cellulase, xylanase	*Serratia rubidaea*	Present	DBT4	[26]
Amylase, β-glucosidase, pectinase	*Sinobaca beijingensis*	Absent	IARI-ABL-18	[28]

(*Continued*)

Table 11.1 List of microorganism strains and enzymes isolated reported to be indigenous to India and are proposed to be industrially important for bioethanol production. (*Continued*)

Enzyme	Name	Genome	Strain	Reference
Amylase, β-glucosidase, pectinase	*Sporosarcina aquimarina*	Absent	IARI-L-77	[28]
Amylase, cellulase, β-glucosidase, pectinase	*Sporosarcina globispora*	Present	IARI-R-111	[28]
Amylase, cellulase, pectinase	*Sporosarcina psychrophila*	Present	IARI-R-110	[28]
Amylase, β-glucosidase, pectinase	*Staphylococcus arlettae*	Present	IARI-ABL-33	[28]
Amylase, β-glucosidase, pectinase	*Staphylococcus xylosus*	Present	IARI-ABR-1	[28]
Xylanase	*Stenotrophomonas maltophilia*	Present	X6 JX220726	[45]
Endoglucanase, cellulase	*Streptomyces albogriseoulus*	Present	C2-221	[7]
Cellulase	*Streptomyces albospinus*	Absent	MTCC 8768	[8]
Cellulase	*Streptomyces griseorubens*	Present	AB184139	[9]
Cellulase	*Streptomyces matensis*	Absent	KF553639	[10]
Endoglucanase, cellulase	*Streptomyces nitrosporeus*	Absent	N2-14	[7]

(*Continued*)

Table 11.1 List of microorganism strains and enzymes isolated reported to be indigenous to India and are proposed to be industrially important for bioethanol production. (*Continued*)

Enzyme	Name	Genome	Strain	Reference
Holocellulase, cellulase, endoglucanase	*Streptomyces* sp.	Absent	ssr-198, S7, M7a, M7b	[5–7]
Cellulase, xylanase	*Streptomyces viridiviolaceus*	Absent	JN645842	[11]
Amylase, cellulase	*Thalassobacillus* sp.	Absent	JN645857	[11]
Amylase, cellulase, β-glucosidase, xylanase	*Virgibacillus halodenitrificans*	Present	IARI-ABR-18	[28]

11.3.3 *Streptomyces* Genus for Hydrolytic Enzymes

Besides being the largest genus for antibiotic production, several species of *Streptomyces* isolated from India have shown to have cellulase-producing ability [5–11]. *S. albogriseoulus*, *S. albospinus*, *S. griseorubens*, *S. matensis*, *S. nitrosporeus*, and *S. viridiviolaceus* have been reported in various reports exhibiting cellulase-producing capability.

Although a significant effort has been made to reduce the production cost of cellulase at industrial scale, it still equals twice the cost of producing ethanol from starch. Hence, realizing the paramount importance of cellulolytic enzymes producing organism, it is necessary to explore new organism and cocktails of enzymes that can be used for production at industrial scale. Besides, modulating transcriptional regulators to produce the desired cocktail of lignocellulolytic degrading enzymes with high yield and productivity can also be an alternative for cost reduction. However, to attain this, one must have in-depth knowledge of the organism's genome, and hence its public availability plays a crucial role.

11.4 Biomass Sources Native to India

In other countries, where bioethanol blending has been successfully implemented (such as the USA and Brazil), second-generation biomass has been actively researched upon and new technologies are developed and simultaneously commercialized for a sustainable bioethanol production. One of the successful crops that have garnered massive attention is switchgrass, a perennial prairie plant mostly found in Midwestern United States. In the case of India, multiple labs have focused on other perennial plants that are not cultivated for food. Here, we list some of those grasses/plants that are found geographically in India and highlight the advances as well.

11.4.1 *Albizia lucida* (Moj)

Albizia lucida, known as Moj, is native to the northeastern part of India. It is a fast-growing tree that is majorly used as fuel by local tribal people. Physiochemical analysis of the plant is carried out to check its use in biofuel production, and it was found that it can be a good alternate for bioethanol production. Specifically, its high cellulose with lower lignin makes it an attractive biomass. Further, the crystallinity content of Moj analyzed using the Ash test was found to be 46.43% and degrades at temperature of 355°C [12].

11.4.2 *Areca catechu* (Betel Nut)

Areca catechu is a species of palm that majorly grows in Asia, parts of east Africa, and tropical Pacific. In India, it is used extensively for cooking and heating. Interestingly, the husk of the betel nut palm is proposed to be used as biomass source. Compared to Moj, the betel nut husk contains higher crystallinity of cellulose and hemicelluloses of 63.84% [12].

11.4.3 *Arundo donax* (Giant Reed)

Arundo donax is a perennial dry energy grass native to Middle East Asia, Indian subcontinent, and Mediterranean Basin. Similar to *Miscanthus*, it has a rhizoidal root system that is tough and forms an extensive knotty network through which it propagates further [13]. It has an ability to grow in erosive and marginal, degraded soils with remarkable increase in biomass in response to nitrogen fertilizers. Additionally, it can improve soil fertility and has higher yield of bioethanol, making it a prominent candidate for bioethanol production [14].

11.4.4 *Pennisetum purpureum* (Napier Grass)

The hybrid variety of Napier grass developed by Tamilnadu Agricultural University, Coimbatore, has a higher biomass yield compared to other perennial grasses. While it has been bred for feedstock purposes, it is highly tolerant to salinity and reduces the pH of the saline soil [15].

11.4.5 *Brassica* Family of Biomass Crops

Brassica carinata (Ethiopian mustard) is a newly introduced semiarid crop in India that is agriculturally significant as it is used as a source for jet engine aviation biofuel [16, 17]. The environmental performance of the biofuel in comparison to conventional gasoline was estimated to be better for ethanol-based application in passenger cars [17].

Another member of *Brassica*, *Brassica napus* (rapeseed), a popular crop for edible oil production, has also been proposed to be a sustainable biomass source for bioethanol production. The investigation of the various factors that influence the saccharification of rapeseed stalks concluded that the lower the quantity of pectin and arabinogalactans, the better the saccharification [18].

Multiple studies have been reported on the common mustard plant, a widely grown agricultural crop in India and South Asia. Specifically, the structural features of dilute acid, steam exploded, and alkali-pretreated mustard stalks and their impacts on enzymatic hydrolysis are investigated [19].

11.4.6 *Cajanus cajan* (Pigeon Pea)/*Cenchrus americanus* (Pearl Millet)/*Corchorus capsularis* (Jute)/*Lens culinaris* (Lentil)/*Saccharum officinarum* (Sugarcane)/*Triticum* sp. (Wheat)/*Zea mays* (Maize)

These crops are grown in huge quantity in India covering almost all parts of the country. Various parts of plants like straw, stalk, waste, and husk are utilized for the production of bioethanol. The roadmap for biofuel production in India [3] shows the total net ethanol availability in 2010/2011 as 27.9 billion liters and estimates an increase in the availability (37.3% by 2020/2021) with the increase in production of these plants. As stated earlier, among the world's largest producer of rice, pigeon pea, pearl millet, jute, sugarcane, wheat, and maize, there are high rates of having biomass resource from various parts that are not edible or form waste.

11.4.7 *Medicago sativa* (Alfalfa)

Alfalfa is a perennial flowering plant of pea family grown almost all around the world. Due to its rich lignocellulosic content and being herbaceous non-edible energy crop, it is considered as a potential source of biomass for bioethanol production. Though not produced in large quantity, West and South-Central India is an ideal location for the production of alfalfa.

11.4.8 *Manihot esculenta* (Cassava)/*Salix viminalis* (Basket Willow)/*Setaria italica* (Foxtail Millet)/*Setaria viridis* (Green Foxtail)

With the efficient and cost-effective lignocellulosic bioethanol production, bioethanol industry would need a more reliable plant biomass that can be produced using minimum water, fertilizer, and agricultural land. To address this issue, various C4 energy plants could be used for bioethanol production as they use an efficient system when compared to C3 plants, hence yielding high amount of biomass. In a recent article [20], the authors investigated the optimization techniques for biomass production and feedstock quality with respect to bioethanol production in C4 plants.

11.4.9 *Vetiveria zizanioides* (Vetiver or Khas)

In many parts of India, Khas grass grows wild and is an important plant for industrial and medicinal uses. Khas/Vetiver's roots are used for cooling purposes, and oil is extracted as well, which is prized for its cooling effect (http://www.vetiver.org/).

Harvesting of Khas/Vetiver's roots is done by uprooting the entire plant and removing the roots after cleaning. Interestingly, systematically cultivated Khas/Vetiver is harvested by removing the roots after 10–12 months, mostly for medicinal purposes. However, the pulp of Khas/Vetiver goes into paper and straw board production.

11.4.10 Millets and *Sorghum bicolor* (Sorghum)

Although there are plants and crop wastes that are being utilized for biofuel production in India (like wheat bran, wheat straw, sugarcane bagasse, rice straw, and rice husk), there are plants that have been investigated by few labs for their utilization in biofuel production. However, the lack of omics (genome, transcriptome, and proteome) data for these plants is acting as a roadblock in the efficient production of bioethanol. Table 11.1 lists a total of 39 Indian plants that have been investigated for their bioethanol production capability and availability of the omics data on the National Center for Biotechnology Information (NCBI) portal. As discussed in Ref. [3], wastes from sugarcane, wheat, maize, jute, pearl millet, pigeon pea, and lentil are being extensively used for bioethanol production. However, plants like Moj, Bonbogori and German grass, foxtail millet, basket willow, and green foxtail can be investigated in depth to evaluate their efficiency in the production of bioethanol. Specifically, sorghum has received a lot of attention recently [21, 22]. Therefore, availability of genome, transcriptome, and proteome of plants not only would pave a better way to understand and overcome the complexity involved in bioethanol production at the industrial level but also would provide various reliable resources from all over the country to meet the challenge of fuels. Moreover, in a country like India with vast land resources to grow biofuel feedstock, it has a potential to not only produce the energy for itself but also distribute the bioethanol to other countries.

11.5 Omics Data and Its Application to Bioethanol Production

"Omics" is a general term applied to biological data that result after sequencing the genome of a particular organism. Derived from the suffix "ome," omics has multiple flavors, such as transcriptomics, metabolomics, etc. With the advent of next-generation sequencing techniques, it has been a matter of hours for any organism's genome to be elucidated. The implication of genome sequence availability is quite long reaching. For example, once the genome of an organism is known, the functional genomics

(process of identifying all the genes and annotating their functions) step enables to study specific genes that influence in a specific pathway.

In the case of bioethanol production, the availability of omics data is a major limitation. Among the ~65 strains isolated from India, there are only 49 species' genome available (73% of strains) in the NCBI. While published reports emphasize on the specific enzyme that was isolated and characterized from the strains, they do not report the genome availability or sequencing efforts. The genome data available for most of the ~65 strains of Indian origin can be analyzed with standard organism's genome available in the NCBI using BLAST and other genome comparative tools. As a general rule of thumb, these genome data can be used as the strain's genome, with the caveat that there might be some unique genes present in the Indian strain that are missing in the standard genome's data. To overcome this limitation, it would be ideal to have the strain's genome sequenced by NGS and deposited in the NCBI. Also, many of the metagenome efforts have led to identification of indigenous strains that have possible implications in bioethanol production in India.

The other way around would be a metagenomic study of microorganisms with characteristics like low pH and sustainability at higher temperature. The strains that produce cellulases and possess any one of the above characteristic can be further explored, i.e., what regulatory factors play a critical role in production of cellulase and other plant-biomass degradation. However, all research to manipulate the production of cellulase at industrial scale requires the presence of omics data. Additionally, availability of genomic information would also increase the computational studies so that it can be well integrated with experimental studies to not only increase the production of cellulase but also at the same time decrease the experimental cost.

Similarly, among the biomass sources that are native to India, there are only 15 genome data available [such as *Brassica juncea* (mustard), *Brassica napus* (rapeseed), *Brassica rapa* (field mustard), *Cajanus cajan* (pigeon pea), *Cenchrus americanus* (pearl millet), *Corchorus capsularis* (jute), *Gossypium barbadense* (Brazilian cotton), *Gossypium hirsutum* (upland cotton), *Manihot esculenta* (cassava), *Populus euphratica*, *Populus trichocarpa* (black cottonwood), *Setaria italica* (foxtail millet), *Sorghum bicolor* (sorghum), *Triticum* sp. (wheat), and *Zea mays* (maize)]. Among these 15, only 10 organisms' proteome data are available. However, there are 21 transcriptome data available for the biomass sources. For strain engineering and development, it is essential that the organism's genome, transcriptome, and proteome are all available. Thus, the availability of all three data for sorghum, maize, upland cotton, and Brassica species will enable for further research (Table 11.2).

Table 11.2 Availability of genome, proteome, and transcriptome data for biomass sourced from India.

S. No.	Name (common name)	Genome	Transcriptome	Proteome	References
1	*Albizia lucidia* (Moj)	Absent	Absent	Absent	[12]
2	*Areca catechu* (betel nut)	Absent	Present	Absent	[12]
3	*Arundo donax* (giant reed)	Absent	Absent	Absent	[13, 46]
4	*Bambusoideae* (bamboo)	Absent	Present	Absent	–
5	*Brassica carinata*	Absent	Present	Absent	[17]
6	*Brassica juncea* (Mustard)	Present	Present	Absent	[18]
7	*Brassica napus* (rapeseed)	Present	Present	Present	[18]
8	*Brassica rapa* (field mustard)	Present	Present	Present	[19]
9	*Cajanus cajan* (pigeon pea)	Present	Absent	Absent	[3]
10	*Cenchrus americanus* (pearl millet)	Present	Present	Absent	[3]
11	*Chrysopogon zizanioides* (Vetiver)	Absent	Absent	Absent	–
12	*Corchorus capsularis* (jute)	Present	Absent	Present	[3]
13	*Cynodon dactylon* (Bermuda grass)	Absent	Absent	Absent	[46]

(*Continued*)

Table 11.2 Availability of genome, proteome, and transcriptome data for biomass sourced from India. (*Continued*)

S. No.	Name (common name)	Genome	Transcriptome	Proteome	References
14	*Echinochloa polystachya* (German grass)	Absent	Absent	Absent	[3]
15	*Gossypium barbadense* (Brazilian cotton)	Present	Present	Absent	–
16	*Gossypium hirsutum* (upland cotton)	Present	Present	Present	[48, 49]
17	*Helianthus tuberosus* (sun root)	Absent	Absent	Absent	[50]
18	*Hibiscus cannabinus* (Kenaf)	Absent	Present	Absent	[51]
19	*Lantana camara* (red sage)	Absent	Absent	Absent	[52]
20	*Lens culinaris* (lentil)	Absent	Present	Absent	[3]
21	*Linum perenne* (blue flax)	Absent	Absent	Absent	–
22	*Manihot esculenta* (cassava)	Present	Present	Present	[20]
23	*Medicago sativa* (alfalfa)	Absent	Present	Absent	[20]

(*Continued*)

Table 11.2 Availability of genome, proteome, and transcriptome data for biomass sourced from India. (*Continued*)

S. No.	Name (common name)	Genome	Transcriptome	Proteome	References
24	*Miscanthus fuscus* (elephant grass)	Absent	Absent	Absent	[20]
25	*Paspalum notatum* (Bahia grass)	Absent	Absent	Absent	[46]
26	*Pennisetum purpureum* (Napier grass)	Absent	Absent	Absent	[46]
27	*Phalaris arundinacea* (reed canary grass)	Absent	Absent	Absent	[13, 53]
28	*Phragmites australis* (common reed)	Absent	Absent	Absent	[54]
29	*Populus euphratica*	Present	Present	Present	[3]
30	*Populus trichocarpa* (black cottonwood)	Present	Present	Present	[3]
31	*Saccharum officinarum* (sugarcane)	Absent	Present	Absent	[3]
32	*Salix viminalis* (basket willow)	Absent	Present	Absent	[3]
33	*Sesbania bispinosa* (prickly Sesban)	Absent	Absent	Absent	–
34	*Setaria italica* (foxtail millet)	Present	Present	Present	[3]

(*Continued*)

Table 11.2 Availability of genome, proteome, and transcriptome data for biomass sourced from India. (*Continued*)

S. No.	Name (common name)	Genome	Transcriptome	Proteome	References
35	*Setaria viridis* (green foxtail)	Absent	Absent	Absent	[3]
36	*Sorghum bicolor* (sorghum)	Present	Present	Present	[21, 22]
37	*Triticum* sp. (wheat)	Present	Present	Absent	[3]
38	*Zea mays* (maize)	Present	Present	Present	[3]
39	*Ziziphus rugosa* (Bonbogori)	Absent	Absent	Absent	[12]

Besides, the higher content of lignin hinders the production of bioethanol and the reason can be imparted to complexity involved in separating lignin from other polymers for efficient enzymatic hydrolysis [23]. Hence, one can think of genetically engineering fuel plants to generate less amount of lignin as compared to other biopolymers and would require information of regulatory factors involved in the synthesis of lignin. Though the biosynthetic pathway of lignin has been deciphered in great depth, regulating its production in various plants would surely involve the knowledge of genome of that particular plant. In addition, one can go for transcriptomics study to know what all genes and regulatory factors are involved in higher production of cellulose and xylose in a given plant so as to increase the content of bioethanol in the long term.

11.6 Conclusion

The success of bioethanol blending as proposed by the Government of India is dependent on two things: (1) availability of biomass sources that are sustainable and (2) characterization of catalysts. For the former, the major limitation is incentive to the farmers to provide the industry enough biomass (such as second-generation biomass) to make it sustainable. In this regard, this chapter summarizes not only agricultural crop residues but also plants that are used majorly as feed or for other purposes. With regards to catalysts, it has been shown that for a developing country like India, there are abundant strains available that produce cellulases and other associated enzymes. Some of these enzymes are attractive for industry in terms of thermostability and other properties that are deemed desirable. At the same time, some of these organisms' genome has been sequenced, and thus there is availability of omics data that can be tapped for further characterization and development of strains that are highly suitable for industrial purposes. In the future, there is a need to generate more omics data (genome, transcriptome, and proteome) to be generated for both the biomass source and strains native to India.

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Comparative Analysis of Solid Waste Management Processes in Himachal Pradesh and Punjab

Anchal Sharma, Rajiv Ganguly & Ashok Kumar Gupta

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Abstract

The study compiles the overview of existing municipal solid waste management processes in Himachal Pradesh. The physical characterization of municipal solid waste has also been assessed to provide the baseline data for the municipalities of respective regions to achieve the purposive waste management goals. It is mandatory for the municipal authorities to quantify and characterize

the municipal solid waste in order to successful management of solid waste. The paper discusses the assessment of existing municipal solid waste processes of two municipal corporation regions of Himachal Pradesh and the comparative analysis of waste assessment with Jalandhar region of Punjab, India using Matrix method. The paper also conducted the 'wasteaware' benchmark indicators for the evaluation of solid waste management processes in Himachal Pradesh. The study of physical characterization revealed that the waste of Himachal Pradesh is rich in organic waste 62.01% (Shimla), 55.12% (Dharamshala) being followed by paper waste however the municipal solid waste of Jalandhar are also having maximum amount of organic waste but the second highest fraction is of plastic waste. The 'waste aware' benchmark indicators study revealed that Himachal Pradesh has better waste management practices than Jalandhar, Punjab.

Keywords

Municipal solid waste **Illegal dumping**

'waste aware' benchmark indicators

Matrix method

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Abstract. The study compiles the overview of existing municipal solid waste management processes in Himachal Pradesh. The physical characterization of municipal solid waste has also been assessed to provide the baseline data for the municipalities of respective regions to achieve the purposive waste management goals. It is mandatory for the municipal authorities to quantify and characterize the municipal solid waste in order to successful management of solid waste. The paper discusses the assessment of existing municipal solid waste processes of two municipal corporation regions of Himachal Pradesh and the comparative analysis of waste assessment with Jalandhar region of Punjab, India using Matrix method. The paper also conducted the 'wasteaware' benchmark indicators for the evaluation of solid waste management processes in Himachal Pradesh. The study of physical characterization revealed that the waste of Himachal Pradesh is rich in organic waste 62.01% (Shimla), 55.12% (Dharamshala) being followed by paper waste however the municipal solid waste of Jalandhar are also having maximum amount of organic waste but the second highest fraction is of plastic waste. The 'waste aware' benchmark indicators study revealed that Himachal Pradesh has better waste management practices than Jalandhar, Punjab.

Keywords: Municipal solid waste · Illegal dumping
'waste aware' benchmark indicators · Matrix method

1 Introduction

Solid waste management is one of the mandatory services that must be provided by municipal authorities to maintain the environment clean and safe. The condition of waste management has becoming more critical due to the rapid growth in urbanization and industrialization (Sharholy et al. 2008; Katiyar et al. 2013). The drastic increase in the population and hence growth in solid waste causes pollution of environment including air, water and soil (Puri et al. 2008; Sethi et al. 2013). The poor waste management practices are mainly due to the unavailability of veritable data and information to examine the waste management practices (Chang and Davila 2007; Shekdar et al. 2009). The population of India is outlined as 1083 million in 2001 and accordingly 1253 million in 2013 according to the Census report, 2011. The per capita

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per day waste generation is 0.17 kg/capita/day in smaller towns and 0.63 kg/capita/day in the big cities of India (Kumar et al. 2009; Modak et al. 2012). The solid waste produced in India has not managed in the adequate manner due to the lack of poor and improper management of Municipal Corporation authorities of the cities. In general, 90% of the waste is disposed illegally in the land, thus become the major contributors to the environment pollution (Rana et al. 2015; Rana et al. 2018). The present study gives the overview of waste management practices and physical characterization of solid waste in the municipal corporation cities (Shimla and Dharamshala) in Himachal Pradesh, India. In addition, the matrix method has been determined for the comparative analysis of the study regions with Jalandhar, Punjab. The description of study areas has been shown in Table 1 and the location of study areas has been shown in Fig. 1.

2 Methodology

2.1 Site Locations

See table and figure.

Table 1. Description of study areas

City	Longitude	Latitude	Waste generation
Shimla	31.1048°N	77.1734°E	90 TPD
Dharamshala	32.2190°N	76.3234°E	25 TPD



Fig. 1. Location of study areas

2.2 Characterization of Municipal Solid Waste

The sampling process was carried out for the physical characterization of municipal solid waste according to ASTM-D 5231-92. The municipal solid waste around 1000 kg was transported to the dumping grounds through transportation vehicles including trucks and tippers. The waste was unroll on the plastic sheet and then mixed properly in order to make the analogous mixture of the waste. Out of total 1000 kg of waste, 100 kg sample was withdrawn randomly at each day of the 10 days sampling period in order to acquire representative waste samples. The municipal solid waste acquired was sorted manually by the rag pickers (Rana et al. 2018).

2.3 'Wasteaware' Benchmark Indicators

Benchmark indicators are the efficient tool for the assessment of municipal solid waste management strategy of the city. The elemental principle of benchmark indicators is to allow the city to understand its performance of municipal solid waste management services and comparison with the waste management practices of different cities. However, it also provides information for decision making on prime issues regarding funds for the improvement of waste management services. The 'wasteaware' benchmark parameters integrated both qualitative and quantitative indicators (Wilson et al. 2013; Wilson et al. 2015). In the Quantitative analysis of waste management, the parameters include Public health collection, environmental controlled disposal and resource management and the qualitative indicators unite governance parameters including user and provider inclusivity, financial sustainability, national policy framework and local institutions.

2.4 Matrix Method

The matrix method is the method of quantification that has been enlisted for the deliberation of existed municipal solid waste management system (Rana et al. 2015). In this context, the 'wasteaware' benchmarks utilized grading system including low (L), Low/Medium (L/M), Medium (M), Medium/High (M/H) and High (H), a five point classification has been allocated to benchmarks. The above grading systems (L, L/M, M, M/H and H) were utilized by assigning each of them a classification point such as (L = 1, L/M = 2, M = 3, M/H = 4, H = 5) (Rana et al. 2015; Sharma et al. 2018).

3 Results and Discussions

3.1 Assessment of Existing Municipal Solid Waste Management in Shimla and Dharamshala

3.1.1 MSW Generation

The average daily waste generation in Shimla city is reported as 90 tons per day and waste generation in Dharamshala is reported as 25 tons per day. The quality and quantity of municipal solid waste generated does not remain the same throughout the seasons but it shows variation during different seasons because of enormous floating population due to touristic activities. The sources of solid waste are residential, institutional, commercial, inert, industrial, agriculture etc. The physical characterization of municipal solid waste has been summarized in Table 2.

The characterization of the municipal solid waste revealed that out of total waste generated in Himachal Pradesh, the highest fraction of waste is the organic waste including vegetables, food and fruits etc. Paper waste formed the second highest fraction out of the total waste generated in Himachal Pradesh. The proportion of plastic has been found very low in Himachal Pradesh because the use of plastic has been banned in Himachal Pradesh since 2003. However, the reported literature showed the fraction of plastic waste in Chandigarh (7%), Jalandhar (9%), Bhopal (10%) that was lesser than Himachal Pradesh (Rana et al. 2018).

Table 2. Physical characterization of waste

Sr. No.	Parameters	Shimla	Dharamshala
1.	Density (Kg/m^3)	542.23 ± 27.32	527.02 ± 22.14
2.	Organic waste	62.01 ± 3.22	55.12 ± 1.45
3.	Paper	21.32 ± 2.45	19.11 ± 0.33
4.	Plastic	5.50 ± 1.99	7.05 ± 0.71
5.	Glass	1.34 ± 0.75	2.48 ± 0.22
6.	Metal	1.92 ± 0.06	2.09 ± 0.39
7.	Inert	4.89 ± 1.02	5.23 ± 0.24
8.	Rubber	2.11 ± 1.24	3.68 ± 1.67
9.	Textile	1.10 ± 0.66	5.24 ± 1.14

3.1.2 Collection of MSW

There is lack of adequacy in the system of municipal solid waste collection in Shimla city. The collection of waste at household level has been started but there is no provision of segregation of waste. No doubt, the dumpers have been placed at different locations in the city but without the consent of need or having no such data about the quantity of waste generation in different places.

Apart from this, Dharamshala city has somewhere improved scenario of waste collection system. Street sweeping is carried out in all 365 days by more than 130 workers from morning 7:30 am to 11:30 am and 2:00 pm to 4:00 pm covering all the roads of the city. About 188 km roads are swiped by more than 130 street sweepers on a daily basis. But no provision of waste segregation is noticed in the city.

3.1.3 MSW Transportation

The condition of transportation vehicles depend on the physical layout of the roads, manpower available and the funds allotted for maintenance provisions. The vehicles provided by municipal authority for the transportation of waste to the dump sites in Shimla city includes tippers, loaders, bulldozers, compactor, three wheelers, tractor trolleys etc. and the vehicles provided by municipal authorities in Dharamshala includes crane mounted truck, container lifting devices, jeep, auto rickshaw etc. In particularly, it is observed in both of the regions that most of the vehicles are worn out and lack of maintenances occurred that become the reason of inadequate management of waste. Moreover, the municipal solid waste is transported mostly in an open trucks and vehicles which cause littering of waste in the roads and thereby generation of flies and mosquitoes are supposed to occur (Rana et al. 2015).

3.1.4 MSW Disposal

The waste collected from different sources from the Shimla city and Dharamshala city is openly disposed of in the dumpsites. Currently, all types of solid waste consisting industrial, biomedical, slaughterhouse and municipal solid waste dumped on the disposal sites. According to the management and handling Rules 2000, only inert waste should be disposed of in the landfills and remaining waste should be transferred to the processing units. There is no such facility of leachate collection system, liner system, gas collection

Table 3. 'Waste-aware' benchmark indicators for Himachal Pradesh and Jalandhar city

Sr. No.	Category	Indicator	Jalandhar City	Himachal Pradesh
Background information of the city				
1	Country Income Level	World Bank Indicator Level	Lower-Middle	Lower-Middle
		GNI per Capita	$1,140	$1,140
B2	Population of the City	Total Population of the City	8,73,725	6,856,509
B3	Waste Generation	MSW Generation (tons/year)	109000	176000
W1	Waste Composition		3keyfractions–as % wt.oftotalwaste generated	
W1.1	Organic	Organics (food and green wastes)	44.53%	58.56%
W1.2	Paper	Paper	3.43%	20%
W1.3	Plastic	Plastic	7.42%	6%
1.1	Public health-Waste collection	Waste collection coverage	70% (L/M)	72% (L/M)
1C	-	Qualityof waste collection service	70% (L/M)	80% (M/H)
2	Environmental control-waste treatment and disposal	Controlled treatment and disposal	10% (L)	15% (L)
2E	-	Degree of environmental protection in waste treatment and disposal	0% (L)	0% (L)
3	3Rs-reduce, reuse and recycling	Recycling rate	0% (L)	0% (L)
3R		Qualityof 3Rsprovision	5% (L)	10% (L)
6N	Sound institutions,proactive policies	Adequacy of national SWM framework	60% (L/M)	64% (L/M)
6L	Degree of Institutional coherence		69% (L/M)	72% (L/M)
4U	User inclusivity	User inclusivity	68% (L/M)	71% (L/M)
4P	Provider inclusivity	Degree of provider inclusivity	65% (L/M)	73% (L/M)

Keys for colour coding

Red colour - low index
Yellow colour - medium index
Green colour - High index
Red/yellow - low/medium
Yellow/green - medium/high

facilities and monitoring wells in the disposal sites. Therefore, it is a threat to the surface and ground water quality because of the permeation of leachate in the soil.

3.2 'Wasteaware' Benchmark Indicators

3.2.1 System Analysis Using 'Wasteaware' Benchmark Indicators

The 'Wasteaware' Benchmark indicators for Himachal Pradesh and Jalandhar city has shown in Table 3 that the municipal solid waste generated at Himachal Pradesh is considerably higher than the waste generated in Jalandhar. In this context, red, yellow and green colours indicated low index (L), medium index (M) and high index (H) respectively. It was observed from the evaluation of 'wasteaware' benchmark parameters that the qualitative indicators collection efficiency and waste collection services (Public Health parameters) of Jalandhar city can be categorized in low/medium index (L/M) but the collection efficiency in Himachal Pradesh lies in medium/high index (M/H). Apart from this, for the Environmental control and 3R's facilities, both Himachal Pradesh and Chandigarh city were classified as low index. The 'wasteaware' analysis also reveals that for the qualitative indicators, Jalandhar city and Himachal Pradesh both lies in low/medium index (L/M). The weightage assignment and scores summary has been shown in Tables 4 and 5.

Table 4. Weight-age assignment for evaluation using matrix method

Sr. No.	Category	Indicator	Jalandhar city	Himachal Pradesh
Quantitative indicators (Public health, Environmental control, 3R's)				
1.1	Public health	Waste collection coverage	70% (L/M) (2)	72% (L/M) (2)
1C	Waste collection	Waste collection services	70% (L/M) (2)	80% (M/H) (4)
2	Environment control facilities	Control treatment and disposal	10% (L) (1)	15% (L) (1)
2E	Waste treatment and disposal	Degree of environmental protection	0% (L) (1)	0% (L) (1)
3	3Rs–reduce, reuse and recycling	Recycling rate	0% (L) (1)	0% (L) (1)
3R		Quality of 3R's provisions	5% (L) (1)	10% (L) (1)
Qualitative indicators (Governance factors)				
4U	User inclusivity	User inclusivity	L/M (60%) (2)	L/M (64%) (2)
4P	Provider inclusivity	Provider inclusivity	L/M (69%) (2)	L/M (72%) (2)
6 N	Sound, institutions proactive policies	Adequate national framework	L/M (60%) (2)	L/M (71%) (2)
6L	–	Degree of institutional coherence	L/M (65%) (2)	L/M (73%) (2)

Table 5. Summary of scores obtained through matrix method

Sr. No.	Category	Indicator	Jalandhar city	Himachal Pradesh
Quantitative indicators (Public health, Environmental control, 3R)				
1.1	Public health – Waste collection	Waste collection coverage	2	2
1C		Quality of waste collection service	2	4
2	Environmental control – waste treatment and disposal	Controlled treatment and disposal	1	1
2E		Degree of environment protection in waste treatment and disposal	1	1
3	3Rs–reduce, reuse and recycling	Recycling rate	1	1
3R		Quality of 3R's provision	1	1
Total Score (Quantitative indicators)			08	10
Maximum score			30	30
Weightage (%)			**26**	**33**
Qualitative indicators (Governance factors)				
4U	User inclusivity	User inclusivity	2	2
4P	Provider inclusivity	provider inclusivity	2	2
6 N	Sound institutions proactive policies	Adequacy of national SWM framework	2	2
6L	–	Degree of institutional coherence	2	2
Total score (Quantitative indicators)			08	08
Maximum score			20	20
Weightage (%)			**40**	**40**
Total score (Overall)			08 + 08 = 16	10 + 08 = 18
Total maximum score			30 + 20 = 50	30 + 20 = 50
Overall weightage (%)			**32**	**36**

The overall results obtained from the quantification of matrix method for Jalandhar city were 32% and 36% for Himachal Pradesh respectively. Hence, it is clearly showed that the quantification score of Jalandhar city was considerably lower than Himachal Pradesh. The results revealed that weight-age acquired from quantitative parameters of 'wasteaware' analysis were reported 26% for Jalandhar city whereas found more for Himachal Pradesh 33%. However, the score for governance factors (quantitative analysis) of Jalandhar and Himachal Pradesh were reported as 40%.

4 Proposals for Strengthening of Municipal Solid Waste Management Services

As a result of urbanization and increasing touristic activities, it is the basic duty of municipal authorities to provide infrastructure and facilities in terms of manpower, machineries, funding to provide effective and efficient services for the adequate and better management of municipal solid waste.

4.1 Hand Cart/Wheel Barrows

For door to door collection of garbage, there should be minimum 40–60 numbers of hand carts in order to meet the primary collection of waste and to improve the collection efficiency of the waste that is the foremost step of the better waste management. The waste sorting and segregation is must at source and at collection stage for efficient management of waste.

4.2 Bins for Segregated Waste Collection

Effective functioning and efficiency of treatment widely varies with the degree of segregation of the waste received at treatment plant. Municipal corporations of Shimla and Dharamshala has already installed underground bins at some urban areas, but still facing the problem in collection of segregated waste. There is a need to provide small dustbins green and blue colour having minimum 10 litre capacities at least at household levels to collect segregated dry waste and wet waste.

4.3 Small Waste Collection Vehicles (E-Rickshaw) for Waste Collection from Litter Bins

Proper collection of solid waste is first important step toward increasing the efficiency of waste management. There is a dire need to float at least 20 more waste collection vehicles (E-Rickshaws) in both of the cities according to the survey of waste management strategy of the cities. The door to door collection of waste from residential and commercial complexes in both the cities should be promoted by municipal authorities in order to avoid littering of waste here and there by the residents.

5 Conclusion

Solid waste management is the globally concerned issue in the present scenario. The study compiled the existing status of municipal solid waste management processes and characterization of waste in Himachal Pradesh. The study revealed that there is dire need to educate every people of the city towards the environmental issues in order to strengthen the aesthetic appearance of environmental and improving health of public. The paper also focussed on the ‘wasteaware’ benchmark indicators and the matrix method system for Himachal Pradesh (Shimla and Dharamshala) and their waste management practices comparative analysis with Jalandhar city. The results clearly

showed the poor performance of environmental control methods including collection and treatment of waste and final disposal of waste in Himachal Pradesh and Jalandhar city. However, the comparative analysis of qualitative and quantitative indicators revealed that Himachal Pradesh exhibits somewhere better results of waste management than that of Jalandhar city. The waste processing facilities should be applicable by the municipal authorities including composting, vermicomposting, reduce derived fuel, vermicomposting, source segregation etc. for the better management of waste. Only inert waste should be disposed in the landfills. However, it is critically observed that there is no such facility of liner, leachate collection and disposal system, gas monitoring facilities, monitoring wells and final cover system for the disposal of solid waste. Open dumping of waste creates annoyance for the health issues of people as well as aesthetic appearance of environment. Hence, open dumps should be avoided and waste should be disposed of in sanitary engineered landfill systems.

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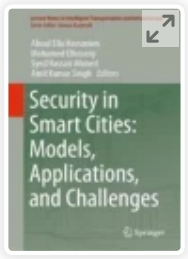

Security in Smart Cities: Models, Applications, and Challenges pp 323–343

Efficient Generation of Association Rules from Numeric Data Using Genetic Algorithm for Smart Cities

Pardeep Kumar & Amit Kumar Singh

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Abstract

Machine learning plays an important role to develop smart cities by gathering real time information using several state of the art algorithms. In the recent past, association rule mining plays an important role in the discovery of accurate information from databases to satisfy the need of real time applications in smart cities ranging from healthcare to intelligent transport systems. It is used in various applications for

decision making, detection and prediction etc. because of its robustness to derive associations among various attributes of datasets. This technique seems to be simple in case of categorical data but becomes quite complex in case of numeric data. In this work, we have mainly concentrated on the problem of generating association rules from numeric data in an efficient way. For accomplishing this task we have taken genetic algorithm as the base of the solution to this problem. Genetic algorithm is selected for this task because of its nature of self-improving and ability to handle large solution set. Here we have proposed genetic algorithm based association rule mining algorithm which generates random association rules on the basis of general property of datasets. The generated rule set is improved at each run of algorithm and filtered for more and more interesting and accurate rules.

Keywords

Association rule mining **Decision making**

Categorical data **Numeric data**

Genetic algorithm **Smart cities**

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Efficient Generation of Association Rules from Numeric Data Using Genetic Algorithm for Smart Cities



Pardeep Kumar and Amit Kumar Singh

Abstract Machine learning plays an important role to develop smart cities by gathering real time information using several state of the art algorithms. In the recent past, association rule mining plays an important role in the discovery of accurate information from databases to satisfy the need of real time applications in smart cities ranging from healthcare to intelligent transport systems. It is used in various applications for decision making, detection and prediction etc. because of its robustness to derive associations among various attributes of datasets. This technique seems to be simple in case of categorical data but becomes quite complex in case of numeric data. In this work, we have mainly concentrated on the problem of generating association rules from numeric data in an efficient way. For accomplishing this task we have taken genetic algorithm as the base of the solution to this problem. Genetic algorithm is selected for this task because of its nature of self-improving and ability to handle large solution set. Here we have proposed genetic algorithm based association rule mining algorithm which generates random association rules on the basis of general property of datasets. The generated rule set is improved at each run of algorithm and filtered for more and more interesting and accurate rules.

Keywords Association rule mining · Decision making · Categorical data Numeric data · Genetic algorithm · Smart cities

1 Introduction

Large amounts of data is being collected routinely in the task of day-to-day management and decision making in banking, business, administration, the delivery

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of social and health services, works related to environmental protection, handling security and in politics. Such data are primarily used for accounting service such as decision building, prediction, etc. to users of the system, later it can be used for maintenance in long term. Typically, data sets to be considered for this task are very large and constantly growing and contain a large number of complex dimensionality. While these data sets reflect properties of the managed subjects and relations between them, and are thus potentially of some use to their owner, but they often have relatively less useful information as compared to its volume. Hence, robust, efficient, simple and computationally efficient algorithm is required to extract information from such datasets.

One of the important data mining tasks is generating association rules, which deals with finding IF-THEN rules by analyzing similarity between combinations of attributes of data. As it can be seen that IF-THEN rules are easy to understand and can be used in multiple applications for deriving inferences for relevant tasks, therefore generating such kind of rules is considered as an important task in data mining.

To generate such algorithm in an efficient way, one of the important subjects of computer science also helps data mining, i.e. machine learning. Machine learning is a subject which keeps efficient solution of various general problems which can be used in any field of study such as data mining, optimization, information retrieval etc. We will also be using one of the machine learning techniques in our work i.e. genetic algorithm.

2 Basic Terminology

2.1 Numeric Association Rule Mining

Association rule mining is a well-known data mining technique that is used for extracting information from raw data in form of IF-THEN statement. These statements can be used in many fields for prediction and decision making. First introduced in Agrawal et al. [1], the process of extracting such rules was quite cumbersome where all the possible combinations are checked for co-relations. The co-relation between attributes was checked on basis of interestingness. Each rule is checked for interestingness using various interestingness parameters such as support, confidence, lift, conviction etc. Various such parameters are given in Tew et al. [2]. Later same author improved the procedure of extracting rules in Agrawal and Srikant [3] where the authors proposed a well-known Apriori algorithm in which only frequent occurring pairs are checked for further co-relation. After the introduction of Apriori, lots of other algorithms were proposed for extracting association rules. Like in Houtsma and Swami [4], association rule mining using sql query was explained but it requires multiple scans of database. In Hidber [5], an online technique for generation of association rule was proposed where the rules are generated at real time. A comparison between two well-known algorithms Apriori–Eclat was discussed in Borgelt [6]. But

all these algorithms were designed for categorical data only. None of these algorithm works well for numeric dataset. The rules needed for numeric dataset are of form:

$$\text{attribute1[lb1, ub1], attribute2[lb2, ub2]} \Rightarrow \text{attribute3[lb3, ub3]}$$

where there is a lower and upper bound attached with every attribute. These kinds of rules are more general in nature as well as contains more information as compared to categorical association rules. By extracting numeric association rule, various inter disciplinary fields can be benefited such as medication, structural engineering, pollution analysis, image processing etc.

2.2 Genetic Algorithm

Genetic Algorithm (GA) explained in Goldberg [7] is a powerful algorithmic technique that can be used for generating solution for a search and optimization problem [8, 9]. It basically follows one of the nature's principle i.e. survival of the fittest as stated in Darwin's theory of evolution. It tells that the one that is stronger survives for longer. This algorithm finds better solution in each generation and keeps on improving the solution in each generation till it finds a near optimal solution.

The process of general genetic algorithm starts with the description of problem; on the basis of problem and the solution needed an encoding scheme is selected. Chromosomes are generated as initial population by using that encoding scheme. Fitness value is calculated for each chromosome and on the basis of that it is decided whether the solution is appropriate or not. Further the population is changed by applying crossover and mutation operators which is meant for introducing diversity in the algorithm. By implementing these operators, a new generation of population is evolved then again on that population fitness is checked. This is an iterative self-improving process which improves its own solution iteration by iteration. The iterations are stopped when the desirable results are generated. The population in the final iteration is considered to be the best solution set. As per the requirement of the problem results can be formulated from the population of last generation. A general work flow of genetic algorithm is illustrated in Fig. 1 given in Obitko [10].

3 Literature Survey

To derive association rules of form IF-THEN statement, we need to get an antecedent and a related consequent part which are co-related to each other. For applying GA for finding such rules as mentioned in Freitas [11], four main designing components are needed i.e. Chromosome encoding for representing rules in form of GA understandable chromosomes, Crossover operator for generating new child chromosomes, Mutation operators for introducing diversity in the population and fitness function

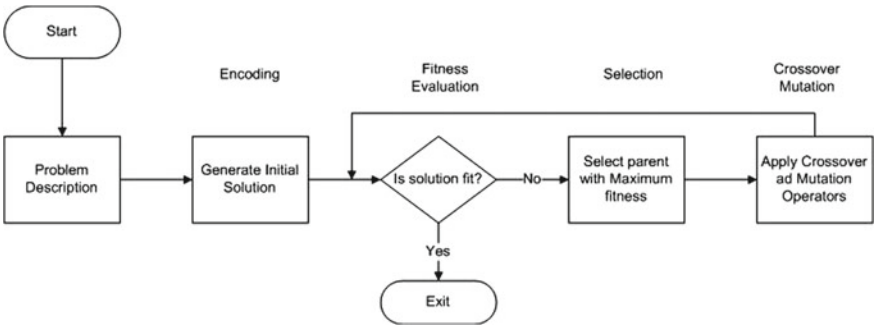

Fig. 1 Flowchart of basic genetic algorithm

which will evaluate fitness measure of each rule. After deciding these factors only thing left is to apply basic genetic algorithm which is defined in introduction part above, using all these components.

3.1 Chromosome Representation

Broadly there are two chromosome representation techniques are present in literature for ARM. In the first approach (Pittsburgh approach), a batch of possible association rules are encoded in a chromosome. This encoding approach is well suitable for classification rule mining, where the goal is to generate a good quality set of rules. However, in ARM, the main goal is to find a set of rules where each rule is good in itself. Therefore, for ARM case, the Michigan approach explained in Goldberg [7] is mostly used. Each chromosome represents exactly one rule in itself, is more suitable in Michigan approach. Most of the ARM techniques use Michigan chromosome representation.

In an early work by Ghosh and Nath [12], the authors use the Michigan approach as follows: each chromosome has length $2k$, where k is the number of items. The chromosomes in this case were binary strings where each attribute is given two bits. If these two bits are 00 or 11, then the attribute is present in the antecedent part or consequent part of the rule, respectively, else the attribute is not present in the rule.

In paper by Anand et al. [13], each chromosome has two parts. The first part indicates the location of the attribute in the rule and the other part indicates the categorical value it has. The prior part consists of two bits where the attribute appears in the antecedent part or the consequent part of the rule, if the bits are 10 and 11, respectively; else, it is meant to be absent from the rule. The other part represents the categorical values carried by attributes in binary form. However, the authors in the paper did not given any justification of how the binary value of the attribute in the second part will appear and how categorical state will be managed if the number of states for an attribute is not an exact power of two. The main demerit of choosing

a binary encoding scheme is that the length of the chromosome is large when the number of attributes increases, because at least two bits are required for each attribute representation. An integer encoding can be used as a solution to this problem.

An integer encoding scheme has been used in association rule mining using multi objective genetic algorithm by (ARMGA) Yan et al. [14]. In this work the chromosomes encode the index of the attributes. A chromosome represented as encoding a k-rule, k is the total number of attributes in the antecedent part and the consequent part of the rule, and this chromosome will have $k+1$ genes. The first gene position represents the differentiating position of the chromosome where the attributes of antecedent and the consequent are separated. For example, if Ai represents the ith item, then the chromosome $\{3 \mid 5\ 4\ 2\ 1\ 3\}$ represents the rule $A2, A5, A4 \Rightarrow A1, A3$. This kind of representation reduces length of the chromosome significantly.

In Alatas et al. [15], encoding scheme used for chromosomes representation where each attributes has three parts. The first part tells whether the attribute is present or not in the rule, and if present, in which part of the rule (antecedent or consequent) it is present. The second and third part tells the lower and upper bounds of the value of attribute. The first part can have integer numbers such as 0, 1, or 2, which represents the occurrence of the attribute in the antecedent part of the rule, the occurrence of the attribute in the consequent of the rule, and the absence of the attribute from the given rule, respectively. Next, the second and the third part can take real numbers from the related attribute range. Further it is to be noted that as MODENAR uses differential evolution as an optimization technique and works on real-valued chromosomes, the authors considered a round off operator for handling the integer value part of the chromosome. In Martin et al. [16], authors use positional encoding scheme. Metawa et al. [17] used binary chromosome encoding scheme in their genetic algorithm based proposed approach for optimizing bank lending decisions to specify the selected customer in the lending decision.

3.2 Objective Functions

Even though support count and confidence are two well-known objectives that are generally to be maximized yet there are several other parameters available to measure the interestingness or strength of association rules as mentioned in Berzal et al. [18]. Some of the parameters, which can be used by different algorithms for optimization in a multi-objective scenario, are comprehensibility, conviction, interestingness, performance, lift, coverage, precision etc. Each function has its own significance and combination of best of these functions gives best result in the end. In Alatas et al. [15], objective function tries to optimize four criteria of the rules: support, confidence, amplitude of the intervals and comprehensibility, which make up the subparts of the rule. In Martin et al. [16], authors use comprehensibility, interestingness, and performance for fitness calculation. Anand and Vinodchandra [19] proposed association rule mining algorithm using treap data structure where they focused on running time rather than rule set quality. Umit and Bilal [20] proposed exploration of associ-

ation rules within numerical databases with Gravitational Search Algorithm (GSA) with flexible fitness function. In Uroš et al. [21], authors proposed a modified single-objective binary cuckoo search for association rule mining (MBCS-ARM) where objective function composed of support and confidence only. The quality of rule sets was still an issue in literature.

3.3 Evolutionary Operators

Mostly, when binary encoding scheme is used, some of the standard crossover and mutation operators are used. For example, in Ghosh and Nath [12], bit-flip mutation and multipoint crossover have been used. In Anand et al. [13], mutation operator, bit flip has been adopted. However, the authors did not specifically mention which crossover operator should be used.

In Qodmanan et al. [22], where integer encoding for the chromosomes is used, an order-1 crossover technique is taken into consideration. In this technique, first a segment is selected from any two parent chromosomes and these are copied to the two child chromosomes. Next, starting from the right side of the segment, the values of the genes that didn't appear in the selected segment of the first parent, are copied to the first child. The same procedure is repeated for the second child as well. The mutation operator introduces diversity by replacing a selected attribute value from the chromosome with a random attribute value not present in the chromosome currently. Alatas et al. [15] used differential evolution based crossover and mutation operators.

4 Proposed Approach

In the literature, till date a lot of work has been done in the field of association rule mining but most of the work is done for extracting rules from categorical data only. A very few algorithm can be seen for dealing with numeric data to get the relevant and interesting association rules. We have kept our focus mainly on mining association rule from numeric data. To handle numeric data efficiently, it is required that the data related to each attribute should be checked individually which increases the search space exponentially. Therefore, to deal with such problem, we have used genetic algorithm which finds solution with the least possible domain knowledge. In this work we have analyzed the basic structure of previously available work on same domain and proposed an algorithm which generates better results from the previously known works of similar kind.

In the proposed work we will be generating the rules of the form:

$$\text{attribute1}[\text{lb1}, \text{ub1}], \text{attribute2}[\text{lb2}, \text{ub2}] \rightarrow \text{attribute3}[\text{lb3}, \text{ub3}]$$

Chromosome Representation

A	B	C	D	E	F
$1,lb_1,ub_1$	$0,lb_2,ub_2$	$2,lb_3,ub_3$	$3,lb_4,ub_4$	$0,lb_5,ub_5$	$1,lb_6,ub_6$

Fig. 2 Chromosome representation for proposed approach

which signifies if the value of attribute1 is between lb1 and ub1, attribute2 is between lb2 and ub2 then the value of attribute3 will be between lb3 and ub3. In this approach there is no limitation on length of either of antecedent or consequent part.

4.1 Technical Details of Implementation

As discussed earlier, for using genetic algorithm for any problem, the basic components of genetic algorithm (i.e. encoding scheme, initial population, crossover and mutation operator and fitness function) have to be decided. Therefore, in our case for generating rules using genetic algorithm, the part of algorithm that we have used is as follows:

Chromosome Representation
We have used Michigan encoding scheme in this implementation where one chromosome represent one rule in the population. The chromosome is represented as shown in Fig. 2 where column under A represents a gene corresponding to attribute A which consists of 3 parts. First part represents the location of attribute whether it will be in antecedent part or it will be in consequent part. If first bit of gene is 0 indicates this attribute is in antecedent part, 1 indicates it to be in consequent part, whereas 2 indicate that the attribute is not present in the rule. Other two parts of the gene are lower bound and upper bound value of the attribute. Chromosome in Fig. 2 shows a rule of form:

$$B[lb_2, ub_2],\ E[lb_5, ub_5] => A[lb_1, ub_1],\ F[lb_6, ub_6]$$

which represents rule as IF B has a value between lb_2 and ub_2 and value of E is between lb_5 and ub_5 THEN the value of A will be in lb_1 and ub_1 and the value of F will be in lb_6 and ub_6.

Population Generation
Initial population generation in implementation is done by keeping in mind the frequency of value of attribute that occurs in the dataset i.e. a value that is more frequently coming into dataset are selected for generating chromosome. This is because the initial population is an important factor for better output of genetic algorithm as the whole flow of genetic algorithm is broadly based on the first generation. It is the solution of the first generation which is improved further in other generation. If we

keep a check on initial population then there is chance of getting better results as the output of the genetic algorithm.

Fitness Calculation

For every chromosome in the population, fitness is calculated. This fitness is the indicator of interestingness and importance of the rule. Various important interestingness parameters have been compared in Tan et al. [23]. It is to be decided prior that which interestingness parameters to be selected for better results. We have selected support, confidence, lift and conviction for our proposed work. If chromosome has fitness greater than the threshold fitness then it is considered for next generation else it is restricted to enter in the next generation. The threshold is calculated as the average of the fitness of rules of last generation. In this implementation we have taken a power fitness function. For calculating fitness function, initially support, confidence, lift and conviction of the chromosome is calculated.

For a sample rule like 'if A then B':

Interestingness Measures used in proposed algorithm are:

1. Support [1]—indicates how frequently A and B occur in the dataset.

$$\text{Support} = \frac{\text{Count}(\text{A} \cup \text{B})}{\#\text{ of Records}}$$

2. Confidence [1]—indicates how frequently A and B occurred when it is known that A was already present in the record.

$$\text{Confidence} = \frac{\text{Support}(\text{A} \cup \text{B})}{\text{Support}(\text{A})}$$

3. Lift [24]—indicates how frequently A and B occurred when it is known that B was already present in the record.

$$\text{Lift} = \frac{\text{Confidence}(A \rightarrow B)}{\text{Support}(B)}$$

4. Conviction—indicates the comparison of the probability that A appears without B if they are dependent with the actual frequency of the appearance of A without B.

$$\text{conviction} = \frac{\text{P(A)P}(\sim\text{B})}{\text{P}(A(\sim\text{B}))}$$

First fitness filter is created on the basis of support. A minimum Support value is taken and only the chromosomes having fitness value greater than support will be considered for rest of the fitness value calculation process.

Rest of the fitness calculation is done by a multi-objective maximizing function of form

$$Fitness = \left(Support^4\right) + \left(Confidence^3\right) + \left(Lift^2\right) + \left(Conviction^2\right)$$

where constant 4, 3, 2, 2 in the power are chosen on the basis of importance of these interestingness parameter. The main motive of this function is to maximize the effect of interestingness parameter. The chromosome with the fitness value less than the average fitness value is not considered for next generation. This chromosome is sent to the mutation repository for generating new chromosome out of it with few improvements.

Crossover Operator

Crossover is done among two fit parent chromosome to generate two new off springs. Various crossover operators and their performance have been discussed in Magalhães-Mendes and Cidem [25]. For this implementation, we have taken a hybrid of two crossover operator i.e. single point and every point crossover operator. In one generation single point crossover is implemented and in next generation every point crossover is applied. This is repeated in the same way for all iteration. This is done to introduce better structure to generate new population. The idea behind combining the two crossover operator is that, at certain iteration we crossover at one point and on certain other iterations we do the crossover at every point in which swapping of gene of each attribute takes place. First operator preserves the quality of fit chromosome whereas every point crossover will introduce more chromosomes with better quality of previous chromosome. By keeping the balance among both of them will generate better chromosomes at different generation.

Mutation Operator

Mutation is applied to bring diversity in population. In mutation some of the bits of previous chromosome are changed to some other random value. For our implementation, we have implemented a selective bit mutation where a bit is selected to change in the chromosome and then generate a new chromosome. And while applying the mutation operator we also have kept a provision of generating some new random chromosome similar to the way it was generated in initial population phase. We apply mutation operator over chromosomes which are not fit i.e. the chromosome that have not come in the threshold fitness range in previous generation. There we select any of the gene (attribute) of the chromosome and increase or reduces the lower bound and upper bound or change the first bit which is representing location of attribute in the rule. By changing lower bound and upper bound there is chance of improvement in chromosome. Once the chromosome become fit by changing range of some attribute next time it will enter the population and may be selected for crossover in next few iterations.

Selection of Chromosome
We have used the probability based procedure for selecting two chromosomes for crossover in which the support count is used as a probability parameter. A parent chromosome is selected having value higher than the average support count of entire population.

4.2 Flow Chart for Implementation

Flow chart of our proposed approach is depicted in Fig. 3.

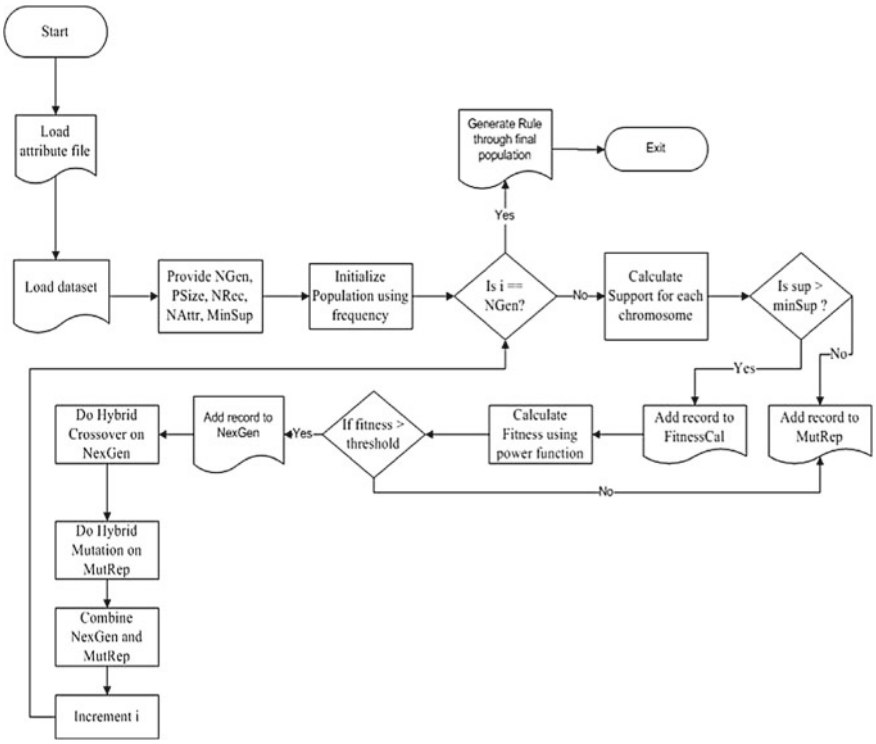

Fig. 3 Flowchart for proposed approach

4.3 Pseudo Code for Implementation

Algorithm: **Implementation**

Input: Dataset D

PSize - Population Size

NGen - Number of generations

RMut- Mutation Rate

RCross- Crossover Rate

Output: Association Rules

1.Begin
2. fori=1 to PSize //No. of Chromosome in one generation
3. for each attribute
4. Check upper bound and lower bound**.**
5. Calculate frequency of values in dataset**.**
6. Generate chromosome from step 4 – 5 information
7. End for
8. End for //Initial population generated
9. for each Psize // for each chromosome
10. Calculate Support
11. If Support >MinSupport
12. Calculate Fitness
13. End for
14. for each number of generated rules of Step 5-9
15. If (Fitness >AvgFitness) //AvgFitness of last generation
16. Add rule to nexGen
17. Else
18. Add rule to MutRep //MutRep:Rules for mutation
19. End for
20. for i=1 to NGen // No. of iteration
21. do Crossover on nextGen
22. do Mutation on MutRep
23. Repeat Step 9 – Step 19
24. End for
25. End

5 Experimental Setup

We have implemented the algorithm in JAVA and tested results on various datasets of keel repository to analyze the proposed algorithm. The program is implemented on NetBeans 8.0.2 and executed on a DELL Inspiron Laptop with Intel® Core™ i5-4210U CPU @ 1.70 GHZ 2.50 GHz and 8 GB RAM.

5.1 Datasets

The above proposed algorithms are implemented in such a way that it can be executed for any dataset of real numbers. For presenting the result, we have implemented and tested our algorithm on 4 datasets of keel repository as mentioned in Alcala-Fdez et al. [26]. These datasets are shown in Table 1.

The implementation done in this work is a generalized implementation which can be applied to any dataset. As the dataset and the name of the attributes have to be given in form of a .txt file in the beginning of the execution of the process. Here we have discussed the performance of the proposed algorithm on the measures of number of rules generated, execution time of algorithm and trends in the average fitness value of the rules at different generation of the execution.

6 Results of Proposed Algorithm

We have first illustrated different results that we got on implementation of proposed algorithms on Quake and Stocks dataset. Later we have illustrated the comparison between algorithms proposed by different authors and our proposed algorithm. We have taken crossover rate as 0.2 and mutation rate as 0.02 carry out results. Results of proposed algorithm on Quake dataset are shown in Table 2.

Figure 4 illustrate the number of rules that are generated by implementation on different support counts. As discussed earlier support count is the first filter of selecting chromosomes for calculating fitness. Minimum support has to be given manually at the starting on the basis of need of application. It can be shown that with increase

Table 1 Datasets taken for analysis

Dataset name	No. of attributes	No. of records	Type of dataset
Quake	4	2178	Real valued
Stocks	10	950	Real valued
Pollution	16	60	Real and integer
Stulong	5	1419	Integer

Table 2 Parameter values for implementation on Quake dataset

Parameters	Values
Dataset: Quake dataset	(4/2178) (attributes/records)
Population size	100
Number of generation	10

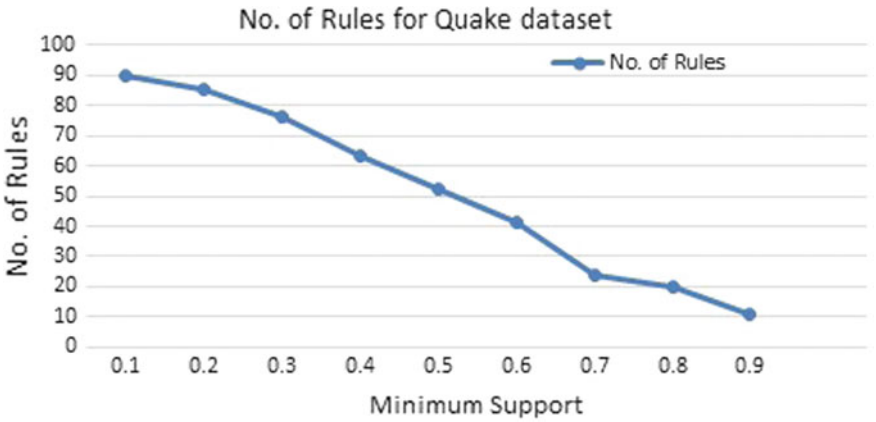

Fig. 4 No. of rules generated for Quake dataset

in minimum support count, the numbers of rules that are generating are decreasing which signify that selecting min. support for filter purpose is a correct decision.

Figure 5 illustrates the execution time taken for quake dataset for single generation. It can be seen that with increasing the minimum support count, execution time is decreasing and it can also be concluded from this graph that for minimum support of 0.1, 0.2, 0.3, the execution time is much higher because number of rules generated are much higher at such a low min. support value. Therefore, execution time of simulation gets increased whereas from minimum count 0.4 onwards, the number of rules that get filtered out for further processing is low. Hence, execution time also decreases to a relevant extent.

Figure 6 illustrates the average fitness of rules with minimum support count. As the min. support count is increasing, the average of fitness value of the generated rules is also increases. It signifies that with increase in minimum support, the relevancy of the rules increases i.e. more interesting rules get generated.

Further we have illustrated some more plots for different generations to analyze the improving nature of rules at each generation. It is a property of genetic algorithm that all iterations of execution lead to improve the solution set. To see the effect of this property in our proposed implementation, we have plotted the results of different generation which are illustrated here.

Figure 7 illustrates the fitness of rules generated for Stocks dataset for generation 1. The fitness of those chromosomes is shown as dots in the figure.

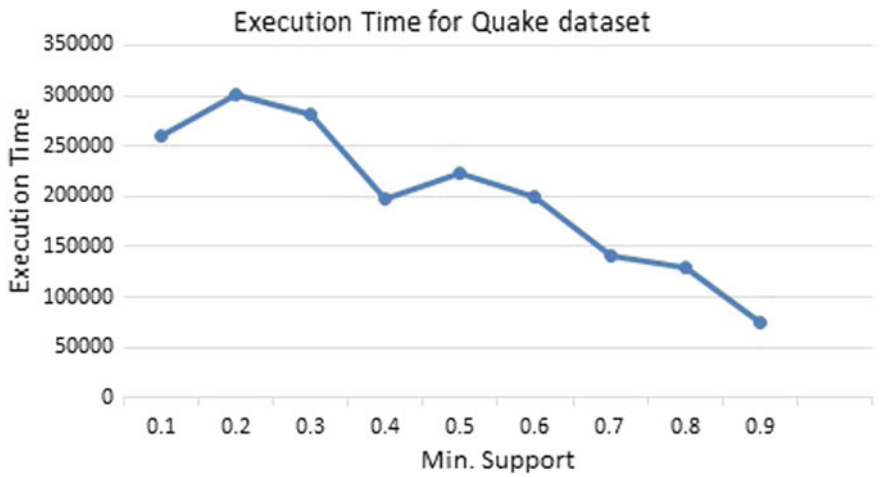

Fig. 5 Execution time taken for Quake dataset

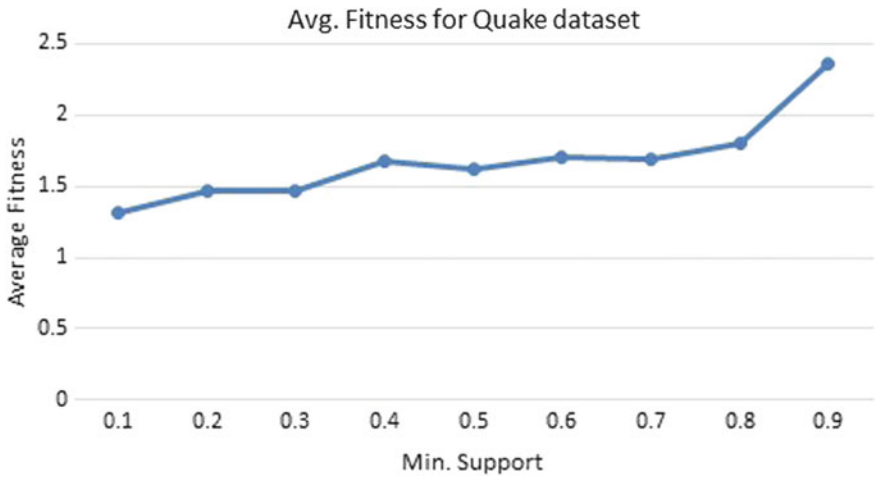

Fig. 6 Average fitness of rules generated for Quake dataset

Figure 8 illustrates the fitness of rules that are being generated at different generation i.e. for generation 1, generation 4, generation 6, generation 8 and generation 10 of the implementation for Stocks dataset. It can be shown in the figure that fitness of rules gets better and better with increasing generation, i.e. at all iteration rules are getting more interesting in terms of fitness. Also the numbers of rules are decreasing at each generation because of filtering of unfit or not-interesting rules at all iteration.

Figure 9 illustrates the fitness of rules at different generation for quake dataset. It shows the similar kind of results as of Fig. 8 i.e. with increase in generation, the rules are getting more refined due to increase in the fitness value of rules (shown by



Fig. 7 Fitness of rules generated for Stocks dataset

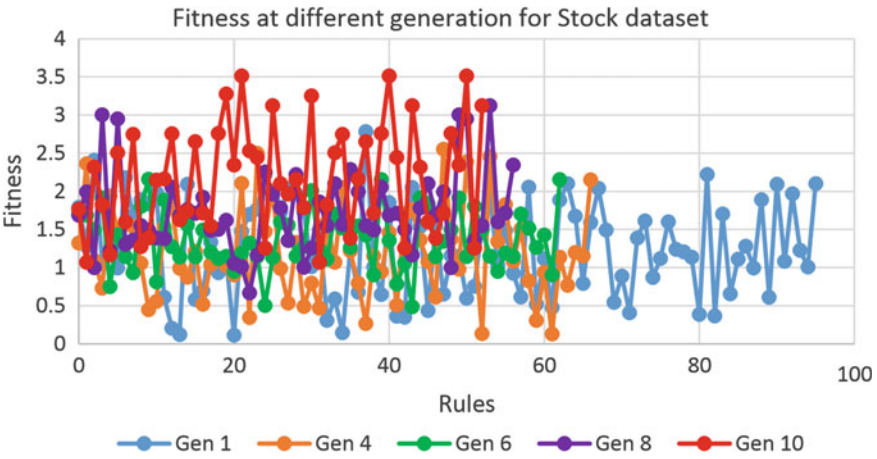

Fig. 8 Fitness of rules generated for Stocks dataset at different generation

peaks in the graph) and decreasing the number of rules (shown by tail of the plot for each generation).

We can see that our proposed algorithm is following the basic property of genetic algorithm i.e. the evolving nature of the solution at all iterations with the results of both the above graphs.

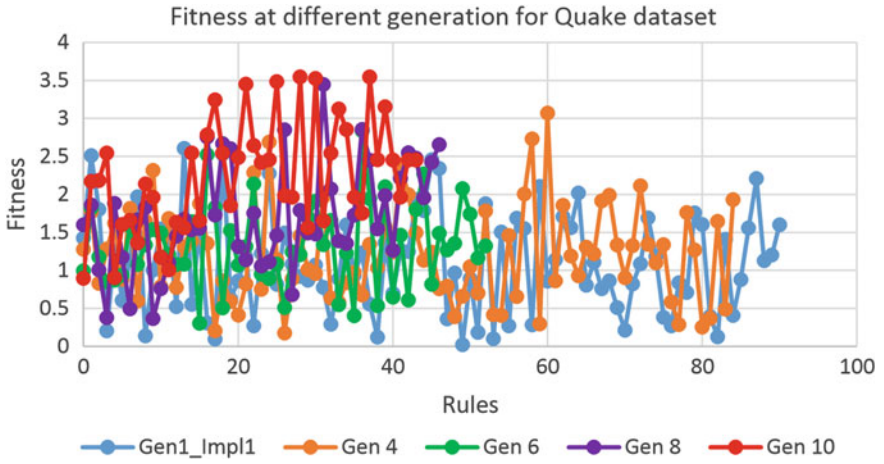

Fig. 9 Fitness of rules generated for Quake dataset at different generation

6.1 Comparison of Proposed Approach with Existing Approach

Next, to compare our proposed algorithm with previously known algorithms, we have plotted the comparison bar graphs. We have compared our results with four previously known algorithms that are EARMGA [14], GENAR [27], MODENAR [15] and MOPNAR [16]. Details of these algorithms have been discussed in the literature survey section. We have compared our algorithm on the basis of number of rules these algorithms have generated at min. support count of 0.5, average of support count of the rules that are generated by these algorithms. For comparison we have taken four datasets from the Keel dataset repository i.e. Quake, Pollution, Stocks and Stulong. The comparison values of previous approaches i.e. number of rules and average support for previously known algorithm have been taken from the literature Martin et al. [16] and that is compared with the results generated by implementing proposed algorithms.

Figure 10 is the graphical bar plot of data presented in Table 3 taken from Minaei-Bidgoli et al. [28], Al-Maqaleh [29], Martin et al. [16] and the results found on implementation of our proposed approach. This bar plot illustrate the comparison between various previously known algorithms with the proposed algorithm of our work on the basis of number of rules generated by these algorithms with different datasets. From this plot, we can conclude that our proposed algorithm have generated less number of rules as compared to EARMGA, MODENAR and MOPNAR (see Fig. 11 and Table 4).

This bar plot illustrates the average support of rules generated by different algorithms on different datasets. Higher average support of rules is a desirable parameter, as higher value of support count indicates the more interesting rules. As per the plot

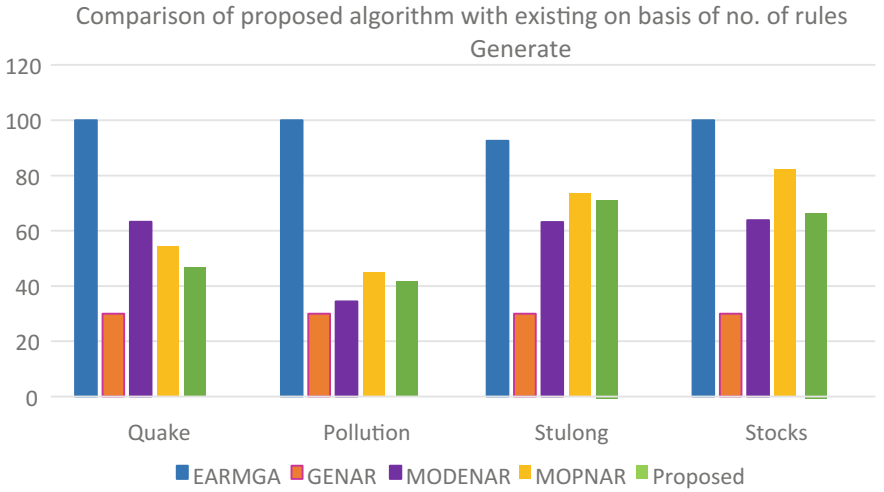

Fig. 10 Comparison of proposed algorithm with existing on basis of no. of rules generated

Table 3 Number of rules generated by different algorithms

	Quake	Pollution	Stulong	Stocks
EARMGA	100	100	92.6	100
GENAR	30	30	30	30
MODENAR	63.3	34.4	63.2	63.8
MOPNAR	54.6	45	73.6	82.4
Proposed approach	45	38	68	64

Table 4 Average support of different algorithms

Avg. support	Quake	Pollution	Stulong	Stocks
EARMGA	0.27	0.25	0.27	0.37
GENAR	0.55	0.22	0.88	0.29
MODENAR	0.36	0.27	0.52	0.48
MOPNAR	0.27	0.26	0.27	0.31
Proposed approach	0.47	0.41	0.35	0.42

shown above it can be concluded that our proposed algorithm results in better average support count than EARMGA, MODENAR, MOPNAR which signify that rules generated by our approach are more interesting than the rules generated by previous algorithms.

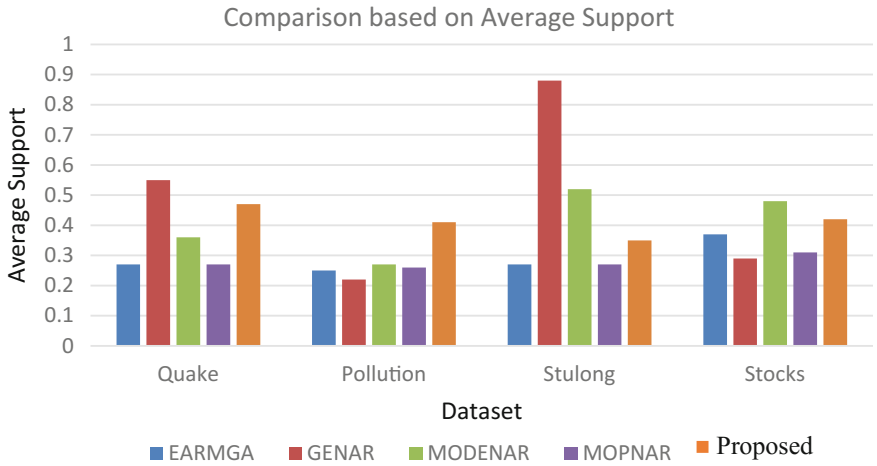

Fig. 11 Comparison of proposed algorithm with existing on basis of average support of rules generated

7 Conclusion and Future Scope

We have studied and analyzed the problem of association rule mining for numeric datasets. Processing of numeric dataset for getting information is a tedious and computationally complex task because of the nature of the data. Association rule mining for numeric dataset was a challenging task as the huge number of expected rules will be generated. Therefore, we needed a technique which runs for many solutions in parallel so that we can process huge number of rules and also have the tendency of improving its solution by itself for generation of more interesting rules. The pre-existing technique that follows these criteria is genetic algorithm which has the property of running for solution in parallel and improving their own solution in all iteration i.e. generation in terms of genetic algorithm. Therefore we have decided to solve the problem of association rule mining with genetic algorithm.

In this work, we have proposed an approach for mining numeric association rules using genetic algorithm and both the algorithms are implemented and analyzed using keel repository datasets. After implementation and analysis, we can conclude that genetic algorithm is a good approach to be used for mining numeric association rules as it analyzes multiple rules together at a time which decreases the probability of getting stuck in a local optimal solution. Further, in all iterations, best rules are more refined and new random rules joined the population which makes the scenario continuous improving i.e. even if we have started from a random initial population of rules but with all iterations rules get improved. Rather than using traditional methods for optimization i.e. derivative function etc., fitness functions are used for optimization which makes it more efficient.

In the current work we have focused only on generating association rules from testing datasets. It is still a long way to go for using this solution in real life scenario. To improve the current solution and embedding that solution to real world problems, various research opportunities could be:

1. Genetic algorithm is a robust technique for handling NP Hard problems and as association rule mining is also an NP Hard problem therefore we can say that we are going in correct direction. But it is still a long way to go as the size of the dataset increases more refine operators and fitness function have to be used. The future research direction for this work would be to develop more refined operators that could be used for better results.
2. Further Genetic algorithm can be applied to many real world problem some of which are discussed in Moin et al. [30], Barak and Modarres [31].We would like to test our proposed work on similar kind of real world problem.
3. Also one of the issues with the proposed algorithm is that with the increase in the size of dataset, the efficiency of the algorithm degrades i.e. proposed algorithms are not scalable enough. Therefore study regarding scalability of such algorithms can also be the future research direction of this work.

The proposed algorithm is efficient one and may be one of the possible candidates for the research community to get real time information from databases in smart city applications ranging from healthcare applications to intelligent transportation system [32–34].

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Chapter 1
Probiotics and Their Potential Applications: An Introduction



Sampan Attri, Niharika Singh, Ashok Kumar Nadda, and Gunjan Goel

Abstract Probiotics constitute beneficial microorganisms or their components reported for their health benefits to the hosts. A plethora of research conducted over the past three decades resulted in elucidating the association of probiotic strains under different clinical manifestations. Although several mechanisms have been reported behind these beneficial activities of these strains, the biological activity is still strain specific which needs further investigation using suitable animal models and clinical trials. This chapter reviews the details on different genera used as probiotic, their potential health benefits and mechanisms behind these effects. The formulation of different dairy or non-dairy products and pharmaceutical formulations has also been discussed.

Keywords Probiotics · Prebiotics · Probiotic products · Intestinal health

1.1 Introduction

In the year 2001, expert team members of the WHO (World Health Organization) and FAO (Food and Agriculture Organization) defined probiotics as "live microorganisms that, when administered in adequate amounts, confer a health benefit on the

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host". The term "probiotics" was derived from the Greek word which means "for life" (Jobby et al. 2020). The most commonly used bacterial genera belong to the group of lactic acid producing bacteria (LAB), mainly the Lactobacillus, Bifidobacterium, Enterococcus and Streptococcus. The common reservoir of these beneficial probiotic microbes are reported to be the traditional fermented dairy products such as kefir, lassi, Maasai milk, curd, buttermilk or kurut, etc. (Ezzatpanah 2020). Probiotics have been reported for an array of therapeutic properties such as enhancement of immune defence system, lowering of serum cholesterol prevention of colonic cancer, gastrointestinal and urinary infections, treatment of atherosclerosis, arteriosclerosis, rheumatoid arthritis, atopic dermatitis and others (Diez-Gutiérrez et al. 2020).

The use of beneficial microorganisms to improve human health is in fact very ancient; several reports mentioned the use of fermented milk for treatment of gastrointestinal tract disorders. In India, live microorganisms and fermented food stuff were and are still used for their beneficial effects on human health since pre-*Vedic* and *Vedic* period. Moreover, Ayurvedic traditional system of Indian medicine recommended *Dahi* (curd, a fermented milk product) for its beneficial effect against diarrhoea much before the microorganism's existence was even accepted (Singhi and Baranwal 2008). During the twelfth century period, fermented milk was consumed as source of good health and strength by the people of Mongolia kingdom under Genghis Khan. At the beginning of the twentieth century, Noble Prize winner Elie Metchnikoff correlated the life span of Bulgarians to their high rate of consumption of fermented milk and suggested that maybe all microorganisms were not dangerous for human health. The benefits of these microbes were suggested as they were able to compete with pathogenic microbes due to production of lactic acid from sugars through fermentation by lactic bacteria. Metchnikoff also suggested autotoxins derived from putrefactive bacteria in the colon turn macrophages into phagocytes and these putrefactive microbes could be prevented by replacing them with good bacteria. In the year 1906, French paediatrician, Henry Tissier reported that "bifid" Y-shaped Gram +ve bacteria were dominant in the stool samples of healthy infants as compared to the stool samples of diarrhoeal infants. In fact, the first time term "probiotics" was coined by Lilly and Stillwell in 1965 and stated them as "substances produced by bacteria that promote the growth of other bacteria" (Setta et al. 2020; Lilly and Stillwell 1965).

Probiotic products are categorized under different categories in different countries such as natural health promoting products (Canada), dietary supplements, drugs, medical food, live biotherapeutic agent, biological agent (United States of America), functional foods (Japan, India, China and Malaysia), food supplement (Sweden, Finland and Denmark) and biotherapeutic/pharmaceuticals (European countries like Belgium and Germany). The development and maintenance of each of these probiotic products is complex depending on the application of the product, which requires special protocols for manufacturing, labelling and safe delivery. Besides these potential technological hurdles, legislative and legal aspects, as well as consumer demands need to be taken into consideration while development of probiotic based functional food or pharmaceuticals. For example, in case of developing country such

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as India, a Task Force was constituted by DBT (Department of Biotechnology) and ICMR (Indian Council of Medical Research) Government of India, New Delhi, comprising of experts from concerned fields to develop guidelines for assessment of probiotics products in India. An attempt has been made by ICMR/DBT to frame the guidelines for probiotic ingredients in food. The guidelines provide update information on requirements for evaluation of safety and efficacy of the probiotic culture, health claims and labelling of probiotic products (Mallappa et al. 2019).

1.2 Classification: Probiotics, Prebiotics, Synbiotics and Postbiotics

During the last two decades, a plethora of research articles have appeared in journals targeting metabolic capabilities and probiotic attributes of bacteria belonging to group of Lactic acid bacteria. The ideal characteristics of probiotic microorganisms are depicted in Fig. 1.1.

1.2.1 Probiotic

The probiotic was first defined by Lilly and Stillwell in 1965 to describe "substances secreted by one microorganism which stimulates the growth of another microorganism". This generalized claim was used to define probiotics later on. Further in 1971, the term was used by Sperti to the tissue extracts that stimulate microbial growth

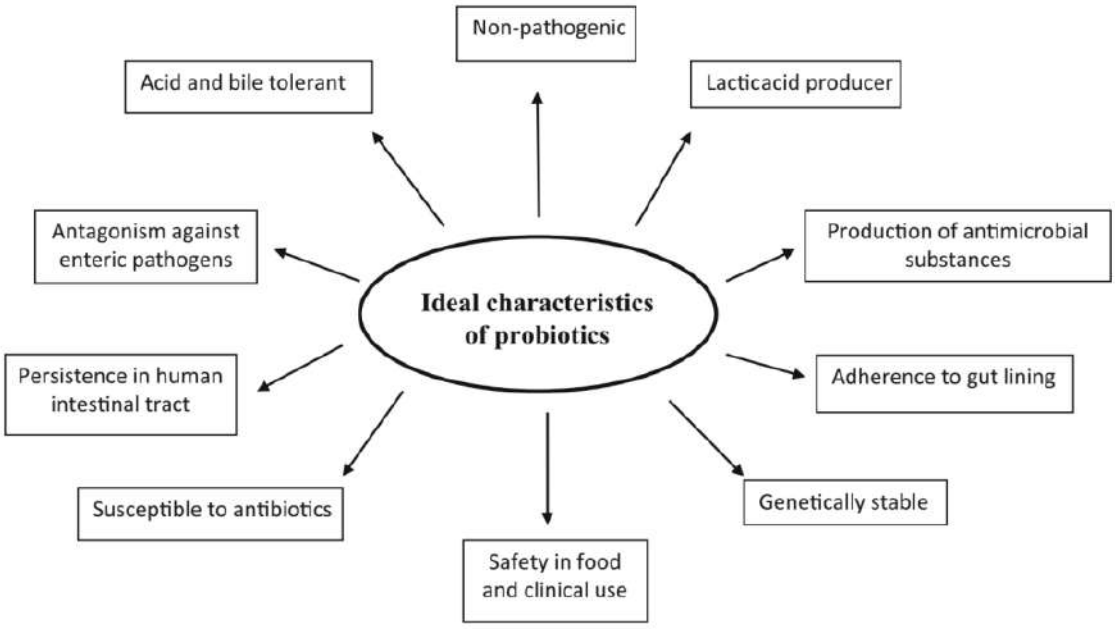

Fig. 1.1 Prerequisites of an ideal probiotic organism

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(Sperti 1971). However, it was Parker who used the term probiotic as live microbes or their substances which lead to intestinal microbial balance (Parker 1974). The fundamental characteristic of probiotics is to deliver "balance" to the growth and bioactivity of beneficial intestinal microbiota, whilst reducing adverse ones. Probiotics mainly focus on improving the host digestive and immune systems as their essential characteristics but the distinctive health benefits, such as the production of bioactives, are strain-specific (Mohan et al. 2017; Hill et al. 2014). To be an active probiotic, a daily dose of approximately 10^8–10^9 colony-forming units (CFU) is recommended during passage through GI tract. The major issue with the probiotics is the viability of the strain during the different production stages. The first generation probiotics used were in the form of live and/or lyophilized bacterial cells only without any protection, therefore, those probiotics were having lesser viability of 7–30%. Further the lyophilized probiotics were encapsulated to increase their survival up to 80% which were often referred as second generation probiotics; however, the release of probiotic strain was the major issue in having the biological activity. Therefore, the process was further improved to get third generation probiotics where the encapsulated probiotic strains are released in metabolic active stage when the microencapusle are destroyed. These probiotics were further improved to produce fourth generation probiotics, whereby bacterial cells exist in the form of biofilms enhancing its survival and viability.

Presently, different groups of microorganisms are used as probiotics possessing beneficial effects on the human health (Tables 1.1 and 1.2). Most of these bacterial groups belong to Lactic acid bacteria.

1.2.1.1 *Lactobacillus* Species

Lactobacilli are Gram-positive, non-spore forming and are the most commonly fermentative resulting in production of lactic acid as a major product. Based on

Table 1.1 Major group of microorganisms used as probiotic agents

Probiotic bacteria	Species
Lactobacillus	*L. rhamnosus, L. acidophilus, L. casei, L. bulgaricus, L plantarum, L. reuteri, L. paracasei, L. gasseri, L. amylovorus, L. helveticus, L. pentosus, L. johnsonii*
Bifidobacterium	*B. bifidum, B. lactis, B. longum, B. breve, B. infantis, B. adolescentis, B. animalis, B. catenulatum*
Bacillus	*Bacillus coagulans, B. subtilis, B. laterosporus, B. clausii*
Streptococcus	*S. thermophilus, S. faecium, S. oralis, S. salivarius, S oralis, S. sanguis, S. mitis*
Saccharomyces	*S. boulardii*
Others microorganisms	*Lactococcus lactis, Enterococcus faecium, Propionibacterium jensenii, Propionibacterium jensenii, Propionibacterium freudenreichii, Pediococcus acidilactici, Pediococcus pentosaceus, Bacteroides uniformis, Escherichia coli* Nissle 1917

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Table 1.2 Commercial probiotic products and their functional properties (this is not an exhaustive list)

Name	Company name	Type	Strain	Functional properties
Yakult	Yakult Honsha	Dairy	*Lactobacillus paracasei* Shirota	Improve bowel and maintain a healthy population of gut flora
Activia	Danone	Dairy	*Bifidobacterium animalis* DN 173010	Improve digestive health
Bifiene	Yakult Honsha	Dairy	*B. breve*	Improve digestive system/gut health
Align	Procter and Gamble	Capsule and tablet	*B. infantis* 35624	Improve digestive system
Actimel	Danone	Dairy	*L. bulgaricus*, *S. thermophilus* and *L. paracasei* ssp. paracasei CNCM I-1518	Reducing the incidence of diarrhoea and rhinitis and improvement of the immune function
Bioflorin	Cerbios pharma	Capsule	*Enterococcus faecium* SF68	Prevention and treatment of gastrointestinal disorders
LC1	Nestle	Dairy	*L. acidophilus* La 1	Improve digestive health
GoodBelly multi probiotic	NextFoods	Fruit drink	*L. plantarum* 299 V	Promote digestive health
Mucilon	Nestle	Cereal based powder	*Bifidus BL*	Protection from pathogens in children digestive tract
Rela caps	BioGaia	Capsule	*L. reuteri* protectis	Prevention and amelioration in gut
Attune bar	Attune Foods	Food bar	*B. lactis* (LAFTI®B94), *L. acidophilus* (LAFTI® L10) and *L. casei* (LAFTI® L26) and	Support digestive health and immunity
Nexabiotics advanced multi probiotics	DrFormulas	Capsule	*L. brevis, L. bulgaricu, L. Casei, L. helveticus, L. acidophilus, L. paracasei. L. plantarum, L. rhamnosus, L. salivarius, L. lactis, Bacillus coagulans, B. breve, B. bifidum, B. infantis, B. lactis, B. longum, Pediococcus acidilactici* and *Saccharomyces boulardii*	Promote beneficial gut bacteria and immune system
Tropicana essential probiotics	PepsiCo	Fruit juice	*Bifidobacterium lactis* HN019	Healthy immune system and gut functionality

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Table 1.2 (continued)

Name	Company name	Type	Strain	Functional properties
LactoSpore	Sabinsa Corporation	Powder	*Bacillus coagulans* MTCC 5856	Beneficial in many gastrointestinal disorders
Kefir milk	Feel well	Dairy	*L. lactis*, *L. cremoris*, *L. diacetylactis* and *L. acidophilus*	Enhance gut health
ActiPlus probiotic dahi	Nestle	Dairy	*L. acidophilus*	Healthy digestive system
Vita biosa	Vital health	Herbal drink	*L. acidophilus, L. casei, L. rhamnosus, L. salivarius, Lactococcus lactis, B. lactis, B. longum* and *S. thermophilus*	Enhanced gut health and immunity
Koji	Graindrops	Dairy free beverage	*L. acidophilus, L. rhamnosus, L. casei, L. bulgaricus, S. thermophilus, B. bifidum* and *B. lactis*	Improve digestion and absorption of nutrients

the metabolic capabilities the species are classified as homofermentative or heterofermentative. The species of this genus are largely discovered in the human digestive and urogenital tracts, while so far there have been studies that their existence may fluctuate within a species, age of the host or the site within the gut. Presently, research data suggest that the Lactobacilli, which are used therapeutically, are considered as probiotics, the reverse of antibiotics. Moreover, they are looked as "friendly" microbes and have prospective implications in enhancing the bioavailability and uptake of minerals, reducing risk of cardiovascular disease and promoting balanced metabolism and proper weight (da Silva et al. 2015).

1.2.1.2 *Bifidobacterium* Species

Bifidobacteria are Gram-positive, non-spore forming bacteria belonging to the family Bifidobacteriaceae which metabolize glucose to generate lactic and acetic acids (Milani et al. 2017). Bifidobacteria spp. generally reside in the human gastrointestinal tract, insect and bird's intestine. Their utmost profusion during infancy of mammals is associated with their suggested character as an imperative microbial modulator of the immune response as well as the gut microbiota of the host (Turroni et al. 2018).

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1.2.1.3 *Bacillus* Species

Bacillus coagulans belonging to the genus Bacillus is a Gram-positive spore forming bacterium, which blends both Bacillus and LAB attributes in its mechanisms. It is able to survive in high temperature of heat treatment and physiological conditions such as very low pH of the stomach and bile salts and directly affecting enteropathogens. Predominantly, this species is also recognized to maintain health and therapy by posing antagonistic effects on the pathogens (Wang et al. 2012). Apart from this species, *B. clausii* is also well documented for its probiotic attributes.

1.2.1.4 *Saccharomyces* Species

The non-pathogenic yeast strain *Saccharomyces boulardii* has also received attention worldwide as both therapeutic agent for gastrointestinal and other diarrhoea disorders caused by the administration of antimicrobial agents. *S. boulardii* possesses many therapeutic properties that make it as a potential probiotic agent, i.e., its survival during transit through the gut lumen, its optimum temperature is 37 °C, both *in vitro* and *in vivo* conditions and antimicrobial action.

1.2.2 Prebiotic

In 1995, the first published definition of prebiotic was provided by Glenn Gibson and Marcel Roberfroid as a "non-digestible food component that beneficially affects the host by selectively activating the growth and/or activity of one or a partial number of microorganisms in the colon, and consequently improves host health" (Gibson and Roberfroid 1995). Bindels et al. (2015) suggested another explanation of a prebiotic as "a non-digestible compound that confer a beneficial physiological effect on the host, through its utilization by gut microbiota, modifies composition and/or activity of the gut microbiota". They also recommended that non-carbohydrate compounds may serve as prebiotics and supplemented the subsequent prebiotics to the normal list: pectin, resistant starch, whole grains, arabinoxylan, several dietary fibres and non-carbohydrates that employ their act through a modulation of the microorganisms in the gut. Further in the year 2016, an expert advisory panel member convened by the International Scientific Association for Probiotics and Prebiotics (ISAPP) customized this to "a substrate that is selectively used by host microbiota conferring health benefits" (Gibson et al. 2017). A clear definition of selectivity is viewed as fundamental to the prebiotic approach; in disparity to fibres, that is, pectins, cellulose and xylans, which promote the proliferation of numerous microbes in the gut principally *Bifidobacterium* and *Lactobacillus* and prebiotics such as galacto-oligosaccharides and fructooligosaccharides.

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An ideal prerequisite for a substrate to be a prebiotic should include the following:

- Resistance to gastric environment.
- It should not be absorbed in the upper gastrointestinal tract.
- Resistance to action of mammalian enzymes.
- Fermentation by the intestinal microflora.

1.2.2.1 Types of Prebiotics

The prebiotics are group of diverse nutrients of various molecular structures that naturally exist in different dietary products consumed in our everyday life.

They are generally composed of linked sugars like short and long chain β-fructans, galacto-oligosaccharides and xylo-oligosaccharides (Tables 1.3 and 1.4). These polysaccharides have the chemical characteristic of being non-digestible by the enzymes present in the gastrointestinal tract. (Brosseau et al. 2019)

Fructans Fructans such as fructooligosaccharides (FOS) and inulin are reported widely for prebiotic activities. These substrates possess linear chain of fructose with β-2,1 bond (Brosseau et al. 2019). The literature reported on fructans indicates that these can selectively stimulate the proliferation of probiotic bacteria. These fructans are found naturally in foods, such as asparagus, artichoke, leeks, wheat, chicory, onions, bananas, honey and garlic.

Galacto-Oligosaccharides Galacto-oligosaccharides (GOS) are enzymatic product of lactose formed by transglycosylation. The GOS generally consist of primarily a combination of oligosaccharides from tri- to pentasaccharide with galactose in β-1,6, β-1,3 and β-1,4 linkages (Ranucci et al. 2018). This kind of GOS is also known as trans-galacto-oligosaccharides or TOS. GOSs are reported for their prebiotic activity for Bifidobacteria and Lactobacilli with a lesser activity towards Bacteroidetes and

Table 1.3 Commonly used prebiotics and their natural sources

Prebiotics	Natural sources
Fructooligosaccharides	Asparagus, chicory, onion, garlic, wheat, leek, Jerusalem artichoke, oat
Inulin	Burdock camas, Globe artichoke, banana, elecampane, costus, agave, chicory, coneflower, dandelion, garlic, Jerusalem artichoke, jicama, onion, wild yam
Isomalto-oligosaccharides	Soy, sauce, miso, sake, honey
Galacto-oligosaccharides	Human milk, kidney bean, chickpea, lentil, lima bean, green pea
Xylose-oligosaccharides	Fruits and vegetables, bamboo shoot, milk, honey
Lactulose	Skimmed milk

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Table 1.4 Commercial prebiotic products and their functional properties (this is not an exhaustive list)

Name	Type	Ingredients	Functional properties
Natural stacks prebiotic+	Powder	Potato starch, green banana flour and inulin	Improves your digestion, metabolism and gut health
Hyperbiotics prebiotic	Powder	Acacia fibre, Jerusalem artichoke and green Banana flour	Improve gut health
DrTobias prebiotics	Capsule	LH01-*Myoviridae*, LL5-*Siphoviridae*, T4D-*Myoviridae* and LL12-*Myoviridae*	Support beneficial bacteria
DrFormulas nexabiotic prebiotic	Tablet	Organic blend of Alfalfa grass, barley grass, broccoli, spinach, kale, cabbage cauliflower, brussel sprouts, apple, carrot, beet, tomato, strawberry, tart cherry and garlic	Enhance gut bacterial composition, nutrient absorption, immune system and reduces constipation
Prebiotin prebiotic	Tablet and powder	Oligofructose and inulin derived from chicory root	Support a healthy microbiome and immunity
Goodgut balance	Capsule	Japanese honeysuckle, pomegranate, grape, kiwi, green tea, apple, bilberry, blueberry, chokeberry, clove, cranberry goji berry and mangosteen	Maintain digestive balance and nourish gut bacteria
Enzymedica prebiotic	Powder	Dietary fibre, guar fibre, tapioca fibre, acacia gum, galacto-oligosaccharides, isomalto-oligosaccharides and fermented barley grass	Improve digestion and nourishes gut microbiota
Benefiber	Powder	Wheat dextrin	Nourishes healthy gut bacteria
Sanitarium so Good Soy prebiotic	Soy milk based drink	Corn maltodextrin and prebiotic fibre (chicory root extract)	Enhances gut health

other probiotics. Lactulose, an isomer of lactose, is also known GOS reported as potential prebiotics used in the therapy of constipation and hepatic encephalopathy.

Other Saccharides Resistant starch (RS) is a category of starch which is resistant to digestion in the upper gut. RS is generally fermented by colonic bacteria and results in production of prominent amount of butyrate; therefore referred as a potential prebiotic substrate. Various studies reported the degradation of RS by fibre utilizing bacteria such as *Bifidobacterium adolescentis* and *Ruminococcus bromii*, and also to a lesser extent by *Eubacterium rectale* and *Bacteroides thetaiotaomicron*.

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Polydextrose, polymer of glucose-derived oligosaccharide, is a food ingredient that is indigestible by intestinal enzymes and thus possibly affects colonic function (Duncan et al. 2018).

Non-carbohydrate Compounds Although carbohydrates are more likely to conform to the criteria of prebiotics definition, there are few compounds that are not classified as carbohydrates, but are recommended to be classified as prebiotics, such as cocoa-based flavanols, polyphenols in berries.

1.2.2.2 Mechanisms of Action of Prebiotics

Prebiotics are reported to stimulate the growth of beneficial bacteria and antagonistic to pathogenic group of bacteria. Prebiotics not only aid as an energy source via production of short chain fatty acids (SCFAs) but also have various health benefits such as decreasing the occurrence and extent of diarrhoea, employing protective effects to avert colon cancer, decreasing gut inflammation and other problems related with intestinal bowel disorder. Moreover, prebiotics are also involved in boosting the bioavailability of minerals, dropping some risk issues for cardiovascular disease and endorsing weight loss and satiety.

1.2.3 Synbiotic

The development in research related to probiotic and prebiotics has driven to formation of term synbiotics which is a selective fusion of both probiotics and prebiotics. The synbiotic action of probiotic or prebiotic on the beneficial effect on human health is supposed to be more dynamic as comparison to the effect of probiotic or prebiotic alone (Kerry et al. 2018). The synbiotic strategy positively enhances the implantation and survival of live bacterial dietary supplements in to gastrointestinal tract.

Most frequently used synbiotic blends comprise of Bifidobacterium, Lactobacilli, *B. coagulans*, *S. boulardii*, as probiotic constituent, and oligosaccharides and inulin as prebiotic constituent (Tables 1.5 and 1.6) (Pandey et al. 2015). The health promoting effects of synbiotic preparation include the following:

- Improved proliferation of bifidobacteria and lactobacilli besides balanced gut microbiota.
- Prevent microbial translocation and limiting pathogenic colonization in surgical patients.
- Improved functioning of liver in cirrhotic patients.
- Enhancement of immunomodulating capability (Zhang et al. 2010).

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Table 1.5 Commonly used Synbiotic preparations for human nutrition

Prebiotics	Probiotics
Fructooligosaccharides	*Bacteroides fragilis, Peptostreptococcaceae,* Bifidobacteria, *Klebsiellae*
Inulin	*L. acidophilus, B. animalis, L. paracasei*
Isomalto-oligosaccharides	*Bacteroides fragilis,* Bifidobacteria
Galacto-oligosaccharides	*B. longum, B. catenulatum*
Xylose-oligosaccharides	*B. adolescentis, L. plantarum*
Lactulose	*L. bulgaricus, L. acidophilus, B. lactis, L. rhamnosus*

1.2.4 Postbiotics

Postbiotics are defined as functional bioactive components generated during microbial fermentation process that trigger the beneficial effects on the host (Collado et al. 2019). Postbiotics consist of peptides, bacterial enzymes, peptidoglycan-derived neuropeptides and organic acids, for instance, acetic acid and lactic acid. The postbiotics exhibit therapeutic effects, *viz.* anti-inflammatory, immunomodulatory and anti-bacterial properties, anti-hypersensitive, anti-proliferative and hypocholesterolemic activity (Tomasik and Tomasik 2020). The metabolic by-products from postbiotic, like lipoteichoic acid, could have an anti-inflammatory effect, prompting the production of cytokines IL-4, IL-6 and IL-10, and reducing the production of reactive oxygen species (ROS) (Nakagawa and Miyazaki 2017). In addition, heat-killed probiotic preparations possessing vital bacterial structures are also reported for biological activity in the host.

The prerequisites for a postbiotic include all the characteristics of probiotics and prebiotics with similar functions as reported for probiotics. Generally the postbiotics include bacteriocins, SCFAs, heat-killed probiotics, polyphosphates, exopolysaccharides, cell wall components.

1.3 Colonization and Alterations of Gut Microflora

The human intestinal tract is colonized by a large number of microbes beginning by birth and is influenced by number of factors such as mode of delivery, feeding practices, environmental factors, etc. (Attri et al. 2018). This region is an extremely complex micro-ecosystem with an interaction between nutrients, gut microbial communities and host intestinal cells. Various studies have reported that the human gut contains approximately 1000 different species of microbes and around 10^{14} in numbers, which are nearly 10 times more microbial cells as compared to number of human cells and over 100 times the amount of genomic material as the human genome. Therefore, the gastrointestinal region is often regarded as "Super

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Table 1.6 Commercial synbiotic products and their functional properties (this is not an exhaustive list)

Name	Type	Prebiotic	Probiotic	Functional properties
Zenwise digestive enzyme with probiotic and prebiotic	Powder	Inulin, apple pectin, fennel seed powder, turmeric root powder, papaya fruit powder, ginger root powder, sea vegetable, peppermint leaf extract	*L. plantarum, L. acidophilus, L. casei, L. rhamnosus, L. salivarius, B. breve, B. bifidum, B. longum, B. animalis lactis* and *Bacillus subtilis DE111*	Supports digestion and promotes proper nutrient uptake
Earth's Pearl probiotic and prebiotic	Pearl shaped tablet	Fructooligosaccharides	*L. plantarum, L. acidophilus, L. reuteri, B. lactis* and *B. infantis*	Improve gut health and immune system
Onnit total gut health	Capsule	Jerusalem artichoke and dandelion root powder	*L. rhamnosus, L. plantarum, L. acidophilus DDS-1, B. lactis, B. infantis* and *Saccharomyces Boulardii*	Immune system support and promote healthy gut flora
Ora organic probiotics with prebiotics	Capsule and Powder	Jerusalem artichoke inulin, Tapioca oligosaccharide, apple, raspberry, rice hull powder	*L. acidophilus DDS-1, L. reuteri, B. bifidum, B. longum* and *B. lactis*	Enhance optimal digestive health and immune function
Activa well-being synbiotic	Capsules	Fructooligosaccharides	*B. longum, B. infantis, L. acidophilus* and *L. rhamnosus*	Enhanced immunity and balanced gut
LactoWise	Capsule	Galactomannan	*Bacillus coagulans MTCC 5856*	Regulate growth of beneficial gut microbiota
Essential-biotic synbiotic	Powder	Xylo-oligosaccharides	*L. acidophilus* DDS-1 and *B. lactis* UABla-12	Enhanced digestive health
Now probiotic-10™ + Inulin	Powder	Organic Inulin (fructooligosaccharides)	*L. plantarum* Lp-115, *L. paracasei* Lpc-37, *L. rhamnosus* Lr-32, *L. acidophilus* La-14, *L. casei* Lc-11, *L. salivarius* Ls-33, *S. thermophilus* St-21, *B. lactis* BI-04, *B. breve* Bb-03 and *B. longum* BI-05	Healthy intestinal flora

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organ". Due to this large genomic content and a number of metabolic activities in gut region, the microbe-nutrient interaction imparts a range of beneficial effects to the host. The major roles of these microorganisms in gastrointestinal tract are to maintain the gut homeostasis, immune system, to provide nutrients such as vitamins, protection from pathogenic microbes and maintaining integrity of the mucosal barrier (Attri and Goel 2018). The antimicrobial action of beneficial bacteria in gut include: Reduction of the adhesion of pathogens to epithelial cells by colonizing the available intestinal sites, competition for nutrients and release of anti-bacterial substances such as bacteriocins, lactic acid and short chain fatty acids which makes the colonic region unfavourable for survival of potential pathogenic microbes. Apart from this, gut microbiota also play a crucial part in production of many important vitamins such as vitamin B_{12} and K, and in enhanced bioavailability of iron, magnesium and calcium ions (Thursby and Juge 2017).

Alterations in the composition of microbiota or dysbiosis can be due to environmental factors, including diet, toxins, drugs and pathogens. Managing dysbiosis and manipulating the microbial environment in the colonic region using probiotics is a promising area for probiotic based therapies. Consumptions of probiotics may result in beneficial effects in the colonic region or enhance the functionality of existing gut microbiota by maintaining the gut homeostasis. Study conducted by Kuugbee and co-workers (Kuugbee et al. 2016) reported alteration in gut microbiota composition in animal model after treatment with probiotics. The relative abundance potential pathogenic bacteria belonging to genera *Clostridium, Helicobacter, Congregibacter, Escherichia, Candidatus, Phaeobacter* and *Pseudomonas* was decreased, whereas an increase in content of species of *Lactobacillus* was observed. However, to extend these beneficial effects, the efficacy is dependent on its ability to survive the conditions of gastrointestinal tract, commonly encountered conditions include: acidic conditions of stomach and alkaline environment small intestinal region. The prerequisite for probiotics also includes their capacity to attach to the intestinal mucous membrane and to colonize in this region. This adhesion by probiotics is considered as important property for colonization, and is one of the main selection criteria for novel probiotic strains. In the colonic region, the mucous membrane covering the intestinal epithelium layer is rich in glycolipids and glycoproteins which act as suitable receptors and carbohydrate moieties for bacterial adhesion. Gastrointestinal conditions such as pH, bile, digestive enzymes also influence adhesion of probiotic bacteria. In addition, due to the presence of different substances such as exopolysaccharides and calcium ions released by probiotic microbes can also alter their adhesion to colonic mucous membrane. The mechanism of adhesion of probiotics involves passive forces, electrostatic and hydrophobic. Presence of complex surface exposed polymer lipoteichoic acids in the cell wall of Gram +ve bacteria are also reported to be involved in adhesion process. Also prebiotics such as oligosaccharides could also enhance the adhesion properties of probiotic cultures (Monteagudo-Mera et al. 2019; Chua et al. 2019). Several reports also hinted that proteinaceous components such as mucus binding protein, mannose-specific adhesion protein, collagen binding proteins, fibronectin, lectin like protein

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also play role in the adhesion of microbes to intestinal cells in animal system and *in vitro* human studies (Collado et al. 2010).

1.4 Immune System and Gastrointestinal Response to Probiotics

The immune response in the host body is initiated by innate immunity after the entry of foreign particles such as pathogens or any tissue injury. However, the uneven immune response may lead to acute inflammation and unrestrained tissue injury and disorders. In the gastrointestinal tract, epithelial cells represent the first barrier against pathogens, followed by mucosal immune system response. Microbes can interact with pattern recognition receptors of intestinal antigen presenting cells such as macrophages and dendritic cells through microorganism associated molecular patterns present on the bacterial cell surface. Sensing of the gut microbiota by the mucosal immune system plays significant roles in maintaining intestinal homeostasis and generation of protective responses (Monteagudo-Mera et al. 2019). Study conducted by Galdeano and Perdigon (2004)) demonstrated that after adherence of a potential probiotic strain to the epithelial cells, immune response is stimulated through formation of toll-like receptor. Following this adherence, there is an enhanced production on the cytokines like IL-6 and macrophage chemo-attractant protein-I, without altering the intestinal barrier. Probiotics also stimulate dendritic cells/macrophages which result in an increased antibody immunoglobulin A (IgA) and cytokines secretion Molecules derived from these bacteria also bind to receptors present on dendritic cells which further activate different signalling pathways. Some probiotic strains such as *L. rhamnosus* can induce heme oxygenase activity in dendritic cells which result in mucosal T regulatory (Treg) cells within the gut associated lymphoid tissues (Delgado et al. 2020).

These probiotics also promote human health by production of low molecular weight compounds such as organic acid and antimicrobial high molecular weight compounds like bacteriocins which further inhibits the growth of pathogenic bacteria. Organic acids such as butyric, acetic and lactic acids have been reported to show strong anti-pathogenic activity against Gram –ve bacteria, such as *E. coli*, *P. aeruginosa, H. pylori,* etc., by disrupting their cell wall. Some reported bacteriocins produced by probiotics are bifidocin B produced by *B. bifidum,* nisin from *Lactococcus lactis,* plantaricin from *L. plantarum* and lactacin B from *L. acidophilus* (Bermudez-Brito et al. 2012).

It is well known that natural killer cells are involved in both innate and adaptive immunity. Natural killer cells also interact with gut microbiota and influence the adaptive T cell-mediated immune response by acting on antigen presenting cells. These natural killer T cells are also effected by lipid antigens present on probiotic cells. Probiotic bacteria *B. polyfermenticus* increase $CD56^+$ T cells, whereas *B. lactis* HN019 consumption improves natural killer cells tumoricidal properties in old-aged

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person. Intake of probiotic *L. casei* Shirota simulates the surface expression of CD25 and CD69 on both $CD56^+$ and $CD56^+$ cells. Also, regular consumption of probiotics products containing *L. paracasei*, *B. animalis* ssp. lactis and heat-treated *L. plantarum* has been reported to enhance the functionality of natural killer cells (Lee et al. 2017).

Probiotics beneficial effects against certain disorders such as allergies and colitis can be ascribed to their potential to enhance the production of T lymphocytes. Probiotic strain *B. longum* improved colorectal colitis in animal model by regulating the proportion of Treg cells, whereas IL-10 and the ratio of IL-10/IL-12 were enhanced in the serum, while the proinflammatory cytokines IL-12, IL-17 and IL23 were downregulated. After consumption of *B. infantis* 35,624 in healthy humans, there is an upregulation of Foxp3 lymphocytes, which further results in low level of proinflammatory cytokines in patients with ulcerative colitis or psoriasis. Probiotics can modulate T cells response by their metabolites like short chain fatty acids. In fact, the short fatty acid such as butyric acid enhances extrathymic generation of Treg cells, while de novo Treg cell generation is simulated by propionic acid (Zhang et al. 2017; Alexander et al. 2014).

1.5 Potential Applications of Probiotics

The promising effects of probiotics attract considerable attention of microbiologists, clinicians, nutritionists as well as food technologists to develop probiotics as such as or probiotic based foods or supplements for consumer applications. Some of the elite properties of probiotics, such as anti-pathogenicity, anti-inflammatory, anti-cancer, anti-allergic and anti-obesity activities, and their consequence on the mind and central nervous system (CNS), are briefly discussed below.

1.5.1 Antimicrobial Activities of Probiotics

One of the most studied effects of probiotics is modulating the intestinal microbiome against pathogenic microorganism. The probiotic microorganisms generate various metabolites such as short chain fatty acids (lactic, acetic, formic, butyric and propionic acids), which are reported to inhibit pathogens such as *Salmonella enterica* serovar Typhimurium and *Clostridium difficile* (Bermudez-Brito et al. 2015; Goldenberg et al. 2017). SCFAs are reported to maintain suitable pH conditions in the colonic lumen, which significantly boosts the metabolism of foreign compounds and carcinogen residues in the gut. In addition, probiotics produce various inhibitory compounds to reduce pathogens, *viz.* peptides, bacteriocins, organic acids, hydrogen peroxide, diacetyl, and hydrogen peroxide. Predominantly components of the probiotic metabolome are engrossed in some metabolic pathways that regulate cellular pathways for proliferation, differentiation, apoptosis (Kumar

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et al. 2013). Probiotics also prompt host anti-pathogenic immunomodulatory pathways such as secretion of anti-inflammatory compounds and others.

1.5.2 Anti-inflammatory Intestinal Activity of Probiotics

Ulcerative colitis (UC) and Crohn's disease (CD) are among the most frequent types of chronic inflammatory disorders and are classified as inflammatory bowel diseases (IBD) that cause digestive disorders and inflammation in the intestinal tract accompanied by abdominal pain (Seyedian et al. 2019).

Crohn's disease commonly affects the intestine, but may exist anywhere in GI tract. The disease is manifested with ulceration and inflammation that influence the digestive health of the body with limited absorption of food nutrients and elimination of wastes. The main causative agents identified are *Salmonella*, *Campylobacter jejuni*, *Clostridium difficile*, Adenovirus. In overcoming the problems related to CD in humans, *L. rhamnosus* strain GG, VSL#3, *E. coli* Nissle 1917, *S. boulardii* are reported as potential therapeutic probiotic strain (Fedorak et al. 2015; Petersen et al. 2014). In contrast, UC mainly affects the lining of the colon and rectum. The supplementation of various probiotic species like *S. boulardii*, *L. casei* and *B. bifidum* has shown to manipulate the intestinal microbial balance, which can be an alternative therapy for IBD (Kelesidis and Pothoulakis 2012). The probiotic intervention in IBD has been suggested due to the competitive action with commensal, pathogenic flora and an impact on overall immune response system (Sivamaruthi 2018).

1.5.3 Anti-cancer Activity of Probiotics

Presently, profound research on application of proteomics, genomics and molecular pathology as technological tools to detect the mechanisms of cancer has elevated the awareness about cancer and public consciousness. Simultaneously, new drugs or molecules with attractive anti-cancer properties have been identified using biotechnology and nanotechnology; however, still tolerance to their load and side effect has been a major restriction in the use of most of the drugs. In this context, probiotics with anti-carcinogenic effects have drawn great interest to prepare effective anti-cancerous targets with minimal or no side effects.

Various modes of actions have been suggested for anti-tumour activities of probiotics, however, a specific mechanism to state is still unclear. Probiotic bacteria play an essential role in the preservation of homeostasis, maintaining sustainable physicochemical conditions in the colon. Reduced pH caused inter alia by the excessive presence of bile acids in faeces may be a direct cytotoxic factor affecting colonic epithelium leading to colon carcinogenesis which include: maintaining the gut homeostasis, modulation of pH and bile acid profile, binding and degradation of

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potential carcinogens, production of SCFAs which may act as signalling molecules affecting the immune system, cell proliferation and apoptosis. There are plenty of new reports on the anti-tumour activities of different probiotic strains, nevertheless, the in vitro studies reported that probiotics could perform a substantial role in neutralizing cancer which needs to be validated in *in vivo* models and progress towards animal and clinical trials.

1.5.4 Anti-allergic Activities of Probiotics

The prevalence of allergic responses due to different food components due to immune disorders has been increasing worldwide resulting in severe economic and societal burden. Embracing the indispensable molecular mechanism that leads to the aetiology of allergic diseases, along with new treatment strategies, is vital in preventing the allergic responses of food components. In this context, the role of the microbiota in allergies is now widely studied; however, the role of probiotics as therapy was only recently noted. The beneficial effects of probiotics have become popular approach for health maintenance and allergic-disease prevention. Different strains have been tested for their anti-allergic responses. The common mechanisms by which these probiotics exhibit anti-allergic responses include modulation of innate lymphoid cells through toll-like receptors (TLRs), production of butyrate as one of the SCFA which protect from intestinal inflammation; act as histone deacetylase inhibitor; increase Foxp3 protein acetylation and immunomodulatory activity such as enhanced secretions of interleukin-4 and interferon-γ (Takeda et al. 2014).

1.5.5 Anti-obesity Activity of Probiotics

The accumulation of excessive fat (obesity) on the body directly deteriorates health which is related to an increase in energy availability, sedentariness and maintenance of environment temperature, resulting in imbalance between energy intake and expenditure. Probiotics possess physiological attributes that devote to the health of host environment regulating microbes. In most citing, weight loss is eased by lipolytic and thermogenic responses through activating the sympathetic nervous system. The mechanisms by which probiotics exert anti-obesity effects include maintaining the gut homeostasis, strengthening the functions of the gut epithelial barrier, production of health promoting substances such as Conjugated linoleic acid (CLA), competitive adherence to the gut mucosa, modulation of the immune system via release of anti-inflammatory compounds and modulation of energy homeostasis.

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1.5.6 *Effect of Probiotics on Brain and Central Nervous System*

The gut microbiota composition is linked with both neurological and gastrointestinal disorders. Moreover, in recent years, new insights have been dedicated towards elucidating promising therapy of probiotics on the central nervous system (CNS) disorders. Probiotic studies in humans are still scarce, but the available data using probiotics against neurological disorders are promising. A study conducted in 2005 suggested that probiotic cultures might be used as an adjuvant therapy for the treatment of major depressive disorder (MDD) (Logan and Katzman 2005). Since stress (a significant factor contributing to MDD) is known to alter the composition of gut microflora, resulting in reduction of lactobacilli and Bifidobacterium spp., it would be conceivable that gut microbiota has significance in chronic stress. Evidently, *Bifidobacterium infantis* showed antidepressant-like properties by normalizing the levels of cytokines and tryptophan (Desbonnet et al. 2008, 2010), an increase in levels of which is associated with depression. Probiotics such as *L. rhamnosus* JB-1 and *L. plantarum* PS128 are known for their anxiolytic and anti-depressive effects on mice, which are some early examples of psychobiotics. The reported psychobiotics modulated the levels of neurotransmitters, serotonin, dopamine and their metabolites, in animal studies which contributed to the psychotropic effects (Liu et al. 2019).

1.6 Commercial Potential of Probiotics

Awareness towards health has grown to a greater extent as the consumers demand healthy diet and functional food products. Therefore, there is a high demand of food products fortified with prebiotics and probiotics in the market. As per the global market trend, probiotic business is projected to reach a turnover value of US$ 46.55 billion by 2020. The most commercial probiotics products available in the foods market belong to the genera of *Bifidobacterium, Lactobacillus, Lactococcus, Streptococcus* and some species of *Enterococcus*. Some non-pathogenic yeasts such as *Saccharomyces boulardii* are also used as probiotics.

Commercially probiotic products are being sold out in the global market mainly in the form of pharmaceutical formulations, fermented dairy products and non-dairy based probiotics (Fig. 1.2). However, since consumers who are allergic to milk proteins, lactose intolerant or due to high content of cholesterol and saturated fatty acids, they are shifting from dairy based products to non-dairy based products. Therefore, nowadays such non-dairy based products like fermented probiotic fruits, herbal, cereals, soy, vegetables and tea derived beverages are in high demand. Also, addition of probiotic strains into various food matrices-based product can alter its properties. Therefore, while developing probiotic food product, selection of an appropriate food system is a very important factor. Also, different types of probiotic

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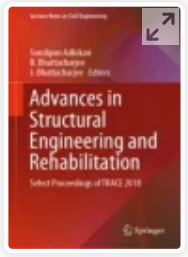

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Experimental and Numerical Study to Improve Lateral Load Resistance of Masonry Stack

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Abstract

Lateral load capacity of any structure plays a very important role to resist earthquake [1]. To understand the lateral load capacity of any low-rise masonry building, a 3D finite element model of unconfined brick masonry stack has been drawn here. The ANSYS modeling of plain brick masonry shows that masonry structure fails at the joint. Therefore, to impart ductility and strength in the stack, shear key of 4 mm diameter TMT bar of

1/8th, 1/6th, and 1/4th of longitudinal length of brick length is provided at every joint separately in different samples and performance of both confined and unconfined prism is tested against vertical and horizontal load [2]. The purpose of this study was to develop a better behavior of low-rise masonry building during earthquake. Numerical as well as experimental methods have been adapted to calculate the stress developed in masonry stack [3].

Keywords

Masonry structure **Confined masonry**

Unconfined masonry

FEM analysis of masonry structure

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Experimental and Numerical Study to Improve Lateral Load Resistance of Masonry Stack

A. K. Shukla, Saurav and P. R. Maiti

Abstract Lateral load capacity of any structure plays a very important role to resist earthquake [1]. To understand the lateral load capacity of any low-rise masonry building, a 3D finite element model of unconfined brick masonry stack has been drawn here. The ANSYS modeling of plain brick masonry shows that masonry structure fails at the joint. Therefore, to impart ductility and strength in the stack, shear key of 4 mm diameter TMT bar of 1/8th, 1/6th, and 1/4th of longitudinal length of brick length is provided at every joint separately in different samples and performance of both confined and unconfined prism is tested against vertical and horizontal load [2]. The purpose of this study was to develop a better behavior of low-rise masonry building during earthquake. Numerical as well as experimental methods have been adapted to calculate the stress developed in masonry stack [3].

Keywords Masonry structure · Confined masonry · Unconfined masonry · FEM analysis of masonry structure

1 Introduction

Unconfined masonry was used in approx. all types of structure since the life begins [4]. The masonry structures were made by two basic materials: brick and stone. These structures were not reinforced and designed to support mainly gravity loads. These masonry structures were very good at resisting wind and earthquakes. Masonry building has shown very poor performance during strong earthquake, so it is very important to improve the lateral load resistance of masonry buildings [5]. So to achieve this objective, many researches have been performed in the past. The main

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focus is on ensuring that these inertial forces caused by the ground vibrations reach the ground without causing major damage or complete collapse in the structures [6].

This research starts with analyzing the scaled unconfined model of four bricks on shake table in laboratory and then confined the same four brick model with varying diameter reinforced to strengthening the unconfined brick model to resist the lateral load [7]. And when the confined models were tested on shake table and compared the result with unconfined brick masonry, a significant lateral strength was observed.

2 Modeling of Structure

2.1 Choice of Elements

The ANSYS software contains more than 100 different element types in its element library. Each element has a unique number and a prefix that identifies the element category, such as BEAM3, PLANE42, and SOLID45. ANSYS classifies the elements into 21 different groups, out of which our main concern is of structural group. SOLID45 is used for the 3D modeling of solid structures [8]. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities [9].

2.2 Material Properties

For the brick element material properties which are assigned are modulus of elasticity (EX) and Poisson's ratio (PRXY) [10]. Values of EX and PRXY are taken according to Ali and page 1986 [5] and are tabulated below (Tables 1 and 2).

Table 1 Material properties of bricks

Properties	Mean
(a) Bricks	
Modulus of elasticity	14,700 MPa
Poisson's ratio	0.16
Tensile strength	1.20 MPa

Table 2 Material properties of mortar

Properties	Mean
(a) Mortar	
Modulus of elasticity	7400 MPa
Poisson's ratio	0.21
Tensile strength	0.78 MPa



Fig. 1 Model of specimen M1

2.2.1 Model Detail of Specimen

To model the masonry, rectangular blocks are used for bricks and also for mortar. Four numbers of bricks of standard size, i.e., 190 mm × 90 mm × 90 mm are used, and mortar of thickness 10 mm is placed in between them as shown in Figs. 1 and 2.

2.3 Result and Discussion

Postprocessing includes defining boundary condition and application of loads. For specimen M1, the one end of the brick masonry is fixed. The load is applied on the other end of the blocks. Pressure loads of 70 kN, 80 kN, and 90 kN are applied on the top face of the brick masonry. In addition to the vertical load, horizontal load is



Fig. 2 Model of specimen M2

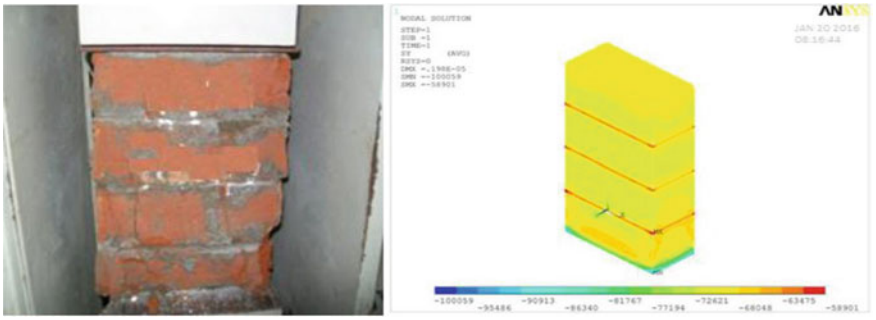

Fig. 3 *X*-component of stress on UTM and ANSYS

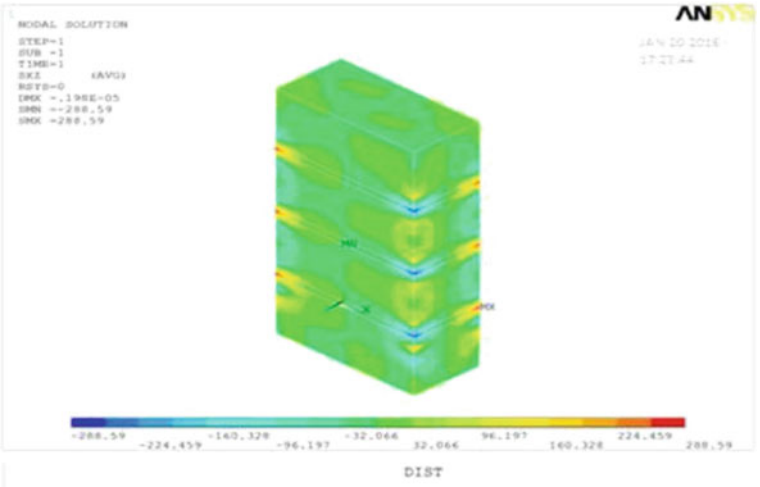

Fig. 4 *XZ* shear stress

also applied to the specimen M1. Different stress contours are drawn, and graph has been plotted between different parameters. For specimen M2 in Fig. 2, one end is fixed to make it confined and vertical load is applied.

2.4 Stress Computation

Stress computation for specimen M1 with vertical loading

From Fig. 3, it can be seen that *X* component of stress is maximum at the middle points. It increases parabolically from ends toward the center. For middle bricks, this stress is more as compared to top and bottom bricks.

Figures 4 and 5 show that the maximum stress is at the joint of brick mortar in *XZ* direction.

It can be observed in Figs. 6 and 7 that shear stress increases with distance along *Y*-axis. At a distance of 90 mm, stress is approximately 1400 MPa but from 90 to 100 mm, i.e., at the level of mortar, it decreases abruptly to −1563 MPa. Maximum shear stress is also observed at 28 mm which is equal to 1693 MPa.

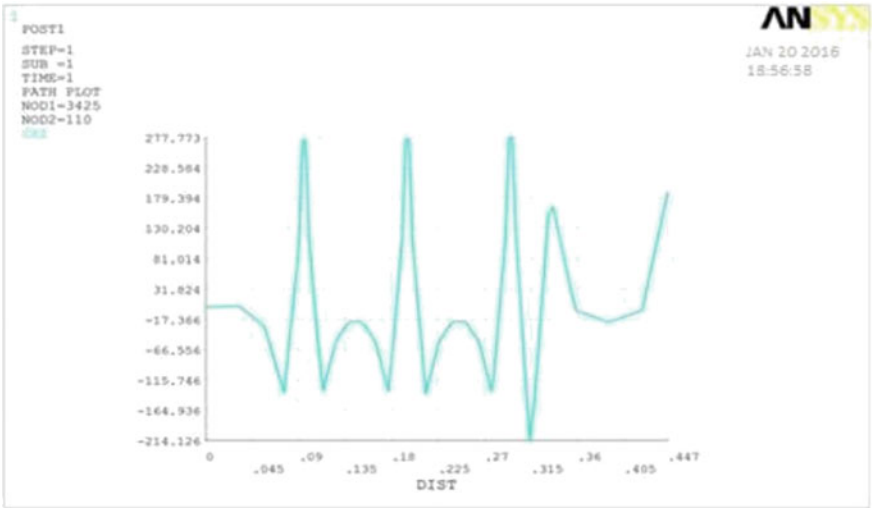

Fig. 5 Variation of *XZ* shear stress *Y*-axis

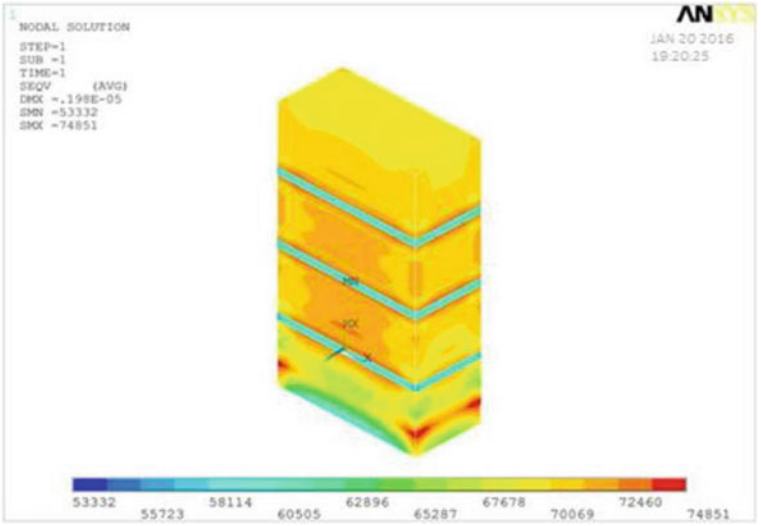

Fig. 6 Von Misses stress along *Y*-axis

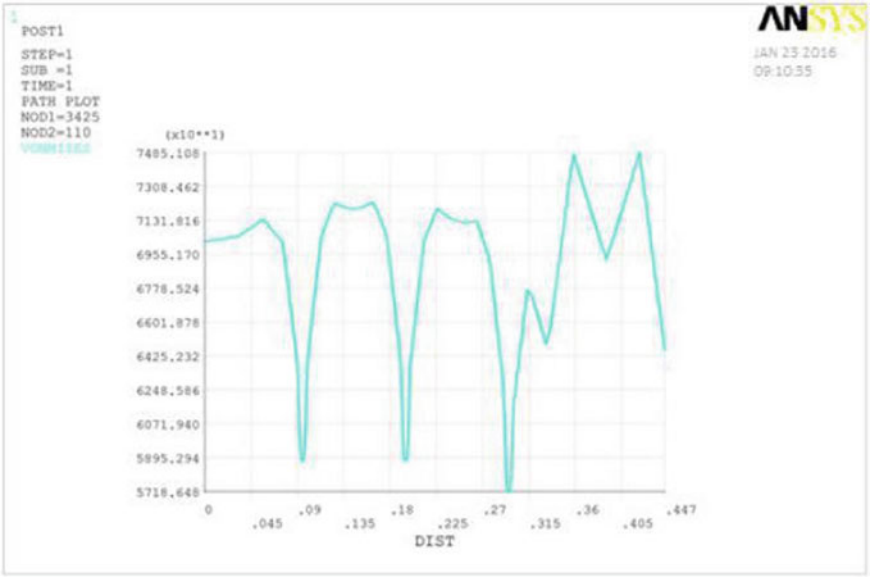

Fig. 7 Variation of Von Misses stress along *Y*-axis

3 Experimental Investigation

For confinement of the masonry prism, TMT steel bars of 4 mm diameter were used. Between every course, shear keys of 26.25 mm = 1/8th, 35 mm = 1/6th, 52.5 mm = 1/4th of longitudinal length of brick length consecutively in different specimens were used as shown in Fig. 8a–c.

3.1 Compressive Strength

For determination of compressive strength, bricks were taken out from curing tank and tested in UTM (Figs. 9 and 10). Tests were carried out at 7, 14, and 28 days of curing.

3.2 Testing of Masonry in Universal Testing Machine

Different Stresses at Failure for Confined and Unconfined Masonry are tabulated below in Table 3.

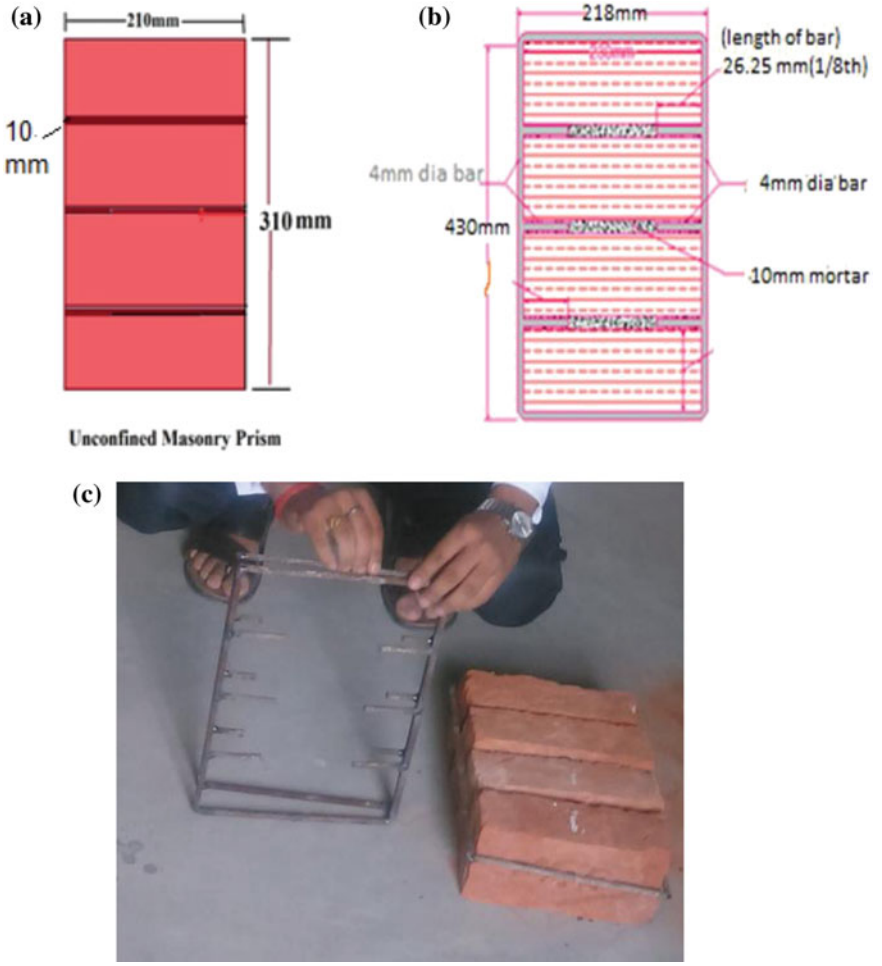

Fig. 8 **a** and **b** Schematic view of masonry prism. **c** Pictorial view of reinforcement used

Table 3 Compressive strengths at failure

Compressive stress at failure				
Prism type		Strength in MPa of stack after		
		7 Days	14 Days	28 Days
Unconfined brick masonry		4.32	6.02	6.66
Confined brick masonry	Shear key length 26.25 mm	5.80	9.19	10.33
	Shear key length 35.00 mm	6.47	9.19	10.33
	Shear key length 52.50 mm	7.61	10.42	12.14



Fig. 9 Unconfined masonry failure



Fig. 10 Confined masonry failure



Fig. 11 Experiments performed on shake table

For understanding the behavior of masonry prism against lateral loading, i.e., in earthquake or in wind load, shaker table test with varying frequency was performed. The unconfined brick masonry samples were put on the shaker table platform and fixed with the help of clamp (Fig. 11). After fixing unconfined masonry tightly on the platform, a frequency of 5 Hz and amplitude of 10 mm was set and the motor was run on this frequency for at least 120 s.

3.3 Testing of Structure Under Horizontal Load: Shake Table Results

All the samples including confined and unconfined masonry are tested under the horizontal load using the unidirectional shake table with varying frequency and amplitude as shown in Fig. 11. The result is tabulated in Table 4.

4 Results and Discussion

When brick was tested under universal testing machine (UTM), the average strength of brick was found to be 9.21 N/mm^2 and strength of cement sand mortar was found to be 14.57 N/mm^2 at 28 days of curing.

So material was found according to weak brick strong mortar theory.

Test conclusion of unconfined and confined brick masonry tested under universal testing machine and under shake table test is summarized below in Table 5.

Table 4 Shake table test results

Stability analysis											
S. No.	Frequency of shake table (Hz)	Amplitude (mm)	'g' value	Unconfined brick masonry		Confined		Confined		Confined	
						Brick masonry (shear key = 26.25 mm)		Brick masonry (shear key = 35 mm)		Brick masonry (shear key = 52.5 mm)	
				Stability	Time (in s)	Stability	Time (in s)	Stability	Time (in s)	Stability	Time
1	0.3	2.5	2	Stable	120	Stable	120	Stable	120	Stable	120
2	0.4	5.0	2	Stable	120	Stable	120	Stable	120	Stable	120
3	0.5	7.5	2	Collapse	26	Stable	120	Stable	120	Stable	120
4	0.6	10	2			Cracking seems at joints after 80th s		Very small cracking pattern observed at joint after 360 s		Stable	360

Table 5 Result of UTM and shake table

S. No.	Sample (after 28 days)	Failure load KN	Stability on shake table		
			Frequency (Hz)	Amplitude (mm)	Remarks
1	Unconfined masonry prism	137	15	35	Total Collapse at 26th s
2	Confined with shear key 26.25 mm	217	20	50	Cracking at 80th s
3	Confined with shear key 35.00 mm	230	20	50	Very small cracking at 360th s
4	Confined with shear key 52.50 mm	255	20	50	Stable after 360 s

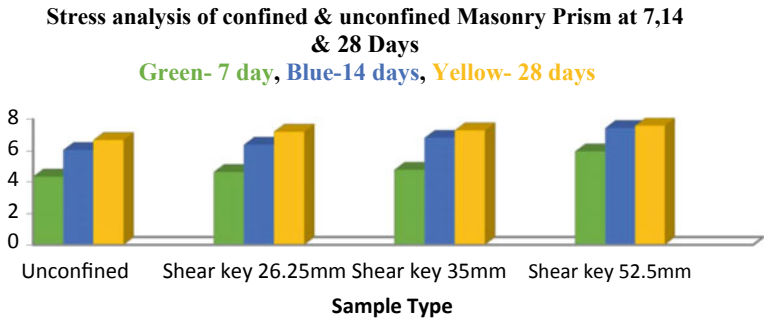

Chart 1 Stress analysis

5 Conclusion

After analyzing Chart 1 of performance of confined and unconfined brick masonry, it is concluded that the stress capacity of unconfined brick masonry at 28 days of curing was found to be 6.6 N/mm^2 while after confinement, stress capacity increased to 12.14 N/mm^2 for shear key length 52.5(1/4th of sample length) mm, i.e., the compressive load capacity of confined brick masonry was approximately doubled of unconfined brick masonry structure at 28 days. But if we look the shake table result, then we found that this stack does not show any crack even after the application of vibration for 360 s.

From the experimental study, it can be concluded that the brick stack with shear key length 1/6th of longitudinal length will be an economical solution for confinement.

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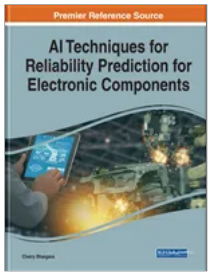

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Chapter 13
PVT Variability Check on UCM Architectures at Extreme Temperature–Process Changes

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ABSTRACT

The UCM (universal compressor-based multiplier) architecture promises to provide faster multiplication operation in supply voltage as low as 0.6 V. The basic component of UCM architecture is a universal compressor architecture that replaces the conventional Wallace tree algorithm. To extend the work further, in this chapter, a detailed PVT (process-voltage-temperature) analysis is performed using Cadence Virtuoso 90nm technology. The analysis shows that the delay of the UCM has reduced more significantly than the Wallace tree algorithm at extreme process, voltage, and temperature.

INTRODUCTION

Today's portable devices are capable of doing image filtering to face recognitions, an audio signal enhancement to voice recognition & gesture-based control to biometric authentication. All those functionalities are the applications of digital signal processing (DSP). A large number of mathematical operations are performed repeatedly and quickly on series of data samples by DSP algorithms. Most operating systems and general-purpose microprocessors can successfully execute DSP algorithms but

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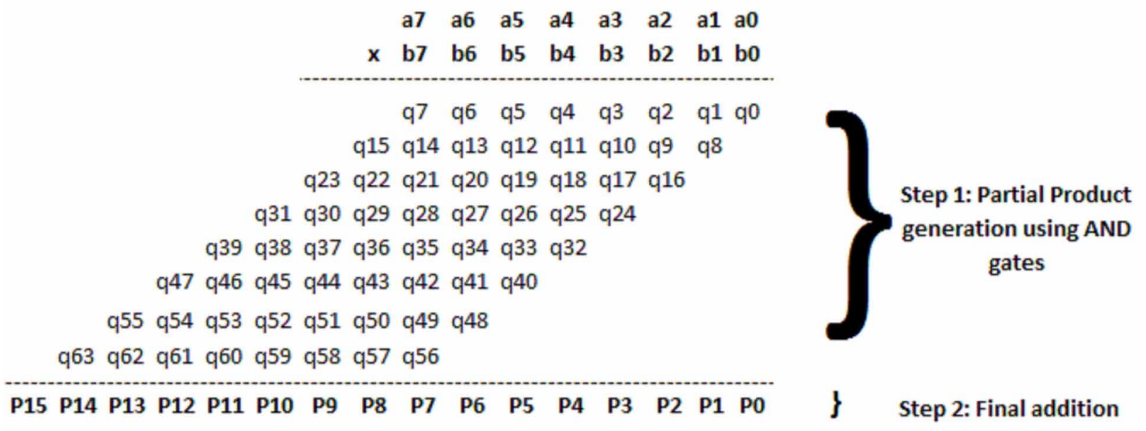
Figure 1. Basic multiplication operation



because of power efficiency constraints, they are not suitable for use in portable devices such as PDAs and mobile phones. However, the rapid growth of portable electronics has introduced the major challenges of high throughput for VLSI design engineers. Among the other digital blocks, multiplier plays a vital role while evaluating the performance of a DSP block. While performing convolution, filtering or any other DSP operations it is always desired to use an efficient multiplier unit. A basic design of a multiplier is as shown in the figure 1.

As shown in the figure 1, the multiplicand's & the multiplier's individual terms are ANDed to produce the partial products & positioned as per their weights. For example, in the figure 1, 'A2B0', 'A1B1' & 'A0B2'are aligned in a single column because the weight is two for all of the mentioned partial products. i.e. the summation of the bit location is any of 2+0, 1+1, 0+2, which are in all cases will be equal to 2. Hence, for the addition of partial products, its alignment is vital. At the next step, the partial product with same weights are added using full adder (in the case of 3 partial products), half adder (in the case of 2 partial products) or any compressor circuit (for adding 'n' number of partial products simultaneously).

In this research paper the novel UCM architecture as proposed in (Sarma, Bhargava & Jain, 2019), is further validated with the PVT analysis in cadence spectre tool in 90 nm CMOS technology. The UCM architecture uses a novel compressor-based multiplier algorithm which reduces the delay substantially.

The following sections are discussed as follows: in section 2, various different notable architectures related to multiplier are discussed in detail, in section 3, a quick review on the novel UCM architecture has been explained, in section 4, a detailed PVT analysis of the UCM architecture is discussed & in section 5, a detailed conclusion, future scopes & application of the UCM architecture is discussed.

VARIOUS MULTIPLIER ARCHITECTURES

As we know that the processing elements mainly involve the multiplication of two numbers. So, there is a need of multiplier in such type of processing systems. Various fast & efficient multipliers are described in the literature. Array multiplier (as shown in figure 2) is a basic multiplier which follows the principle of product generation & addition. But as the total number of addition levels increases, this architecture becomes bulkier with higher PDP.

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HANDBOOK ON MINIATURIZATION IN ANALYTICAL CHEMISTRY

Application of Nanotechnology



Edited by
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Chapter 2

Microfluidics in lipid extraction

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1. Introduction to biodiesel production from lipids

Vegetable oils have been widely tested to synthesize biodiesel. However, due to the exorbitant cost, the food versus fuel dilemma, and the requirement for acreage, the need to look for alternative substrates has become necessary [1]. To overcome the problems associated with vegetable oils, tree-based oils (TBOs) such as *Jatropha curcas*, *Pongamia pinnata*, *Simarouba glauca*, jojoba, etc. are now being used [2, 3]. Nevertheless, these TBOs are nonremunerative and it is expensive to maintain the plantations. Besides, they yield very low amount of lipids, which is a major setback for their efficient use as an alternative to biodiesel. To herald new options, oleaginous microbes are a promising option to consider for biodiesel production, as these are endowed with higher lipid productivity coupled with a desirable lipid combination using inexpensive carbon and nitrogen substrates. Moreover, they have no need for acreage, they are low maintenance, and there is no land versus fuel dilemma [4, 5]. Oleaginous microbes are defined as microbes that can synthesize 20% of lipid content on a dry weight basis using various inexpensive feedstocks [6]. These lipids are similar to vegetable oils and have great potential as an alternative substrate for biodiesel production. Biodiesel production from microbial lipids consists of several steps such as cultivation of oleaginous strains, lipid extraction (lipid synthesis is mostly intracellular), transesterification of lipids to fatty acid methyl esters (FAME), and purification of biodiesel (FAME). Every step in biodiesel production is very important and attention must be paid to the commercial viability of the process. Among oleaginous microbes, microalgae lipid extraction

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comprises dewatering, aggregation of algal biomass, drying, and lipid extraction with green solvents [7].

Unlike microalgae, fungi and yeast biomass are readily accessible from nature; hence, they can easily be separated by filtration followed by drying and lipid extraction using green solvents and techniques. Lipid extraction is an important step that determines the quality of biodiesel [8, 9]. Since lipids are amphipathic in nature, optimization of the solvent system and the technique used are crucial parameters [10]. Furthermore, to minimize the amount of solvent and time used in the process, microfluidics can be deployed that have the potential to carry out the process in less time with reduced solvent usage [11]. Therefore optimization of the microfluidics method for each strain would be highly desirable for the development of a viable approach [6].

2. Positive attributes of microfluidics over existing technologies

The major pitfalls in existing microalgal bioproduct/biofuel research include high cost, labor intensity, low throughput, time consumption, and poor control over cell manipulation [12, 13]. Microfluidic systems leverage artificial tubular channels or reactors of micron size and rely on small volume manipulation in the range of microliters to picoliters, thereby reducing the large quantity of sample required or consumed. They consist of a polymer device made up of polydimethylsiloxane (PDMS) and drive devices. This combination enables researchers to automatize, miniaturize, and parallelize their study. Additionally, microfluidic systems offer researchers the opportunity to continuously monitor microbial cells in microenvironments with high-precision control at the single cell level, and open an avenue to perform high-throughput culture screening as well as lipid separation, biomass analysis, and cultivation [14–17] (Fig. 2.1). Because of their micron-scale dimension, microfabricated devices offer advantages like laminar flow [18], rapid diffusion [19], and thermal transport [20].

The last decade has seen a renewed importance in utilizing microfluidics in processes involved in industrial production [21, 22]. Additionally, recent developments in microfluidic technology have enabled us to categorize these

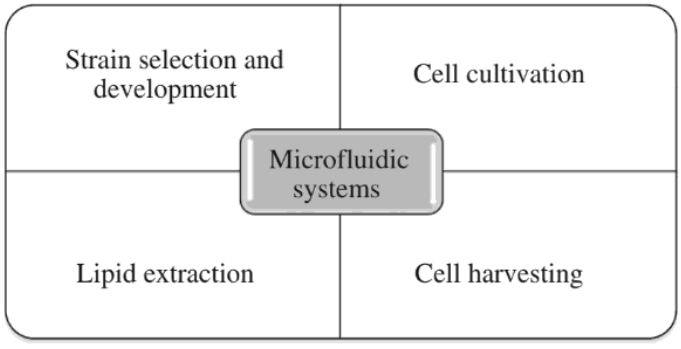

FIG. 2.1 Applications of microfluidic systems.

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processes into microdetection, microseparation, microculturing, microdroplets, and microreaction. A wide gamut of research has already transformed a simple PDMS-based microfluidic device into a lipid separation unit. Berger et al. successfully separated chloroform from a lipid and oil suspension with an extraction efficiency of 93.5%–97.9% [23]. Interestingly, a two-layer microfluidic chip was developed by Bang et al. to extract lipids by the solid-phase extraction method, which also shows a very high recovery rate (95%–100%) [24].

"Oils" secreted from microbes are generating considerable interest and can be an ideal option for biofuel production. Most of the microorganisms, including yeast, microalgae, bacteria, and fungi, can be deployed for accumulating oils [25]. Roughly 2–8 million microalgal species are present in our ecosystem; however, only a small number of species have been reported so far [26, 27]. It is necessary to identify strains with better stress tolerance and yield. Conventionally, the microalgal samples collected from different locations are further identified through light microscopy and molecular biology techniques with bulky instruments in high-end laboratory settings.

Lim et al. demonstrated an energy-efficient and less labor-intensive way of cultivating *Chlamydomonas reinhardtii*, and analyzed lipid accumulation as well as separation using a microfluidic platform. Because of the controlled environment and reaction system, lipid separation efficiency is found to be much greater than in traditional bulk experiments [28]. Besides lipid extraction, Eu et al. designed a microfluidic device to monitor the cytotoxic response of microalgal cells and their lipid production under the influence of nitrogen [29].

Undoubtedly, by integrating cell culture, lipid production, and lipid extraction in a single microfluidic system a robust and multiplexed device for biomass products can be created. Kwak et al. used an intriguing approach by deploying an eight-chamber microfluidic device to carry out multiple processes from various microbial strains. Strikingly, lipid extraction efficiency was amenable with the traditional Bligh-Dyer method [30]. Bensalem et al. applied pulsed electric fields and mechanical stresses using microfluidic systems as a pretreatment method to enhance lipid extraction [31]. Another remarkable way of simplifying the lipid extraction procedure was proven with the assistance of superabsorbent polymers and microsystems. Interestingly, this method witnessed an increase in extraction rates [24]. With such diverse applications and benefits, certain microfluidic systems can be a potential alternative to conventional cell culture reaction systems, and considered as an unprecedented tool in current biomass analysis, lipid extraction, strain selection, and biofuel research.

3. Ideal characteristics of microfluidic devices

The rule of thumb for microfluidic devices relies on the manipulation of samples by decreasing or downsizing the device lengths (preferably micron scale) and also possessing the following characteristics. First, surface phenomena, including surface charge and capillary forces, dominate gravitational forces, which

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leads to passive actuation of samples. Second, fluid flow will always be laminar (due to low Reynolds number) offering a reliable liquid/liquid interface analysis and also generating large concentration gradients at single cell resolution. Third, smaller dimensions enable researchers to utilize less reagent or assay volume (picoliter) as well as manipulate monophase and multiphase systems in a single device with the scope for massive parallelization in resource-limited settings. Because of their advantages like portability, better sensitivity, low cost, faster analysis time, and less sample and space consumption, different microfluidic platforms (pressure driven, centrifugal, electrokinetic, and acoustic-based) have outweighed conventional bulk experiments for bio(chemical) and industrial assays [32, 33].

4. Design of microfluidic devices in lipid extractions from microalgae/oleaginous microbes

The production of biofuels from microalgae or oleaginous microbes should be economically viable. Conventionally used benchtop methods for culturing microalgae or oleaginous microbes, collecting accumulated lipids, and extracting lipids are often time-consuming and tedious processes.

Development of microfluidic platforms over the last two decades has helped in the extraction of lipids from numerous microalgae species with high productivity. Microfluidics also provides a platform for quantitative analysis of the extracted lipids. Numerous integrated microfluidic platforms have been developed to efficiently perform multiple steps on a single chip, from culturing microalgae to the extraction of lipids. In this section, we will discuss some of these commonly used microfluidic designs for lipid extraction from microbes and microalgae.

4.1 Reservoir with filter design

In this type of lipid extractor, cell growth and lipid collection are carried out in two separate chambers. A microfluidic filter connects these two chambers. The microfluidic filter blocks cell debris and allows only produced lipids to go through. Fig. 2.2 represents a simple design in this approach by Lim et al. [28]. Fig. 2.2 shows the complete setup for the collection of lipids from microalgae. The syringe pump first seeds the microalgae into the cell chamber along with media. After seeding, culture is allowed to grow for 4 days. Next, during the next 4 days of the induction period, the syringe pump is used to feed nitrogen-deficient media. Finally, solvents (ethanol and isopropanol) are pumped for the extraction of lipids.

The debris from microalgae are separated from lipids using a rectangular pillar filter. Here, any kind of microfluidic filter should work but preferably one that does not clog because it will allow the user to reuse the microfabricated device. To improve the efficiency of collected lipids, multiple reservoir and filter designs can be connected in a circular manner, as shown in Fig. 2.3. Kwak et al. [30] used a

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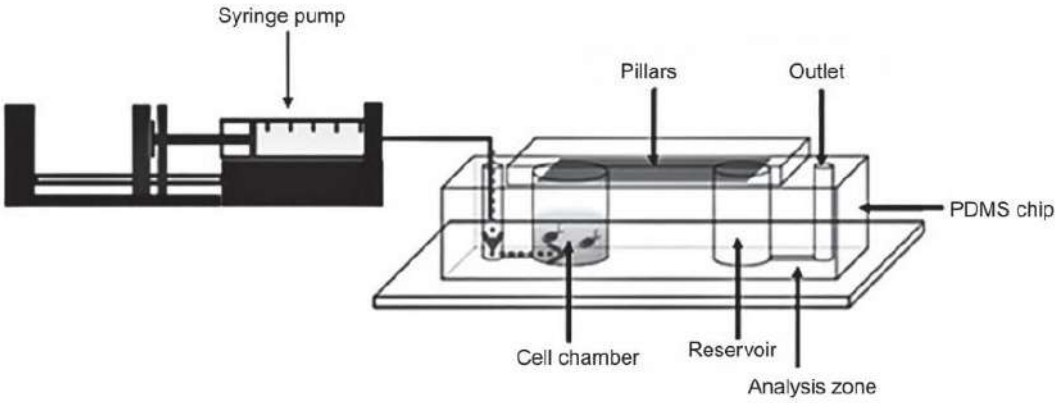

FIG. 2.2 Schematic representation of the reservoir with filter design. The syringe pump is used to load buffer, lysing solution, and lipid extraction solution into the microfluidic chip. The cell chamber is used to culture microalgae. The pillar filter is used to separate debris from lipid. The reservoir is used for accumulation of lipid. The analysis zone is used to analyze lipid quality. The device is based on two-level lithography and bottom and top glass sealing.

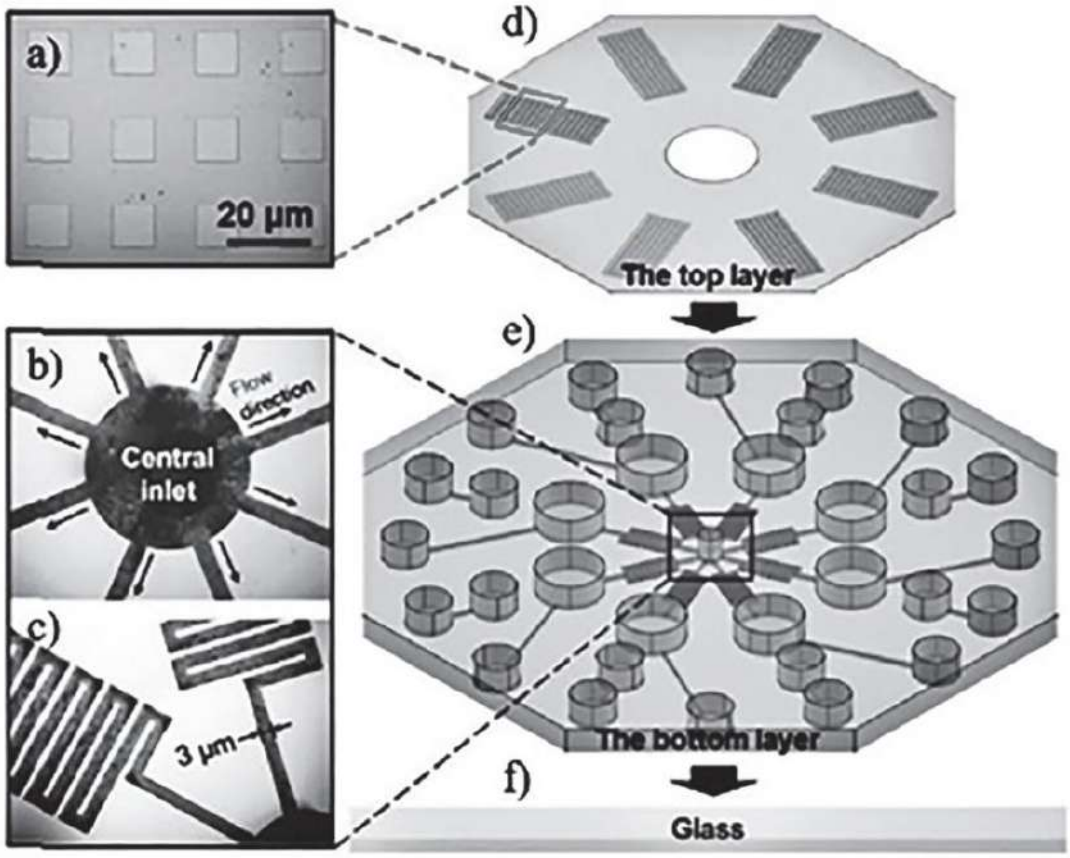

FIG. 2.3 Concentrically arranged reservoir and filter design. (A) A rectangular pillar filter with 10 μm pillars. (B) Common central inlet for inserting different media using a syringe pump. (C) Coregulated channel to prevent cell leakage. (D) The top layer of the device with filter pillars. (E) PDMS chip with multiple reservoirs and channels connecting them. (F) Bottom glass for analysis. *(Modified and adopted from H.S. Kwak, J.Y.H. Kim, S.C. Na, N.L. Jeon, S.J. Sim, Multiplex microfluidic system integrating sequential operations of microalgal lipid production, Analyst 141 (2016) 1218–1225.)*

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concentric design with a central inlet and eight chips around the inlet (Fig. 2.3B). The top glass has a rectangular pillar filter array with 10 μm gaps. Circular and linear alignment with the reservoir is critical in such a design. The 3 μm corrugated channel is used to connect the central inlet with the culturing reservoir (Fig. 2.3B). The groove in the channel increases the path length and hydrodynamic resistance. Thus the corrugated channel helps to prevent cell leakage. The cell chambers are 8 mm in diameter and 10 mm deep. The output lipid collection chamber is 4 mm in diameter and 10 mm in height.

Another major advantage of using multiple reservoirs with filter design is to optimize the culturing conditions such as temperature, salt concentration, starvation, etc. In that case, instead of a common inlet, there could be one inlet per reservoir. Alignment and two-level lithography are the two major drawbacks of the reservoir and filter design.

4.2 Lab-on-a-disc design

In lab-on-a-disc designs, sequential steps of lipid extraction from microalgae are automated with the help of centrifugal force and valves. Fig. 2.4 shows one such design, where carbon valves are irradiated using a laser.

As shown in Fig. 2.4, lab-on-a-disc has five sections for lipid extraction and quantification from microalgae. There are chambers for sample inlet, lipid extraction, and collection. Reagents, dyes, and waste are also stored in the same disc. The disc is fabricated by hot embossing four layers that contain flow channel, inlets, valving polycarbonate (PC) film, and vent holes. The carbon dot

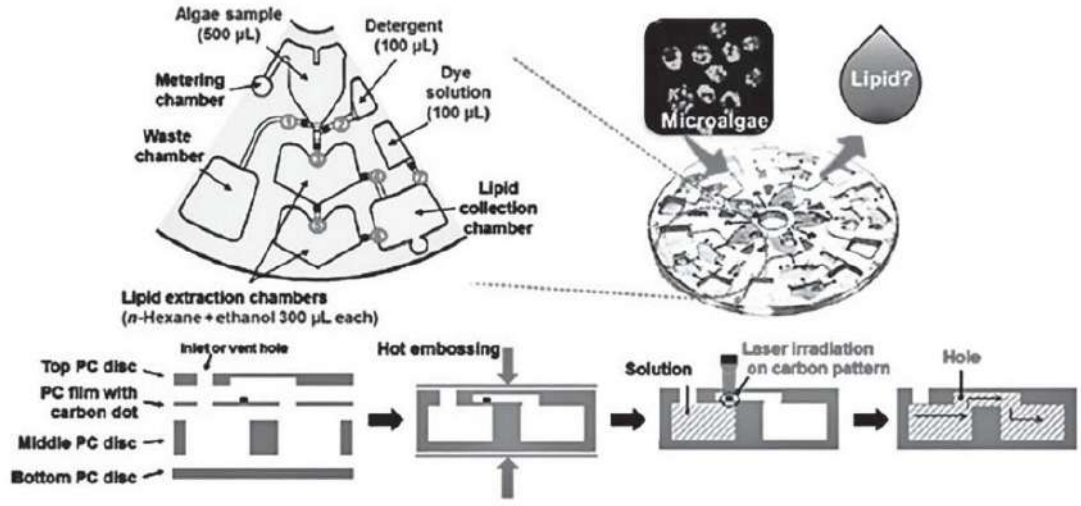

FIG. 2.4 Schematic illustration of a lab-on-disc platform for lipid extraction using microalgae. Four layers of polycarbonate (PC) disc are hot embossed along with a carbon pattern for valving purposes. The holes are drilled using CNC machining. Laser irradiation on a carbon pattern is used to open up the valve. Once the valve is open the liquid is carried to the next chamber because of centrifugal force. *(Modified and adopted from Y. Kim, S.N. Jeong, B. Kim, D.P. Kim, Y.K. Cho, Rapid and automated quantification of microalgal lipids on a spinning disc, Anal. Chem. 87(15) (2015) 7865–7871.)*

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in PC film is burnt using laser irradiation, which allows the sample to flow through. A 500 µL algae sample is loaded into the chip. Spin speeds of 6000 and 3000 rpm are used alternatively along with shaking (6 Hz at an angle of 5 degrees) and 13 valves are used to extract lipid from microalgae within 13 min. This method is based on mixing lysate and microalgae samples.

The valving and the speed of rotation help in achieving timely operations for lipid extraction purposes. Though the method is very fast (13 min), it requires four layers of complex fabrication and a rotating mechanism with vibration support.

4.3 Bead-packed microchannel design for lipid extraction

In this kind of design, microbeads are packed into the microchannels such that the debris of lysed microalgae are blocked and only lipid is extracted from the lipid collection outlet. Sun et al. designed a similar microfluidic chip [34] as shown in Fig. 2.5. An isometric view of the bead-packed microchannel is shown in Fig. 2.5A. The bead-packing hole is used to load the 15 µm beads inside the microchannels. The lysed samples are fed to the chip using a syringe pump, and lipid is collected at the lipid collection outlet while the bead-packing hole is kept blocked. Fig. 2.5B shows a cross-sectional view of the channel. The channel is 200 µm high and has a 100 µm flat channel with a total channel width of 300 µm. The idea behind this design is a simple chip that can filter microalgae

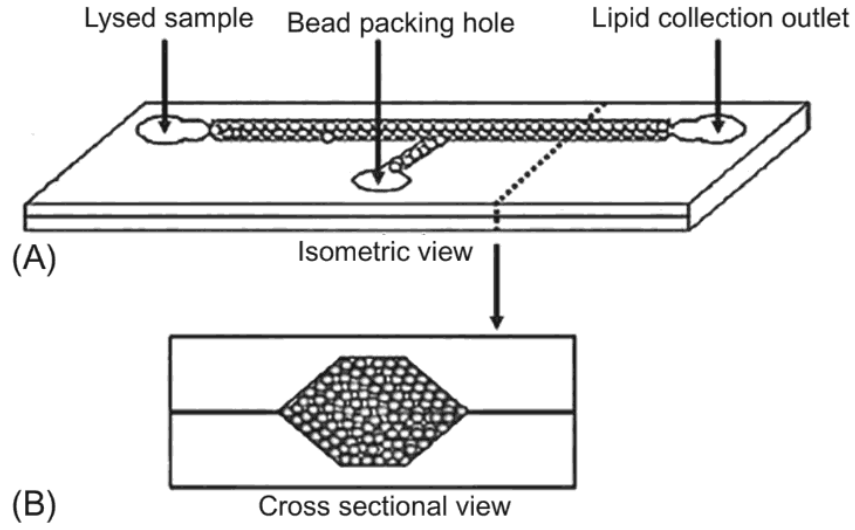

FIG. 2.5 Design schematic of bead-packed microfluidic device. (A) Isometric view of the microfluidic device. The device has a lysed sample inlet, bead-packing hole, and lipid collection outlet. The bead-packing hole is only used initially to load the bead into the channels and remains blocked during lipid extraction. (B) Cross-sectional view of the channel showing the hexagonal structure. The channel height is 200 µm, the flat channel width is 100 µm, and the total channel width is 300 µm. Beads are 15 µm. *(Modified and adapted from T. Sun, S. Pawlowski, M.E. Johnson, Highly efficient microscale purification of glycerophospholipids by microfluidic cell lysis and lipid extraction for lipidomics profiling, Anal. Chem. 83(17) (2011) 6628–6634.)*

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debris and allow the user to control the gaps between the beads using a bead-packing hole. This design lacks the on-chip cell lysing facilities and also need to utilize injection with valves to pump the sample and cell lysing reagents.

4.4 U-shaped trap split-channel design

The U-shaped trap is useful when the user needs to observe lipid production and accumulation inside microalgae. A single U-shaped trap with four pillars was designed by Bodénès et al. [35]. Fig. 2.6 shows a schematic representation of the U-shaped trap split-channel design. The split channel helps to improve throughput. The design involves four light-blocking layers of fabrication and valving at suitable light wavelengths. The second layer is the cycle-controlled layer that allows light and dark cycles by pneumatically controlling deionized (DI) water and black dye simultaneously. The third layer is a gradient layer that controls light intensity using black dye and DI water. The last layer consists of the microalgae culture layer with U-shaped traps with a 77 μm radius of curvature for pumping the culture media. Although the proposed design allows the high-throughput screening of lipid production, it is difficult to achieve perfect alignment of the four layers. Also, multiple external units of syringe pumps are needed to perform the experiment.

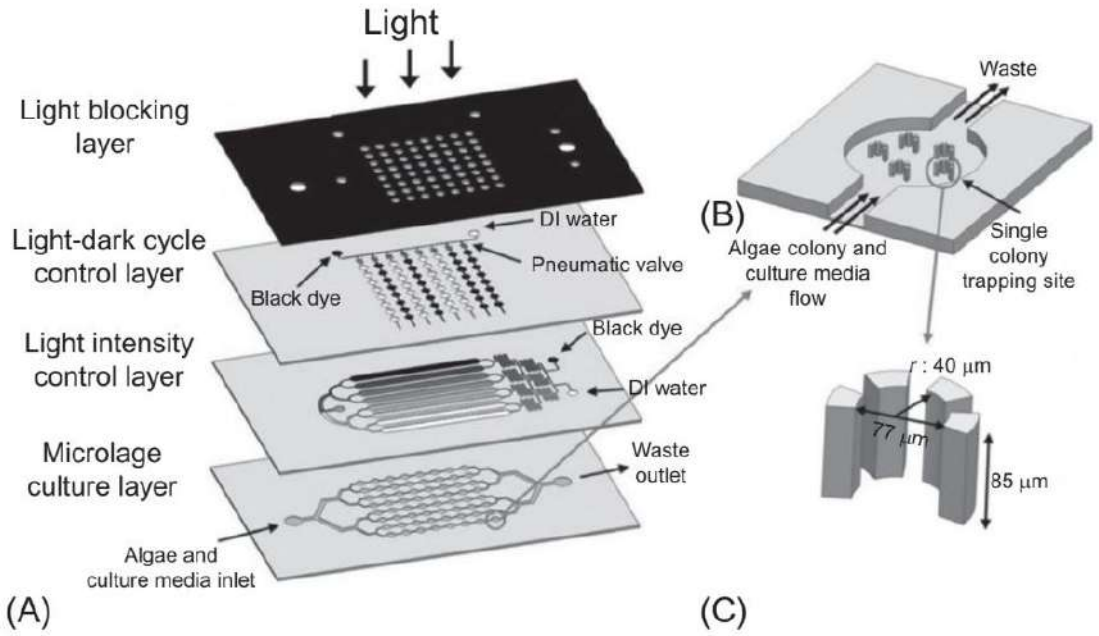

FIG. 2.6 High-throughput microfluidic U-shaped trap to monitor microalgal lipid production and accumulation. (A) The design layers of the microalgal culture monitoring chip. The four layers were composed of a light blocking layer, cycle-controlled layer, light intensity-controlled layer, and microalgae culture layer. (B) Enlarged view of a single culture compartment with multiple U-shaped trapping size. (C) A single microalgae trapping site composed of four micropillars. *(Modified and adapted from P. Bodénès, H.Y. Wang, T.H. Lee, H.Y. Chen, C.Y. Wang, Microfluidic techniques for enhancing biofuel and biorefinery industry based on microalgae, Biotechnol. Biofuels 12(1) (2019) 33.)*

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4.5 Confined impinging jet mixer design

The confined impinging jet mixer design is used to burst the cell using shear force to extract lipids from it. Tseng et al. [36] designed a lipid extraction method using a microfluidic-confined impinging jet mixer. Fig. 2.7 shows a schematic representation of a confined impinging jet mixer where organic solvent and lipid-rich microbial suspension are mixed in the central round chamber. At the exit, due to confinement, the oleaginous cells experience a high shear force that eventually breaks them apart, and lipid is extracted. Though it is a very simple design, it depends greatly on shear force for its operation. The design lacks the provision for filtering the cell debris, which allows the passage of oleaginous cells into the lipid stream.

5. Lipid extractions from microalgae and oleaginous microorganisms

The lipid extraction process is an important step, which incurs 90% of energy as per the life cycle assessment of the microalgal biodiesel process [7]. Moreover, in the conventional lipid extraction process, a solvent system such as chloroform:methanol has been widely used, which requires a huge amount of solvent and time. To address these issues, microfluidic-based lipid extraction is highly desirable because of the miniaturization of the equipment, highly efficiency solvent usage, and the process can be performed quickly.

Lim et al. [28] developed an in situ double-layered PDMS device for lipid extraction from *C. reinhardtii*. In this setup a microcolumn with micropillars (made of PDMS) was used not only for lipid extraction but also to retain the microalgae cells in the bioreactor for the extraction process. Unlike conventional solvent systems (chloroform and methanol), in this study, ethanol and isopropanol were used, since the chloroform solvent can easily absorb chloroform [3, 37].

Pertinent to the efficiency of the lipid extraction process, isopropanol and ethanol have shown to be less efficient than chloroform and methanol solvents.

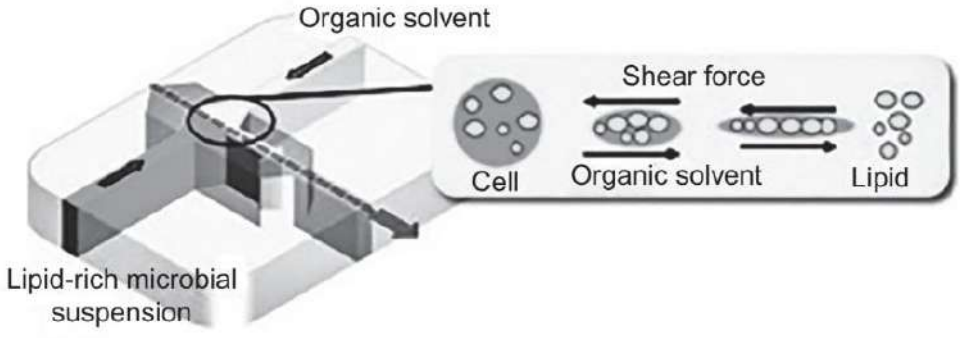

FIG. 2.7 Schematic of the confined impinging jet mixer [36]. The algae from the left and solvent from the right are mixed in the central chamber. The mixed sample then exits from the confining outlet.

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Besides, the composition of extracted lipids showed that isopropanol and ethanol result in higher polyunsaturated fatty acids (C18:3) than chloroform:methanol, which showed a higher content of saturated fatty acids (C16:0, C20:0). This study showed the potential of microfluidics to integrate various steps like cultivation of microalgae, estimation of lipids (electroporation), and the lipid extraction process. However, the major drawbacks for effective implementation are the incompatibility of polymers studied for reaction and extraction conditions, upscaling of microfluidic cell concentration, and the cell lysis process. The common polymers studied for molding microchannels using poly(methyl methacrylate) and PDMS are nonresistant and react with NaOH, particularly in the transesterification process. To address these problems, future studies of microfluidics should envisage to use of inert materials such as ceramics [38], silicon, and glass [39, 40] for microalgal extraction and transesterification processes.

Recent research attempts at utilizing microfluidics for lipid extraction are summarized in Table 2.1.

6. Future prospects

Microfluidic intervention lipid extraction technology is capable of solving existing algal-biorefinery problems and helps in the upgradation of the lipid-based biofuel sector by addressing biofuel substrate depletion. Microfluidic intrusion in lipid extraction has been greatly enhanced through research into the development of compatible molding polymers, which can withstand extraction conditions. The compatibility issue has been studied through the utilization of inert materials (silicon, glass, ceramics) to develop microfluidic devices for better utilization in lipid extraction [35, 44]. Moreover, better lipid extraction efficiency is possible by studying the emulsion (due to the presence of hydrophilic solutions and organic solvents)-related problems by mainly focusing on reducing the contact area between the hydrophilic and hydrophobic phases of the lipid extraction system. Microfluidic-based lipid extraction has to be practiced on pilot-scale studies, which paves the way for industrial exploitation of microfluidics in the biorefinery sector [6, 45].

7. Conclusion

The better utilization of algal and oleaginous microbial lipids alleviates the current scenario of substrate scarcity in the biorefinery sector. Many researchers are working actively for better utilization of rheology-based microfluidics in microalgal technology and oleaginous biorefinery for enhanced results from the lipid extraction process. The profound knowledge attained through the extensive intrusion of microfluidics in proteomic research has to be applied to the development of better microfluidic devices for lipid extraction. The successful development of better microfluidic devices for lipid extraction helps to reduce the cost of algal- and oleaginous-based biofuels. More research is anticipated to

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TABLE 2.1 Research attempts at lipid extraction through microfluidics technologies.

Source of microbial lipid	Microfluidic device characteristics	Enhanced yield/array of compounds	Any other relevant data	References
Adenocarcinomic human alveolar basal epithelial cells (A549)	Three-layered microfluidic device [two polydimethylsiloxane (PDMS) layers were attached to an indium-tin oxide-coated glass] for cell capture	>90% cell occupancy with single-cell occupancy of ~25%	Not suitable for single-celled organisms	[41]
Sulfurospirillum barnesii strain SES-3 cells	T-shaped channel, 300 μm W × 200 μm D, Schott Boro float glass based	Six major classes of phospholipid	Suitable for subsequent lipidomics analysis	[34]
Chlamydomonas reinhardtii CC503 (cw92 mt+), CC124 (mt- agg-1 nit1 nit2), and CC4348 (BAF-J5; cw15 arg7-7 nit1 nit2 sta6-1::ARG7)	PDMS-based two-layer device (top layer has a microchannel filled with an array of square micropillars (5 μm H × 100 μm^2 CSA × 10 μm of interspacing) and bottom layer is a cell-capturing chamber)	Enhanced lipid extractions yielded by using 70% aqueous isopropanol	Suitable for a broad range of microbial sources	[28]
Phaeodactylum tricornutum in F/2 medium	2D-hydrofocusing microfluidic chip was fabricated (total volumetric flow of ~220 μL/min) and attained a 260 mm/s typical cell velocity	Real-time measurement of photosynthetic efficiency (as Fv/Fm) and lipid accumulation (as Nile Red fluorescence)	Suitable for lipid extraction with stressed algal systems	[42]
Chlorella vulgaris	Fabrication of dielectrophoresis device	The operating conditions seem to be 1.4–2.95 mS/cm conductivity, 1–20 MHz operating frequency, and a crossover frequency of 11 wt% lipid content	Suitable for sorting and harvesting of high lipid content	[43]

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develop an integrated process of lipid extraction coupled with online monitoring of extracted lipid analysis.

Websites

https://microfluidics-master.fr/
https://ufluidix.com/circle/microfluidic-companies/
https://web.uvic.ca/~kelvira/
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Lignin as Potent Industrial Biopolymer: An Introduction



Swati Sharma, Abhishek Sharma, Sikandar I. Mulla, Deepak Pant, Tanvi Sharma and Ashok Kumar

Abstract Lignin is a complex biological molecule and well known as a second abundant biopolymer on the planet. It also produced as a by-product of lignocellulosic biomass, paper and pulp industry. It has not been well explored for industrial applications due to its poor solubility and complex molecular structure. Hence, since last two decades, lignin has gained the attention of researchers as a raw material for the synthesis of value-added products of commercial importance. However, the major part of the lignin derived from the pulp industry is being utilized as boiler fuel. The efficacy of lignin produced from lignocellulosic-based bio-ethanol industry to synthesize the renewable polymeric material is much higher as compared to the lignin obtained from pulp industry. These days lignin has also been exploited to synthesize various chemicals like esters, ethers, bio-adhesives, biolubricants, foams, nano-particles and nano-composites. The excessive production of lignin from paper or bio-ethanol industry has also appeared as critical environmental problem. The conversion of huge amount of lignin will not only help to solve the environmental threat but also boost the bio-economy of bio-ethanol and paper industry. In this chapter, we highlight the sources, extraction of lignin and its immense industrial importance.

Keywords Ethanol · Lignocellulosic biomass · Biofuel · Esters · Ethers · Adhesives · Foam

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1 Introduction

Lignin is the most abundant in plants and an important component of the cell wall. It is highly hydrophobic and insoluble in water and alcohol. Lignin is a complex organic polymer formed of monolignol units. Lignin waste is also appeared as an environmental issue as this waste is dumped or burned as low-grade fuel causes wastage of natural resources. Hence, upgradation of lignin valourization through technological improvements for the realization of sustainable resource management is very necessary. Due to the technological improvements like thermochemical tailor technologies of lignin, numerous value-added chemicals can be synthesized, e.g. ethylbenzene (vital intermediate for organic synthesis) (Regmi et al. 2017), guaiacol (phenolic resin making) (vom Stein et al. 2015) and *p*-hydroxyl acetophenone (cholagogue drug making and perfume synthesis) (Luo et al. 2018). Currently, more than 80 million tons of lignin is being produced as a by-product from lignocellulosic biorefinery and paper/pulp industry. On the other hand, only a small fraction of this lignin is used as fuel or energy source in the industry. Thus, researchers are intended to synthesize various fine chemicals of higher commercial value from lignin to make the biorefinery process more sustainable. However, the direct conversion of lignin into valuable chemicals is also challenging due to its poor solubility and complex phenolic ring structures with high bond energy. Lignin falls within important biomass resources due to the depletion of fossil resources and increasing environmental pollution by the excessive use of fuels (Peng et al. 2014).

Literature showed that lignin is a good source for manufacturing the phenolics as it is one of the potent sources of aromatic chemical compounds (Alonso et al. 2010). As stated in previous reports, lignin can be hydrolysed into phenolic resins and alkylphenols which can act as highly efficient fuels and energy sources (Graglia et al. 2015; Li et al. 2015; Xu et al. 2014; Zakzeski et al. 2010). The lignin-derived derivatives can also be used in the synthesis of polyurethane resins, polyols, foams, antifungal agents and various products of industrial use (Dos Santos et al. 2015; Mahmood et al. 2016; Rößiger et al. 2018). The major challenges in the lignin conversion are formation of char as a by-product, complexity in the purification and separation of products and also poor selectivity for product synthesis which are needed to be considered during operation of lignin-based biorefinery.

2 Sources and Structure of Lignin

2.1 Major Sources of Lignin

Lignin was primarily studied for its significance in the pulp and paper industry, where fibrous product rich in cellulose was produced by eliminating lignin from the wood. Therefore, the major studies were focused on the composition and structure of lignin (Chen et al. 2018; Fernández-Rodríguez et al. 2019; Glasser 2019; Rahimi

et al. 2014). Some studies of lignin were also related to herbaceous plants (Buranov and Mazza 2008; del Río et al. 2012a, b; Marques et al. 2010) where lignin partly triggered by digestibility and dietary conversion issues in animal feed (Campbell and Sederoff 1996). But nowadays, these lignocellulosic wood species and wastes provide opportunities for the production of green chemicals, bioproducts and energy within the biorefinery (de Gonzalo et al. 2016; Graglia et al. 2015; Keegstra 2010; Zakzeski et al. 2010). Lignin is mostly bound to polysaccharides in close association with cellulose and hemicelluloses in plants. But the distribution of lignin, cellulose and hemicellulose is not uniform throughout the plant body. Vascular plants contain lignin mainly between the cells, with second largest in quantity to cellulose among natural polymers (Gellerstedt 2015; Gierer 1985; Graglia et al. 2015; Keegstra 2010; Moura et al. 2010; Zakzeski et al. 2010). Lignin is proven fundamental source of complex organic polymers for the chemical industry in a biorefinery. More specifically in woody plants, the lignin content is approximately 15–40% (Fengel and Wegener 1984), whereas in herbs or annual plants, the lignin content is less than 15% (Table 1). So, the paper and pulp sectors yield a large quantity of lignin with greater potential in biorefineries. Negligible lignin is recovered from solid waste, where their content (lignin) is assessed to be less than 15%.

Table 1 Quantity of lignin in various classes of plants

Plant	Lignin contents (%)	Reference
Piceaabies sp.	20–40	Önnerud (2003), Önnerud and Gellerstedt (2003)
Pinus pinaster	25–35	Baptista et al. (2008)
Pinus taeda	28–45	Huang et al. (2011)
Pinus radiata	25–30	Sjöström (1993)
Acasia mollissima	20–25	Sjöström (1993)
Acacia mangium	27–35	Pinto et al. (2005)
Cynara cardunculus	16–25	Gominho et al. (2001)
Betula verrucosa	15–25	Önnerud (2003)
Eucalyptus globulus	20–25	Sjöström (1993)
Populus tremula	18–22	Önnerud and Gellerstedt (2003)
Quercus suber	25–40	Lourenço et al. (2016)
Tectona grandis	30–45	Lourenço et al. (2015)
Arundo donax	15–20	Shatalov and Pereira (2005)
Miscanthus x *giganteus*	15–20	Pascoal Neto et al. (1997)
Musa acuminate	10–25	Oliveira et al. (2007)

2.2 Structural Composition of Lignin

In order to understand the properties of lignin and to propose a lignin-based pathway, its structural aspects need to be understand deeply. Lignin is primarily constituted of three monolignol precursors: coniferyl alcohol (guaiacyl), *p*-coumaryl alcohol (hydroxyphenyl) and sinapyl alcohol (syringyl) (Fig. 1) which synthesizes lignin polymers in the cytoplasm via shikimate pathway (Boudet 2000; Glasser 2019; Rahimi et al. 2014; Rößiger et al. 2018). The chemical structure of lignin possessed abundance of the chemical sites which indicated that lignin might be a key precursor in the synthesis of aromatic chemicals. Few other non-conventional monolignol precursors are also identified in negligible amounts (Gellerstedt and Henriksson 2008). Also, these polyphenolic rings provide hydrophobicity in aqueous systems which ultimately gave resistance to chemical and biological degradation of plants (Keegstra 2010). The composition of these monolignol precursors in different types of plants is represented in Table 2. In angiosperms, syringyl–guaiacyl-type lignin is

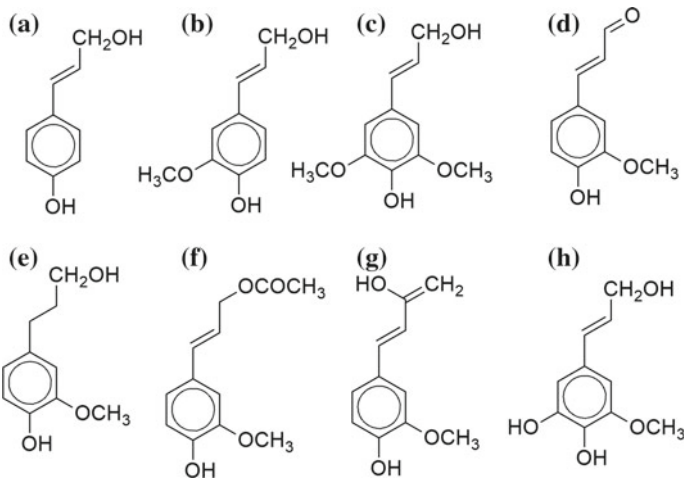

Fig. 1 Types of monolignol precursors for lignin syntheses: **a** *p*-coumaryl alcohol, **b** coniferyl alcohol, **c** sinapyl alcohol, **d** coniferaldehyde, **e** dihydroconiferyl alcohol, **f** coniferyl alcohol-9-acetate, **g** ferulic acid and **h** 5-hydroxyconiferyl alcohol

Table 2 Amount of monolignol precursors is in different types of plants (Gellerstedt and Henriksson 2008)

Plant	Hydroxyphenyl (H) (%)	Guaicayl (G) (%)	Syringyl (S) (%)
Softwoods	5	95	0
Hardwoods	0–8	25–50	45–75
Grasses	5–35	35–80	20–55

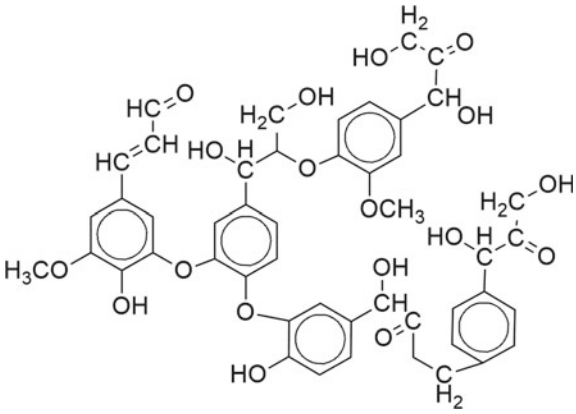

Fig. 2 Structure of lignin showing G, S and H units

present which makes angiosperm (hardwood) lignin more readily detached during pulping process, while in gymnosperm, only guaiacyl lignin is present (Fig. 2).

3 Lignin Extraction from Different Types of Biomass

The extraction of lignin from different types of biomass usually depends on a starting material or the wood to obtain the pulp (Chen et al. 2018; Radotić and Mićić 2016). The yield of the lignin is affected by various parameters such as the method of extraction, reaction time, type of reaction medium and temperature. There are several methods which have been developed for the extraction of lignin from cellulosic pulp which involves enzymatic, chemical and physical.

3.1 Biological or Enzymatic Methods

Enzymatic methods involve the use of cellulolytic enzymes for carbohydrate's hydrolysis which produce the insoluble fraction of lignin (Radotić and Mićić 2016). Successive enzymatic treatments of the pulps ensure absolute hydrolysis of carbohydrates to enhance the recovery of lignin with good yield as compared to other methods like unbleached kraft pulps. These enzymes are quite effective to hydrolyse the entire pulp polysaccharides of the wood. The obtained fractions contain ~65 to 80% lignin with ~7 to 8% carbohydrates and some fraction of other impurities (Radotić and Mićić 2016). These impurities are difficult to remove by enzymatic methods. However, the residual lignin obtained from enzymatic hydrolysis or dissolution of carbohydrates is considered to be effective and economic as lignin structures remain unchanged with a higher yield. In order to remove the impurities and ensure the high purity of lignin, we need to apply an integrated approach which

involves the use of chemical agents and mechanical amenities along with enzymatic method.

3.2 Chemical Methods

Various chemical methods for extraction of lignin are employed; some of them are acid hydrolysis, kraft process, lignosulphonate process and organosolvolysis. In acid hydrolysis, the extracted pulp from the wood is refluxed under N_2 or Ar (argon) and HCl to solubilize the lignin (Fernández-Rodríguez et al. 2019; Gellerstedt et al. 1994). The solubilized lignin is free from contaminants with minimum impurities and makes this method better and rapid as compared to enzymatic hydrolysis. However, strong acidic environment results in structural changes in the lignin like the cleavage of aryl and alkyl ethers in benzyl alcohol moiety, alterations of molecular structure, which could be the possible drawbacks of this method.

The extraction of lignin through lignosulphonate process involves the treatment of wood at high temperatures with sodium sulphite (aqueous) under acidic conditions. The functional moieties, e.g. carboxylic, phenolic and –SH, allow their use as surfactants, additives, dispersants and flocculants (Aro and Fatehi 2017). Approximately, 1 million tons of lignosulphonates are produced every year as dry solids. Nowadays, kraft process is more preferred as compared to sulphite pulping because of its better product quality and fibre strength obtained in lignin extracts (Zhu et al. 2009).

Presently, the usage of volatile organic solvents (VOS) is growing to prevent environmental pollution and minimization of the greenhouse effect (Dos Santos et al. 2015; Mahmood et al. 2016). Also, ionic liquids are in trend for biomass treatment due to their low volatility as well as reusable behaviour. Lignin obtained by organosolvents like ethanol or alkaline NaOH is assisted with the combined treatment of ionic liquid 1-butyl-3-methylimidazolium methylsulphate [Bmim][$MeSO_4$] (Meng et al. 2012). Overall, when compared to lignosulphonates or kraft lignins, the alkaline and organosolvolignins are sulphur-free and most suitable for the synthesis of various value-added products (Zhang 2011).

3.3 Physical Methods

Various physical or mechanical methods like pyrolysis and heat steams are used in lignin isolation from wood. Pyrolysis is known to be a thermochemical process as it can convert 60–75% of the original biomass into crude oil (Garcia-Perez et al. 2007; Jiang et al. 2010). This crude oil of biomass can replace the petroleum-based fuels (Czernik and Bridgwater 2004). Pyrolysis is generally operated at relatively high heating rate, ambient temperature range and short residence time of gas in order to obtain more liquid products (Demirbaş 2001). There are only a few reports on

extracting pyrolytic lignin from bio-oils (Jiang et al. 2010; Scholze et al. 2001). It may be separated by adding water to precipitate lignin-derived hydrophobic components.

Another method for lignin extraction is steam-assisted process. In this process, wood is subjected to high temperature (200 °C) and quick release of pressure which ultimately liberates bundles of fibres. Nowadays, this process has gained more attention due to its low-cost ease of polymer separation. However, chances of homolytic cleavage reactions of lignin are higher due to the high temperature (200 °C) which could be the major drawbacks of this method. After condensation reaction, this method results in a highly heterogeneous lignin-containing discrete fragments as well as recombined bundles (Tian et al. 2017).

3.4 Miscellaneous Processes of Lignin Extraction and Conversion

Lignin content is isolated from plant tissues and purified cell wall regions. Cell breakage is mostly used technique for lignin isolation. These techniques enable to achieve pure cell wall material. FastPrep method for isolation of lignin helps to preserve its native structure which is free from proteins and other contaminants. This type of lignin is principally used for accurate determination of structure and sensitive assays of its functions (Chen et al. 2000). The major advantage of using FastPrep method is improved homogenization which accelerates the purification and product recovery and also making this process faster than other methods. Similarly, Saisu et al. (2003) conducted a study on conversion of lignin using supercritical H_2O and phenol. They evaluated that biomass of plants consists of cellulose (50 wt%), hemicellulose (20wt%) and lignin (30wt%). In a previous study, the gasification of lignin with a nickel catalyst in supercritical water was carried out at 673 K (Hagaman and Lee 1999). The conversion of lignin by hydrothermal reaction using alkali has also been used to convert lignin into chemicals/fuels. Hydrothermal degradation has also been reported to perform under subcritical or supercritical conditions for the improved production of phenolics (Peng et al. 2014).

4 Challenges in Lignin Conversion

Presently, the main challenge is to convert lignin into valuable chemicals by improving the overall economics of production to make it suitable for commercial scale. The development of competent methods for product separation, complexities in purification and minimizing the char formation are major challenges of lignin processing (Rößiger et al. 2018). Thus, the valourization of lignin is one of the most important challenges in the development of sustainable and economic biorefinery processes. However, the biological strategies for lignin valourization hold the stance

by overcoming the complexity of lignin in the improvement of bioprocesses. The polyalkylphenolic lignin molecule can be cleaved into low-molecular-weight products like phenols, alkylphenols and phenol resins using enzymes or chemical catalysts (Graglia et al. 2015; Zakzeski et al. 2010). These products are extremely efficient fuels, fuel additives (Li et al. 2015; Xu et al. 2014) antifungal components (Dos Santos et al. 2015) and can synthesize polyols or polyurethane resins (Mahmood et al. 2016). Till date, the highly stable intramolecular bonds in the lignin make its depolymerization as a difficult task. In addition to this, efficient technologies for the selectivity of defined products, downstreaming process, product recovery and their purification from the reaction cocktail are still the major subjects of concern related to lignin conversion.

5 Lignin-Derived Products of Industrial Importance

5.1 Lignin-Based Foams

Foam is generally formed by mixing suspension of lignin and carbohydrates which results in the formation of small particles, long fibres, sheets and fibreboards. A variety of foams have been developed from lignin such as polyurethane lignin foams (PUL foam), phenolic resin lignin foams (PRL foam), silicone–lignin foams (SiL foam), lignin–furan foams (LF foam) starch–lignin foams (SL foams), polystyrene-lignin foams (PS foams) and tannin–lignin foams (TL foam). These foams have immense applications in goods packaging and foundries' cushioning of utensils and machinery. PU foams are synthesized from isocyanate and polyol components of lignin-containing various free OH groups (Cateto et al. 2014; Obaid et al. 2016). The PU foams can be soft or hard types. The synthesis of hard or rigid PU foam was reported by Li and Ragauskas (2012). PRL foams are generally synthesized from phenol urea-formaldehyde resin, and these are widely used as insulating material (Ghorbani et al. 2017). SL foams have been prepared by moulding and compression of the lignin mixture and widely employed for the packing of goods and machinery (Obaid et al. 2016). Another important class of foam is lignin furan foam which can be synthesized from used spent liquor of pulp industry. The industrial liquor produced in magnesium bisulphite pulping reaction was precipitated using 30–40% of surfactant (Tondi and Pizzi 2009). Similarly, PS–lignin foams are the polymeric foams produced from styrene and lignin which have various applications in transportation industries for packaging.

Silicone–lignin foams are prepared by hydrosilanes and lignin polymerization as reported previously (Brook et al. 2011; Zhang et al. 2015). Tannin–lignin foams are well known for their high flame resistance and low chemical reactivity (Sánchez-Martín et al. 2013; Szczurek et al. 2014). The synthesis of TL foams was carried out by a mechanical frothing process as reported for PU foam preparation. Thus, all these lignin-based foams have high commercial value and numerous applications in day-to-day life.

5.2 Epoxy Resins from Lignins

The petroleum-based epoxy resins are synthesized using bisphenol A and epoxy resin in the presence of thiols, phenols or amines. The bisphenol A component is not environmentally friendly. Lignin is one of the biological components which can replace the bisphenol A and can be used to synthesize the epoxy resin with better stability and physicochemical properties (Delmas et al. 2013). To prepare the epoxy resins, the liquefied wood was subjected to glycidyl etherification using NaOH and epichlorohydrin under boiling conditions (Kishi and Fujita 2008; Kishi et al. 2006).

5.3 Lignin-Based Ethers

Ethers are fragrance and flavouring agents used in the cosmetics, food and confectionary industry. The ethers are usually produced by chemical reactions, but these can be synthesized from the lignin too. A polyoxyethylene is industrially important ether which can be synthesized from kraft lignin (KL) and polyethylene glycol (PEG). In a recent study, alkaline lignin derivatives were synthesized by etherification and epoxidation reactions. These can be used to increase enzymatic hydrolytic reaction in detergents and fermentation industry (Chen et al. 2016). In a previous study, the addition of hydrophilic and lipophilic groups in the lignin using dodecyl glycidyl ether in the presence of dimethyl benzylamine and followed by sulphonation using chlorosulphonic acid yields the ethers of commercial value.

5.4 Lignin-Based Esters

Esters are also one of the important organic compounds synthesized by the chemical reaction of acid and alcohol in the presence of catalyst such as alkali (NaOH). The esters of fatty acids are essential oils and many naturally occurring flavours. In the last decades, enzymatic synthesis of esters also becomes popular due to environmentally friendly biocatalytic reaction (Chandel et al. 2011; Sharma et al. 2017). The microbial lipolytic enzymes and esterases have also been reported to catalyse the conversion of fatty acid in the presence of alcohol into their respective esters (Kumar and Kanwar 2011, 2012; Kumar et al. 2013, 2015; Ramesh et al. 2014; Sharma et al. 2018). Zhao et al. (2017) have proposed the mechanism of esterification of lignin which involved the mechanical activation of solid-phase synthesis technology. In this reaction, sodium acetate and sulphuric acid were used as the catalyst. Generally, the esterification was carried out using acid chloride, acid anhydride, imidazole, pyridine or dimethylaminopyridine (DMAP) under controlled conditions (Nevárez et al. 2011; Thielemans and Wool 2005). In the literature, the esterification of hardwood and softwood was performed using various anhydrides. These conventional processes of

esterification are more time-consuming and laborious. Thus, with the advancement of technology, the rate of reaction and recovery of product can be enhanced using supercritical CO_2 and ionic liquid as solvent (Cachet et al. 2014). The rate of reaction can also be enhanced using microwaves and mixture of ionic liquids (Monteil-Rivera and Paquet 2015; Wang et al. 2018). In a recent study, the esters of *p*-coumaric acid and ferulic acid were obtained by esterification of lignin (Tana et al. 2019). Conclusively, the esterification of lignin can reduce the amount of waste product and improve the bio-economy of the process.

5.5 Lignin-Based Paints and Coatings

Lignin-based paints can be prepared by mixing the lignin liquor with paints and treatment with phenol oxidizing agents such as enzymes (Sena-Martins et al. 2008). The enzyme-treated mixture will be incubated to increase the viscosity of paint. The lignin has also been used to coat the fertilizers such as urea for its controlled release in the soil and increase its availability to the plants. Urea has been partly soluble in aqueous lignin dispersion, and the lignin layer results in fine coatings around the urea particles. Lignin has abroad range of molecular mass and various free functional groups which make it easier to modify with various polymeric materials to form insulation coating (Kai et al. 2016).

6 Conclusion

Despite various challenges in lignin valorisation and conversion into products of commercial value, it still holds the potential of alternative of various harsh chemicals and fossil fuels. Continuous efforts have been made by the researchers to scale up the lignin-based biorefineries and replace the chemical products by these biobased products. The question arises whether the lignin-based industries are sustainable and economical or not? How the formation of by-products such as char, phenols and alcohols can be controlled and materialized for mankind use? The presence of oxygen-rich contents in the lignin and its by-products hinders the easy implementation in industries. New strategies for the easy recovery of lignin with high purity level are the need of hour which should be scaled up for industrial usage.

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CHAPTER 2

Evolutionary Optimization Techniques as Effective Tools for Process Modelling in Food Processing

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1. Introduction

Most food processing firms are making persistent efforts to maximize their returns and minimize their process costs to compete in the existing market scenario. Consequently, these industries need to opt for advanced alternative technologies for improving, monitoring, optimizing and controlling process parameters like nutrients, moisture content, temperatures, etc. (Rodríguez-Fernández et al., 2007). Processing operations in these industries are conducted in a dynamic, unpredictable environment, subject to a large number of constraints, i.e., quality of the final product, financial, environmental, safety aspects, etc. Therefore, extracting an optimal solution from a large set of options for a food processing problem is an arduous task. Hence, a useful model-based optimization tool is essential to accomplish it. An exhaustive evaluation of the cons of the existing tools has been summarized below:

1.1 Limitations of mathematical optimization techniques

Specific characteristics of the food processing operations, like those mentioned below, make it difficult for application of mathematics-based optimization tools:

- Most of the processes are conducted in a batch or semi-batch mode. Hence, the models employed need to be dynamic, non-linear models with discrete events.
- Many process variables of these studies (temperature, pH, concentration, etc.), are more often spatially distributed and coupled with transport phenomena, thus making it difficult for mathematical models using only partial differential equations.
- Complicated nonlinear constraints issued from safety and quality aspects associated with food processing operations cannot be effectively represented in mathematical optimization models.
- Also, the food processes more often involve coupled time-dependent transport phenomena, making it even more difficult.

Thus, optimization of such processes requires an alternative physics-based model capable of being used in a systemic search approach in conjunction with explicit and implicit constraints.

1.2 Empirical equation-based models

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Operational barriers limit extensive use of statistical, empirical equation-based models (Garlapati and Roy, 2017; Chauhan and Garlapati, 2014; Sharma et al., 2016) for optimization in food process engineering operations. Most of the simulators consequentially developed using these tools trail the traditional path of employing low-level languages. These tools are both highly resource-consuming and error-prone, thereby making them non-applicable for plant-wide simulation.

1.3 Challenges in extensive utilization of tools and simulators in food industries

Modern-day simulators can increase productivity much more effectively in comparison to the traditional modelling approach. These high-level modeling systems are advantageous in terms of (i) better and ease of maintainability, (ii) flexibility in facilitating effective communication between co-workers and partners, (iii) ease in development, reusability, etc.

- In spite of their advantages, many of these models lack robust and efficient optimization solvers and, hence, preclude a more widespread use for optimization studies in the food industry.
- Another type of barrier arises from human-resources and knowledge issues:
  In most food processing industries, the managerial and technical human resources are often not familiar with these simulation and optimization tools. Even competent people with the relevant technological know-how are skeptical in applying these tools for food industries as these processing operations are incredibly complex.
- The food industries are need dynamic models that mimic their processes because, for a long time, there have been a lack of tailor-made modeling and optimization software tools. These may be like the tools developed by de Prada (2001) for the sugar industry.
- Most of the real-world problems of food processing operations have multiple, often competing for objectives as the raw materials involved are complex and of wide variations, making it difficult.
- Food processing operations more often encompass multiple suboptimal and equivalent solutions, thus posing a major challenge in developing an optimization model for them adequately.

Non-convex problems of these industries are solvable using conventional global optimization methodologies but, for issues of non-identifiability, the complexibility to be dealt with persists. Additionally, the desired process performances of these operations encompass variables and constraints that attribute to the economic impact on efficiency product quality and safety. A class of linear search algorithms, i.e., Evolutionary Algorithms (EAs), are seemingly vital tools for challenges that make things difficult in existing search and optimization situations. These algorithms have gained popularity in recent times because of their ease in the way of handling multiple objective problems, irrespective of the multi-objective optimization problems being constrained or unconstrained (Karaboga, 2004; Saputelli et al., 2004). Thus, evolutionary optimization tools may be successfully applied to these food processing industries.

2. Evolutionary Algorithms/Optimization Tools

These computational biological-inspired optimization algorithms, based on natural evolution and selection principles, are popularly used for solving non-differentiable, intermittent and multimodal optimization problems.

Salient aspects of EAs include

- They operate on a population of potential solutions and yield effective and improved results using evolutionary-like operations that work on the principle of survival of the fittest (selection, reproduction and mutation) (Ronen et al., 2002).

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- These optimization tools can generate Pareto optimal solutions for complex processes with many objective functions and constraints and, hence, can be used for optimization processes (Garlapati et al., 2017; Garlapati and Banerjee, 2013; Garlapati et al., 2011).
- Evolutionary algorithms (EAs) are the ultimate tool to overcome limitations (Price, 1999; Boillereaux et al., 2003; Mariani et al., 2008) of a situation lacking problem-solving technique because of multiple local minima due to unidentified process parameters.

EAs differ from the traditional methods in the following aspects

- These algorithms work with coded versions of the parameter set and do not operate with the parameters themselves directly.
- Optimal search is made from a population of points and not a single point.
- Objective functions are used, not derivatives or other ancillary information.
- Probabilistic transition rules are applied instead of deterministic rules.

3. Basic Operational Characteristics of Evolutionary Algorithms

An evolutionary algorithm is a biologically inspired, generic, population-based optimization algorithm. Its mechanism includes:

- **Reproduction/procreation:** The process of producing new "offspring" from their "parents".
- **Mutation:** Alteration in the order of the process being considered (e.g., organism, production or business process, code).
- **Recombination:** A process of exchange of information between two processes yielding a new combination of processes (e.g., operations in a workflow process).
- **Selection:** A method by which traits become either more or less common in a population as a function of the influence of traits concerning the intended goal (e.g., increased production efficiency in a production process). Selection is a key evolution mechanism. Probable solutions of the optimization problem for which an evolutionary algorithm is employed to arrive at, are viewed as entities in a population. A fitness function is used to assess its suitability as a solution. **A fitness function** is an objective function that is used to summarize how close a given solution is to fulfilling the optimization goals. All the stated operators are applied several times in the process and, hence, the term "evolutionary".

The evolutionary process thus involves

- **Generation** of the initial population (i.e., first-generation) of individuals randomly.
- **Evaluation of the fitness** of each entity of the population based on the optimization criteria given.
- **Repetition of the fitness evaluation** on this generation till its termination, wherein the termination criteria can be time limit, etc.
- **Selection of the best-fit individuals**, i.e., parents for subsequent reproduction.
- **Breeding of** new individuals through crossover (for bringing in variation from one generation to the other) and mutation (for varying the programming from one generation to the next) operations to yield offspring from the best fit individuals.
- **Evaluation of** the new individuals fitness.
- **Replacement of least-fit population** with new individuals.

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➢ This sequence of the evolutionary process is repeated until an individual fulfilling the fitness criteria within the given parameters is obtained.

4. Types of Evolutionary Algorithms

Evolutionary algorithms are robust global optimal solutions that help in overcoming the limitations of traditional methods. The various evolutionary optimization techniques available include: Genetic algorithm (GA), differential evolution (DE), particle swarm optimization (PSO), artificial neural networks (ANNs), fuzzy logic (FL), and ant colony optimization (ACO) (Bhattacharya et al., 2011; Adeyemo, 2011; Sarker and Ray, 2009; Kennedy and Eberhart, 1995).

4.1 Genetic Algorithm (GA)

GAs, as depicted in Fig. 1 below, are optimization algorithms that mimic natural evolution (Holland 1975, 1973; Mohebbi et al., 2008; Babu and Munawar, 2007). They have been employed to obtain near-optimum solutions for a large number of situations (Gen and Cheng, 1996). One limitation of GAs is the long processing time required for the near-optimum solution to evolve.

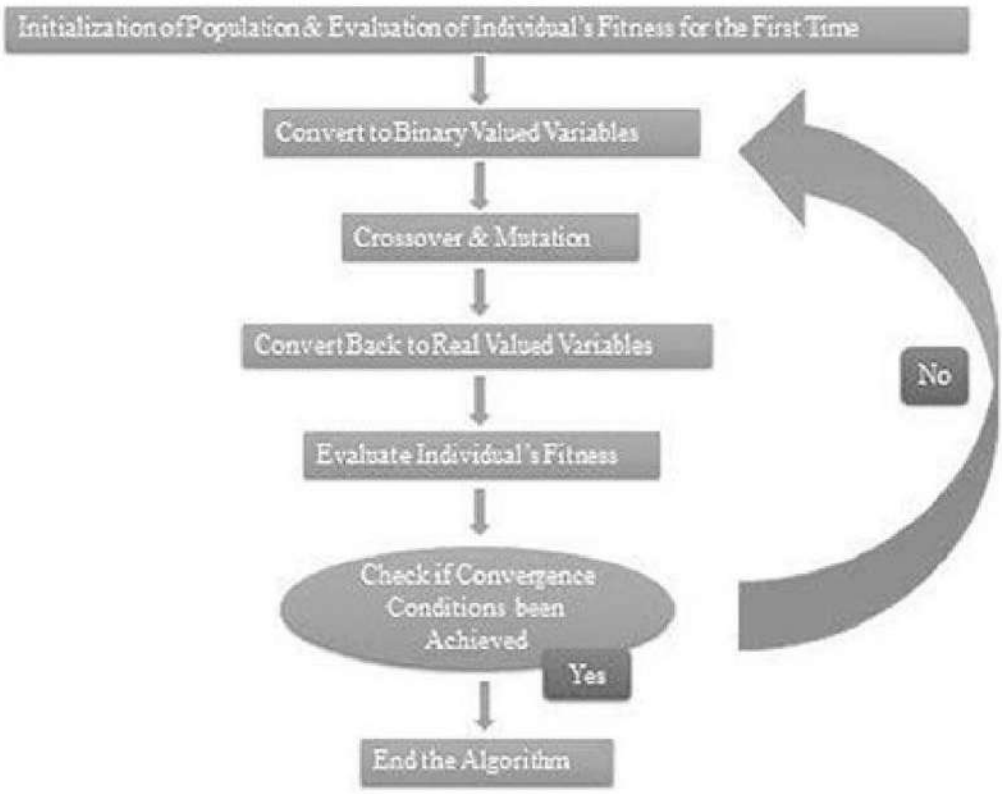

Figure 1: Flow chart of GA.

4.2 Differential Evolution (DE)

DE algorithm is a stochastic, population-based optimization method like GA; optimization functions with real variables and multiple local optima (Storn and Price, 1997; Pierreval et al., 2003) can be effectively optimized with this algorithm. A mutation is the primary search mechanism (Godfrey and Babu, 2004) for these search optimization tools. DE is self-adaptive (Karaboga, 2004). These algorithms have many advantages (Abbass et al., 2001; Strens and Moore, 2002). DE exhibits more convergence speed than genetic algorithms (Abbass et al., 2001; Strens and Moore, 2002; Karaboga, 2004). Its process flowchart has been depicted in Fig. 2 below.

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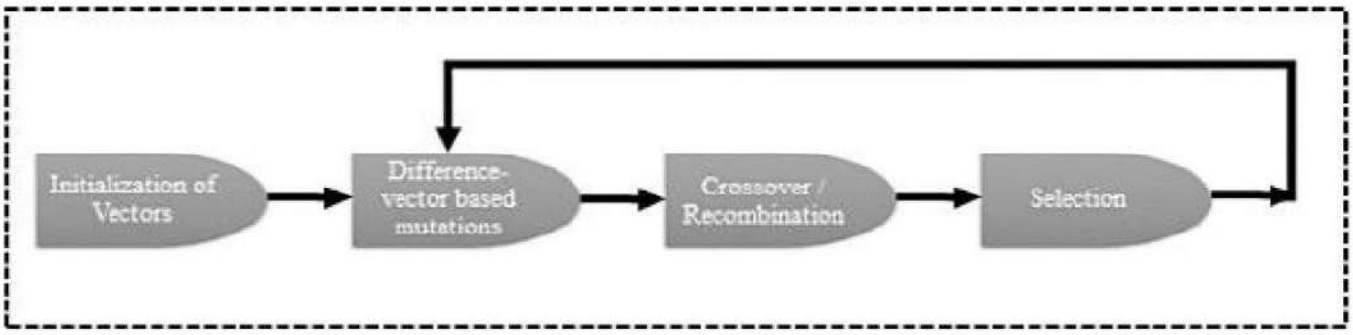

Figure 2: Sequence of events in DE.

4.3 Fuzzy Modeling (FM)

It is a robust method, encompassing scientific and heuristic modelling approaches. It mimics human control logic wherein they utilize the data and expert knowledge. Its input data may be an imprecise, descriptive language as a human operator (Huang et al., 2010). Fuzzy systems have been extensively applied to solve different problems. The present trend is towards enhancing their effectivity by employing soft-computing methods, such as fuzzy genetic systems.

4.4 Particle Swarm Optimization (PSO)

These are metaheuristic algorithms. PSO's mimic the social behavior of flocks of birds and schools of fish. Its process flowchart is depicted by Fig. 3.

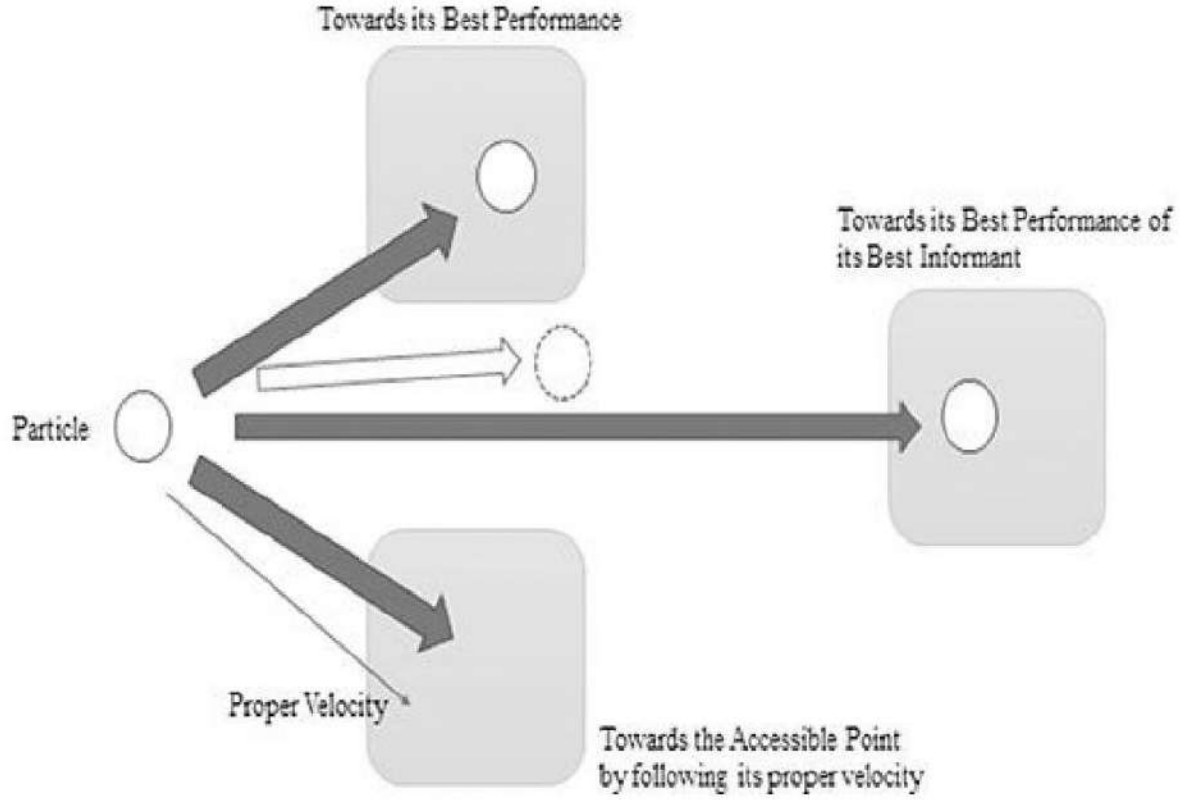

Figure 3: Process events in PSO.

5. Overview of Application of EA's in Food Processing Industries

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Food processing industries involve a large number of unit operations, each **governed by a series of dynamic conditions** that include mass, heat and momentum transfer operations. Likewise, **market-driven parameters**, like cost, demand and consumer acceptability factors and **the regulatory norms** on the quality parameters of the product, all **dictate the decision of fixing the operable strategy** for a product. Thus, modeling and optimization of these processes are highly challenging with the development of models governed by laws of mass, energy, etc., and capable of predicting the physicochemical, quality properties and safety aspects of the products. Kinetic models reflect the **change in relevant state variables** with time and position when the food sample is subjected to **different processing conditions** (Tijskens et al., 2001; Wang and Sun, 2003). The **Shelf life of products** impact, shortage and surplus of goods which in turn may impact income for the manufacturing units and, hence, this aspect also needs to be considered. Therefore, it may be summarized that optimization techniques are essential tools in food processing operations, used to enhance the economic values of processing and for the marketing of food.

Table 1: Comparative summary of evolutionary algorithms/optimization techniques.

Algorithm	Pros	Cons
Genetic algorithms	• Alter information (crossover or mutation) • Effective to solve continuous process issues	• Lack retention • Early convergence • Meager local search ability • Effective and impressive computational effort • Challenging to translate a problem in the form of a chromosome
Particle swarm optimization	• Possesses memory • Convenient for execution as it employs a simple operator • Promising to resolve continuous problems	• Early convergence • Poor local search ability
Ant colony optimization	• Retains the information • Yields good solutions rapidly • Effective in solving discrete and varied types of problems	• Untimely convergence • Ineffective local search ability • Yields changes in probability distribution with iterations • Ineffective in cracking the continuous problems

Currently, there lies a pressing need to ensure admirable product quality. Consequentially, the food industries are focusing more attention on improving their processing operations (e.g., Effective methods for drying, wetting, heating, cooling and freezing of foods are necessary (Doganis et al., 2006). Thus, it is becoming imperative to implement advanced optimization tools like EAs and the related techniques thereof, in the complex operations of modern food processing industries. EAs, like Differential evolution (DE) algorithms, have been successfully applied to solve several optimization problems of chemical and biological processes (Liu and Wang, 2010; Cheng and Ramaswamy, 2002; Chiou and Wang, 2001; Lu and Wang, 2001) while other similar EA tools have been used for the fuzzy-decision making problems of fuel ethanol production (Wang and Cheng, 1999), fermentation process (Wang and Cheng, 1999) and other engineering issues (Garlapati et al., 2010; Garlapati and Banerjee, 2010a,b; Babu, 2004, 2007; Angira and Babu, 2006; Babu and Angira, 2002; Babu and Jehan, 2003; Sarimveis and Bafas, 2003). These studies concluded that these techniques are less time consuming than the existing techniques and can adequately estimate the optimal parameters. Summarized below is the current status of application of these tools in various operations.

5.1 Role of EA's in food-based fermentation

Fermentative processes are dynamic and involve a large number of process variables (e.g., media parameters and

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process parameters like aeration rate, temperature, duration of incubation, etc.). These processes are governed by mass transfer, heat transfer principles, kinetic models and operational constraints. Traditional optimization techniques for resolving the multiple intended objectives of these operations are mostly non-lucrative. Evolutionary algorithms (EAs) are preferred alternative methods for monitoring the state variables of these dynamic fermentative operations (Soons et al., 2008). Artificial neural networks (ANNs) and genetic algorithm (GA) that mimic different aspects of biological information processing for data modelling and media optimization have proven to be effective for optimization problems of these sectors (Baishan et al., 2003). Impressive results have been obtained from ANN-GA for simultaneous maximization of biomass and conversion of product, e.g., pentafluoroacetophenon with *Synechococcus* PCC 7942 (Franco-Lara et al., 2006), and fermentative production of xylitol from *Candida mogii* (Desai et al., 2006; Baishan et al., 2003), exopolysaccharides production by *Lactobacillus plantarum* isolated from the fermented *Eleusine coracan*. In the latter application, Plackett Burman (PB) was applied to identify the three most influential media components, ANN for modeling the nonlinear relationship between the operating variables and the intended objectives, finally the ANN model was used as an input for the optimization through GA. The optimization of hydantoinase production from *Agrobacterium radiobacter*, lipase production from a mixed culture and glucansucrase production from *Leuconostoc dextranicum* NRRL B-1146 was performed with ANN–GA model using RSM-based data by Nagata and Chu, 2003; Haider et al., 2008; Singh et al., 2008, respectively. Kovarova-Kovar et al., 2000 demonstrated optimization using hybrid algorithms in the fed-batch process for riboflavin production. GAs with their multi-objective problem-solving capabilities have been applied in synthesis and optimization of non-ideal distillation systems (Fraga and Senos, 1996), computer-aided molecular design (Shunmugam et al., 2000), optimal design of xylitol synthesis reactor (Baishan et al., 2003), estimation of parameters in trickle bed reactors (González-Sáiz et al., 2008), on-line optimization of culture temperature for yeast fermentation (Yüzgeç et al., 2009) and optimal ethanol production (Guo et al., 2010; Rivera et al., 2006).

5.2 Evolutionary optimization for extrusion-based processes

RSM integrated GA-based optimization was reported to be effective in predicting the optimal process conditions with the intended quality of an extruded fish product. The conditions yielded a product with more desirable features than those obtained by specific condition optimization. Process variables taken for consideration included: Screw speed, feed moisture content, expansion ratio, water solubility index, barrel temperature, bulk density, hardness, and fish contents for single-screw extrusion cooking of a fish and rice flour blend (Shankar and Bandyopadhyay, 2004).

5.3 EA's application in the dairy industry

Preparation of different types of milk powder, i.e., whole milk powder, spray dried milk powder, skimmed milk powder, etc., in the dairy industry involves operations with multi-process parameters affecting the final product quality. Independent parameters required may include screw speed, process temperature, milk powder feed rate to the drier, addition rate of additive, etc. (Koc et al., 2007). The depended parameters include free fat content, lactose crystallinity, particle size and colour, while the constraint was desired power consumption. The intended multi-objectives include maximization of free fat content, the crystallinity of lactose and minimization of particle size (Koe et al., 2007). Fuzzy logic was also used in the real-time control of a spray–drying of whole milk powder processing. The algorithm used controlled the process at the desired power consumption and yielded entire milk products with the desired attributes (Queiroz and Nebra, 2001).

5.4 Application of EA's in oil processing

Neural network-based genetic algorithm optimization tools have been employed for multi-objective estimations during oil processing. Experimental data from vegetable oil hydrogenation process plant was used to develop the

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model and the intended objectives included minimization of isomer and maximization of cis –oleic acid (Izadifar and Jahromi, 2007).

5.5 EA tools for food product quality evaluation

Quality parameters of the final food product play an important role in the consumer acceptability and approval by the food safety standard norms. Quality parameters may vary for the type of food products and the processing conditions also affect these parameters. Artificial neural networks have been applied in predicting the selected intended quality parameters with variations in process conditions during different unit operations for varied types of food products, e.g., extruded products (Linko et al., 1992), rheological dough properties in bakery operations (Ruan et al., 1997), meat quality (Yan et al., 1998), bakery products (Cho and Kim, 1998) and post-harvest processed products (Morimoto et al., 1997a,b). The impact of thawing conditions on Thermal properties of gelatin was determined using artificial neural networks (Boillereaux et al., 2003). Mittal and Zhang, 2000 developed a feed-forward neural network to predict the freezing and thawing time of food products with simple regular shapes. The results demonstrated that the developed ANN-GA-based models were useful for the estimation of parameters that were usually considered for foods of varied structural, morphological configurations and compositions.

5.6 Utilization of evolutionary optimization tools in drying operations

Performance of a drying process in the food industry is assessed from improvement in manufacturing quality and reduction in energy consumption. Optimization techniques, when applied to drying operations, are intended for reduction of drying time and occasionally the process cost. Nonlinear predictive control genetic algorithm and the like have been developed and reported (Yüzgeç et al., 2006, 2009; Na et al., 2002; Potocnik and Grabec, 2002; Mankar et al., 2002; Quirijns et al., 2000). The intended objective was final product quality enhancement, minimal energy consumption during drying and reduced process cost by developing a control procedure for the drying process.

In recent times, ANNs have been receiving more considerable attention in modelling the drying operations (Chen et al., 2000; Kaminski et al., 1998; Sreekanth et al., 1998), food rheology (Ruan et al., 1995) and thermal processing (Sablani et al., 1997a,b). Structural identifiability analysis of model methods for improvement in the efficacy and robustness of the model parameter has been proposed and demonstrated in many reports (Rodríguez-Fernández et al., 2007; Movagharnejad and Nikzad, 2007). ANN model was reported to be more accurate than empirical correlations in describing the drying behavior of tomato.

The optimization of multiproduct batch plants design issues for protein production using fuzzy multiobjective algorithm concepts was demonstrated by Dietz et al., 2008. The model developed provided an up-and-coming framework that could take imprecision into account during the new product development stage and finally in making the decision. Kiranoudis and Markatos, 2000 considered the multi-objective design of food dryers using a static mathematical model for simultaneous minimization of economic measure and the colour deviation of the final product.

6. Case Study of EA in Thermal Processing Operation

Thermal processing is an active food preservation strategy, for inactivation of microbial spores that are a public health concern or of microbial species responsible for spoilage of foods in containers. These operations are conducted at temperatures well above the ambient boiling point of water. For these purposes, pressurized steam retorts/autoclaves are operated at conditions not detrimental to food quality (Simpson et al., 2003; Holdsworth and Simpson, 2007; Abakarov et al., 2009). For obtaining the extended shelf life of products and their intended safety, cost-efficient treatments are widely preferred in industries. The imperatives, like health value, drive these thermal treatment operations and the economic aspects of sustainable food supply, they also minimize food-borne illness and food waste and retain or enhance nutritive quality to ensure affordability. Thermal treatments are mostly

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capable of catering to the imperatives mentioned above. There is an increasing concern regarding the harmful effects of these thermal treatments, i.e., compromised nutritive quality, deteriorating effects on essential nutrients and unique bioactive phytochemicals.

6.1 Basic objective

Thermal treatment optimization is a **dynamic process** where the **intended objective** is to determine the **optimal heating temperature-time combination** that effectively **maximizes the final nutrient retention** of a per packaged conduction heated food. The operable **constraint** involved is that the heating temperature should be effective **to impart microbiological lethality**.

Thus, there are two contradictory demands: To obtain the **desired minimum lethality**, all the sections of the food must be subjected to a high enough temperature for sufficient duration. However, the same exposure is likely to destroy nutrients; therefore, it is desired to **minimize that undesirable effect**.

6.2 Challenges

- Thermal destruction of microbes is conventionally proven to follow a first-order semi-logarithmic rate. Consequentially, it is not likely that, theoretically, a sterile product can't be produced with certainty even after exposure of the food product for long process time.
- If the intended product is to be rendered utterly void of microorganisms, then the thermal treatment is likely to yield a product which is unwholesome or inferior in quality. Thus, commercial sterility or shelf stability of the products is the most preferred or sought-after objective by the processing authorities of industries.
- Thermal destruction issue is dynamic and, hence, it implicates dynamic optimization techniques to determine optimal operating policies. The EA techniques are more effective than the traditional (constant temperature) processes. The optimal strategies can enhance the quality of the final product, and/or reduce the processing time to yield the desired quality level. Reduced-order models have generated cost-effective simulations (Banga et al., 2003). With these "accelerated" models, the dynamic optimization issue can be performed in just a few seconds. Since EA tools are capable of minimizing the complexity of a process model which seems promising for food process operations with a new avenue for real-time optimization and control.
- Treatments engaged in thermal destruction of microbes encompass a multi-objective optimization problem where the reduction of total process time and significant retention of several nutrients and quality factors need to be deliberated simultaneously (Fryer and Robbins, 2005). To this effect, Sendín et al., 2006, 2010 proposed and applied a novel multicriteria optimization method to the thermal processing of foods.

6.3 Background and principle

Designing an effective thermal processing strategy makes it imperative to have an extensive understanding of process methods, the heating behavior of the product and its impact on a target microorganism. Thus, the dependable factors for gauging the severity of any thermal process must be known and they include:

- **The physical characteristics of the food product**.
- **The type and thermal resistance of the target microorganisms**.
- **The changes in intrinsic properties of the food which affect the survival of microbes in thermal processes**.

6.4 Basic design premise and concerns of thermal processes

For design optimization studies, the user should be reminiscent of the following:

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- The **heat resistance of microorganisms** for each specific product formulation and composition. Thermal inactivation kinetics of microorganisms is essential and may be obtained from a survivor curve, i.e., a logarithmic plot of the number of microorganisms surviving a given heat treatment at a given temperature against the heating time. Thermal inactivation generally follows a first-order reaction. Two key parameters (D and z values) are then determined by the survivor and resistance curves, respectively.
- **The heating rate of the specific product:** This is essential for mathematical modeling of experimental data, which aids in understanding the impact of process parameters, on relevant pathogens. The effective heating rate of the product is accomplished from a detailed analysis of product and system parameters affecting the heating behavior of the product.
- **The conditions for which such models apply** and
- Their **limitations** since food matrices are complex and can influence microbial resistances in different ways.

Design concerns include

- Simple, Robust, flexible models operable for process deviation analysis and ensuring appropriate levels of public safety are becoming popular. A single "fit-all-data" model is not effective for explaining or describing the complex behavior of microbes when subjected to external agents (such as temperature, salt, pH, etc.), and their interactions.
- Varied time-temperature combinations, processing methods, systems or techniques may yield the desired lethality. However, these variations are also likely to impact the quality of the end product to different extents. Therefore, minimal changes to the desired sensory and organoleptic attributes of food products are always intended through process optimization routines and thereby determine system appropriateness using kinetic data for the most heat-sensitive nutrient.
- The time-temperature history of a product undergoing thermal treatment will depend on several factors that include but are not limited to: (i) the processing system (conventional, static or agitating retorts, etc.), (ii) the heating medium (steam, water immersion, etc.), (iii) product characteristics including consistency, solid/liquid ratio, and thermophysical properties, (iv) product initial and heating medium temperatures, and (v) container type, shape and size.

6.5 Guidelines for applying evolutionary algorithms for thermal process optimization studies

Step 1: Identification of process parameters affecting the process under consideration.

Step 2: Collection of data from experiments conducted based on chosen Design of experiments (DOE). Selection of DOE is from amongst Plackett Burman, Factorial designs, Central composite design, etc., to have representations from the significant combinations of the process parameters (Kumari et al., 2013; Chauhan et al., 2013; Mahapatra et al., 2009).

Step 3: Developing the thermal process schedule, i.e., model development using the experimental data from the heat penetration and kinetic data (z and Freq values) by the conventional methods. Formula methods have been currently developed and employed to impart flexibility to establish times to achieve the desired cumulative lethality. Incidentally, these formula methods have limited implementation in optimization studies and automatic control systems as they are incapable of defining dynamic functions during the entire processing. Artificial neural networks (ANN) are effective to computerize mathematical aspects of thermal process calculations. These models mitigate the need for a large storage space while computerizing.

Step 4: Application of optimization tool to the developed model.

The main factors/selected objective functions taken into consideration during the optimization of thermal

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processing include **final product quality and safety, consumption of energy** and **total processing time**. The diversity of the sighted processing objectives imposes different optimal conditions to sterilization/thermal processing. Hence, an algorithm capable of considering various objective functions is preferred for the determination of the optimal thermal processing of food. These software packages are intended to ascertain the optimum variable temperature profiles concerning the intended objective functions, geometric options and constraints chosen by the processor/user. The packages should facilitate/automate **the calculation of heat transfer coefficient** for irregular or regular geometries, various shapes and heating conditions, **predict moisture loss, shrinkage, yield loss, internal temperatures** and **lethality for different sizes of product**. These capabilities would make them a useful tool in taking processing decisions. These algorithm packages should be proficient at simulating food safety by combining a physics-based model of food processes, with the microbial kinetics and chemical transformations to provide a microbial count and/or nutrient and/or undesired chemicals amounts at any time and in any location in the food during processing.

Step 5: Mathematical formulation of the Problem statement for thermal sterilization of foods.

In canning operations, the problems mentioned below may be addressed using modeling and optimization techniques:

- Estimation of a retort function, where the final quality retention or surface quality retention is maximized, while the final process lethality is held to a specified minimum.
- Determination of a retort function, such that the final process time is minimized subject to the same lethality requirement, while the quality retention does not fall beneath some specified minimum.
- Fixation of a retort function, where the cooked value is minimized, while the final process lethality is held to a specified minimum.
- Fixation of a retort function, such that the final process time is minimized subject to the same lethality requirement, while the quality retention is not below some specified minimum, and the energy consumption is not above a specified maximum; minimum and maximum values are computed at constant retort temperature profiles.
- The thermal process optimization problem is, thus, posed as a multi-objective optimization problem.

In each of these cases:

- **The lethality constraint** is specified as: (i)

$$F0(t)=\int 0tf10T-Teffzfdt$$

where $F_{0(t)}$ is the final required lethality which is calculated using: $\int 0tf10T-Teffzfdt$
where T is the temperature at the critical point or cold spot, normally the geometric center of the container (in the case of conduction-heated canned foods), Teff is the reference temperature and Zf the thermal resistance of the microorganisms.

- **The quality retention constraint** is specified as:

$$Cav(tf)=1Vt\int 0Vtexp[\ -ln10Drefc\int 0tf10T-TreffZcdt\ ]dVt$$

where Cv is the desired volume-average final quality retention value and is calculated using the equation given above, where Treff is the reference temperature, z c and D are kinetics of the degradation of nutrients.

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- **The surface retention is given by**

$$S(tf)=\exp[\ -\ln 10 Dfefs\int 0tf 10T-TrefsZsdt\ ]$$

where Trefs is the reference temperature, z and D are kinetics of the degradation of nutrients, and the surface retention constraint can be specified as S(t), which is the desired final surface retention value.

- Also, a common relationship for estimating quality losses is the "Cook or Cvalue", which is calculated using …… $C(tf)=\int 0tfT-TrefvZqdt$

where z and Trefv represent the z-value and reference temperature for the most heat-labile component. The z-value for cooking degradation within the given range corresponds to sensory attributes, texture softening, and color changes. The z-value of 33.1ºC and Tref equal to 100ºC are often used to compute a cook value to describe the overall quality loss. The cook value constraint is specified as Cd, where Cd is the desired minimum final cook value.

These expressions are standard model equations and, for consideration of new process parameters, model equations may be obtained using regression analysis or artificial neural network algorithms. The obtained models are then subjected to numerous iterations within the set range of the individual parameters and subject to the constraint of the individual problem statements to attain the set levels of the objective functions. The iterations are performed using evolutionary optimization techniques until the deviations between the set and predicted values are minimal enough to achieve the optimal conditions, which are further validated by performing the processes at those conditions.

7. Advantages of EA's

Evolutionary computation techniques only require an evaluation of the objective function and not an exhaustive mathematical requirement on the optimization problem. There are zero order methods capable of handling nonlinear problems and dependent on discrete, mixed or continuous spaces, irrespective of whether they are unconstrained or constrained using operators that are global in scope.

- Evolutionary algorithms are a potential source of breakthroughs for most of the food industrial engineering processes that include challenging, unstructured, real-life problems to be modeled as they include unfamiliar factors ranging from risk factors to aesthetics. They have the potential to provide many near-optimal solutions at the end of an optimization run which facilitates selection of the best solution later, based on criteria that were either incoherent from the expert or poorly modeled. The efficiency of EA's can be enhanced because of their flexibility and comparative ease of being hybridized with domain-dependent heuristics.
- These optimizers are global optimization methods that can be scaled up to higher-dimensional problems. EAs are robust concerning noisy evaluation functions, and can effectively handle evaluation functions which do not yield a sensible result in a given period.
- The algorithms are incredibly flexible and, hence, can be moderated, changed and customized to fit the problem at hand. They are applicable in many complex problem-solving applications, unlike classical search and optimization techniques.
- EAs are inspired by natural evolution and, hence, conceptually flexible and straightforward.
- EAs use prior information and, thus, outperform the methods which utilize the prior information minimally and with restricted search space.
- EA is representation independent, i.e., applies to constrained or unconstrained sets and to sets whether discrete or continuous, unlike most of the numeric techniques.
- Evaluation in Evolutionary optimization processes is performed as a parallel operation and only operations

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of the selection process are serially processed.

- Evolutionary algorithms that develop adaptability to yield a solution in changing environment are robust, unlike the traditional optimization tools which vary according to variations in the surrounding environment.
- EAs are capable of solving problems without any human intervention, hence, handy tools. However, these tools do not perform satisfactorily for automating problem-solving routines.

8. Disadvantages of EA's

- Evolutionary algorithms do not always assure an optimal solution to a definite problem within the anticipated time. There lies a great need for tuning of parameters by trial-and-error, thereby necessitating lots of computational resources.
- The performance of evolutionary search methods in the optimization of food engineering problems is highly impacted as the majority of these are constrained problems.
- The confirmatory conclusion of the best suited evolutionary algorithm for a given problem remains unanswered. The standard values provide good performance, but, interestingly, a variation in configurations tends to yield better results. The adverse configuration may lead to premature convergence, generating local optima and not the global optima.

9. Conclusion

This chapter provides an overview of the use of computational-based optimization algorithms in major real-world applications, intending to find global optimum solutions for food processing industry issues. Multi-objective optimization problems of modern food processing operations, whether constrained or unconstrained, have been resolved using new hybrid optimizers. Process treatments affect product quality, safety and marketing. Hence, the use of new techniques for the optimization of food treatment processes becomes vital. Consequentially, basic research on the modeling, simulation, designing and evaluation of parameters affecting different food processes is vital. It is suggestive that EA's are likely to have a positive impact on solving real-world issues/challenges in the food processing industries shortly. Also, it is noteworthy that, though these EA's are extensively applicable in many areas, these too come with marginal success in performance. Hence, the current efforts are focused on the application of some parallel algorithms along with Evolutionary Algorithms, that is, to hybridize two or more algorithms or to improve the existing algorithms.

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Mathematical and Statistical Applications in Food Engineering

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CHAPTER 1

Role of Mathematical and Statistical Modelling in Food Engineering

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1. Importance of Mathematical Modelling in Food Engineering

The food engineering domain is considered to be a complex process due to the presence of various scalable throughputs, rheological properties of food molecules, different processes and environmental parameters, quality and stability concerns. Moreover, the influencing parameters impact the other parameters through the mutual dependencies. The complexity also lies in the raw and processed food commodities in the form of variability, which impacts the composition and their processability in further operations. Various food engineering problems, such as heat and mass transfer operations, are heterogeneous and variable. Therefore, it is not possible to handle them with only basic disciplines, such as mathematics, physics and science (Barnabé et al., 2018).

The heterogeneity and variability encountered in the food engineering domain can be made manageable by utilizing the modelling approaches which put forth the non-linear relationship of the different process parameters on the performance of the process or on the final yield of the food product (Shenoy et al., 2015). Mathematical modelling plays a vital role in understanding the food process related to thermal (heat and mass transfer) and non-thermal processes (high-pressure processing, pulsed electric field) and in assessing the possible microbial and biochemical changes during the shelf-life of the food products (Farid, 2010). The modelling approaches also tackle the scale-up associated problem and are useful in simulations, since they take care of impossible process parameters, such as high temperatures (Dutta, 2016).

The machine-learning/simulation-based optimization approaches help in attaining/predicting the optimum output by considering the individual, square and interaction parameters of the process. The machine-learning based optimization approaches produce a huge set of data for processing with the intuitive knowledge of the nature-based phenomenon. Moreover, the modelling and optimization approach also helps in attaining a deductive conclusion with a smaller set of experiments with the positive expert-knowledge based methodologies (Perrot et al., 2016). Computational Fluid Mechanics (CFM) also play an essential role in the food engineering domain, with various applications in process operations, such as drying, freezing, cooking, sterilization and baking, by providing food engineers with new insights into the probable performance of the equipment during the time-course of quality or safety (Dutta, 2016). Artificial Neural Networks (ANN) are also one of the machine learning tools with the potential for use in the food industry to tackle the food characteristics and understand the structure-process interaction during the production step of food products (Huang et al., 2007).

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2. Experiment Design and Data Analysis

The most important step in food engineering is the experiment design. In all the related work, such as enzyme production and other food related products, there is a need to design the experiment before beginning in the laboratory or at pilot scale. All of the dependent and independent variables need to be defined before the experiment, and based on the optimization methods, an accurate mathematical method should be chosen. Figure 1 explains the various basic terminologies used in experiment design.

Figure 2 shows the three basic principles used for the design of experiment (DOE). The three basic principles for DOE are 'replication', 'randomization' and 'control of experimental error'.

Using randomization eliminates the systematic bias and aids in the distribution of all the designed experiments. In order to make a completely randomized design (CRD), the entire experiment must be divided into a number of experimental units, say x. In this design, the total number of replications for different treatments are fixed in advance. The replication procedure helps in repeating the experiment at the centre stage and it also estimates the experimental error. The experiments are repeated twice or thrice and mean values are also estimated. The control of experimental error will in turn increase the efficiency. If the sample size is large, the CRD experiments are not homogenous and there are n treatments to be compared, then it may be possible to: # Blocks are build and this procedure is called as randomized block design (RBD). The experimental material is divided into rows and columns in the Latin square method (LSD). In the LSD, each experiment occurred only once in the each row and column.

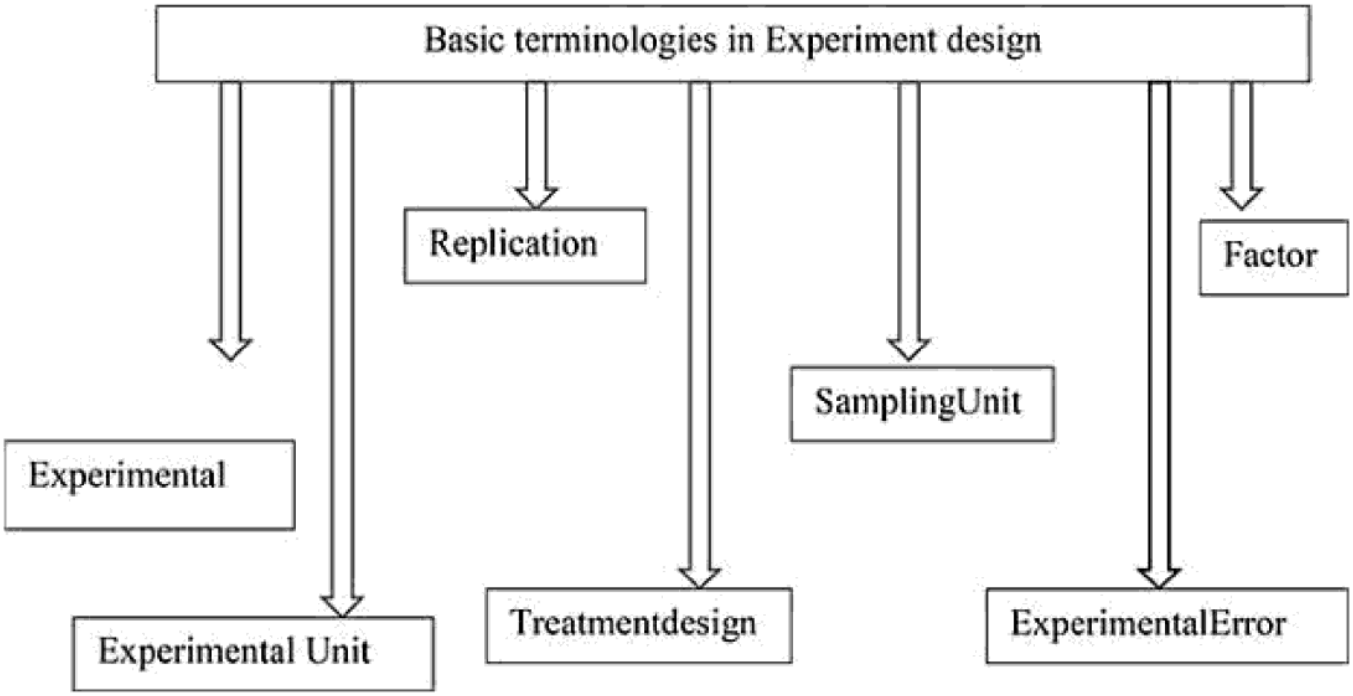

Figure 1: Shows all the basic terminologies in the experiment design.

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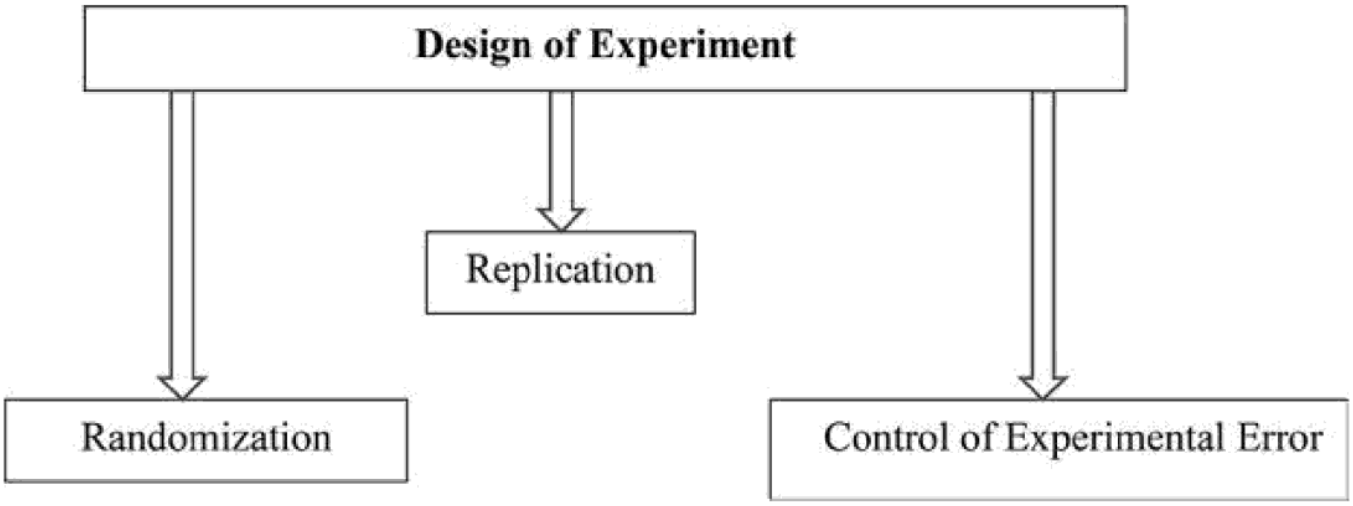

Figure 2: Shows the basic principles used for the design of experiment.

3. Typical Problems in Application of Mathematical Modelling in Food Engineering

The typical problems encountered while using the modelling and optimization approaches in a food engineering discipline are mainly due to the usage of low-level manual-coded languages, such as FORTRAN or C, for implementation. This is highly resource-consuming and error-prone. Furthermore, it is impossible to utilize the approaches to plant-wide simulation by taking care of multiple interacting units. The FORTRAN or C-based modelling approaches also lack robustness and efficiency in dealing with the multitask problems associated with the food engineering domain (Banga et al., 2003).

Despite the well-proven modelling and optimization approaches in the food industry for the typical processes, the utilization of the adopted approaches for other food engineering operations is limited due to the following factors:

- The developed food process model's applicability is not straightforward (Bimbenet et al., 2007).
- Uncertainties encountered due to the raw material properties, process parameters and unreliability associated with the process conditions (Ioannou et al., 2006).
- The developed process models are applicable to tiny sectors of the food engineering domain (Perrot et al., 2006).
- The proposed process models are not able to integrate with the other developed models (Bimbenet et al., 2007).

Moreover, due to the dynamic nature of food processes, the developed food process models are very complicated in terms of the structural understanding, nature of simulation and optimized control. The complexity will be greater while developing a process model and taking care of relationships between composition, structure, properties, quality and shelf-life of the food, resulting in a very challenging task (Fito et al., 2007).

4. Conclusion

Mathematical/statistical modelling facilitates a real understanding of the non-linear problems associated with food engineering operations with the aid of statistical heuristics and helps in the development of validated non-linear regression models. This approach helps in attaining the process optimization with well-planned and less experimental DOE. The developed mathematical models help in straightforward extrapolation towards the scale-

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up studies. In conclusion, there is a need for the industry and academia to work together in order to further the progression in modelling approaches by handling the typical problems encountered in the execution of modelling approaches in food engineering.

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Predictive Analysis of Absenteeism in MNCS Using Machine Learning Algorithm



Krittika Tewari, Shriya Vandita and Shruti Jain

Abstract Absenteeism has become a severe problem for many organizations. The problem posed in this paper was to build a predictive model to predict the absenteeism for MNCs by previously recorded data sets. This exercise not only leads to prevent or lower absenteeism but forecast future workforce requirements and suggests ways to meet those demands. For faster processing of massive data set, the data was analyzed efficiently so that we get the minimum response time and turn-around time, which is only possible when we use the right set of algorithms and by hard wiring of the program. Different machine learning algorithms are used in the paper that includes linear regression and support vector regression. By analyzing the results of each technique, we come across that the age parameter mainly affects the absenteeism that is linearly related to absenteeism.

Keywords Absenteeism · Machine learning · Linear regression · Support vector regression

1 Introduction

Absenteeism is a vital issue that requires immediate attention by both, the employee and the employer. If the employee enjoys the work they do, then they will not take leave. The employers are expected to keep their employees in good spirit and motivated so that the employees deliver their best to the organization for the benefit of both. It is a habitual pattern of the absence from duty. Absenteeism not only affects the cost but is also an indicator of the poor morale of the employees. Absenteeism can be a result of depression, personal stress, and anxiety which can lead to an employee being detached and unable to cope up with the work and interaction at workplace, burnout, heavy workloads, stressful meetings/presentations, bullying at workplace,

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childcare, illness, and unequal treatment that leads to heart burning and feelings of being unappreciated (non-recognition of his/her contribution). Absenteeism has become a severe problem for many organizations. Obviously, it has been an undeniable issue faced by companies which can result in serious financial and non-financial losses [1]. Because of the negative consequences of employee absenteeism, it is important that the organization keep the absenteeism low [2]. The following may be adopted by the organization to check or reduce absenteeism:

1. Adopting a clear attendance policy.
2. Providing healthy and safe working environment to the employees.
3. Encouraging the employees by visiting the workplace during working hours by the higher management.
4. Celebrating the success of any project as a team.
5. Providing some reward to the employee for excess extra paid time off.
6. Maintaining a flexible work schedule if an employee comes late, he/she may be allowed but should be asked to put extra working hours in the week to compensate.

Employees can cope with stress much better when they are given some autonomy for self-governance, social support, and opportunities for personal growth. It has been seen that the rate of absenteeism does not follow a normal distribution, but it is skewed and truncated distribution that denies the beliefs of conventional statistical methods such as correlation analysis and ordinary least square (OLS) regression [3]. It has been seen that correlation and multiple regression dominate absence research. Managers and organizational practitioners need a detailed method for measuring absenteeism loss as well as other measures needed for managerial evaluation to decrease absenteeism rate and compare the effectiveness of absence/attendance policy from period to period. Since the 1980 s, the companies have collected abundant amount of customer data stored in databases [1]. The data is collected by the companies and the thought process on how to provide additional benefits or to improve the operations. This type of thought process formed a natural progression toward the use of improving estimates, forecasts, decisions, and efficiency [2]. These databases grew to such a large extent that it becomes difficult for humans to analyze on their own. Predictive analytics is an answer on how to handle such large databases. It is a procedure that incorporates the use of computational methods to determine important and useful patterns in large data. It was conceived from the study of related areas like artificial intelligence, statistics, machine learning, pattern recognition, and data mining [2].

We can use either supervised learning based models or unsupervised learning models for prediction. The basic idea behind supervised learning based models is to predict a target variable. Supervised learning is also referred to as predictive modeling. Classification is a popular predictive modeling algorithm while dealing with categorical variable [4–8]. Another type of supervised learning is regression where we predict continuous outcomes [9, 10]. This procedure determines the computational methods and incorporates the patterns in large data. In descriptive modeling or unsupervised learning based approaches, a model is always constructed through clusters of the data [11].

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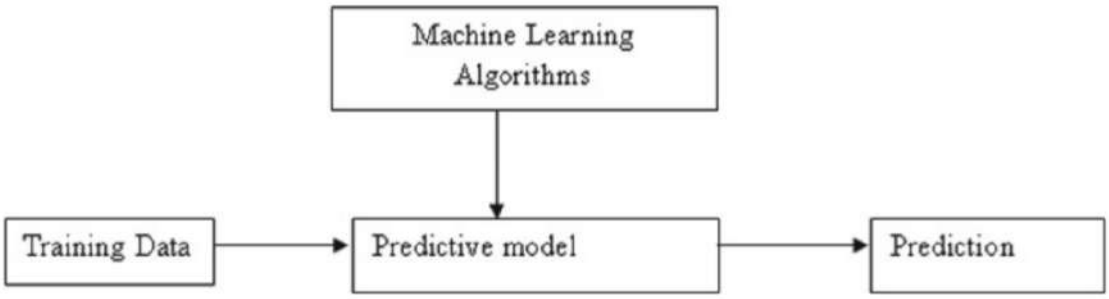

Fig. 1 Steps using machine learning algorithm

Authors in [12] explain machine learning is a scientific discipline which focuses on automatically recognizing complex patterns and making intelligent decisions based on available data. This branch of study evolves behavior that helps in developing an algorithm for the computer. Figure 1 signifies the typical machine learning algorithm [11, 12]. Machine learning focuses on the development of computer programs that can change when exposed to new data. It is the process of converting experience into expertise or knowledge [12]. There are different machine learning algorithm which includes linear regression, decision tree, logistic regression, Naïve Bayes, support vector machine (SVM), k-nearest neighbor (kNN), and random forest.

Predictive model is made to train data that helps in analyzing the parameters which affect the absenteeism in MNCs and how to reduce that absenteeism. Data is collected from online source which is preprocessed by removing outliers. Feature engineering is applied to the data. There are various parameters which affect the absenteeism. Using feature selection, best features were selected and different machine learning algorithms like linear regression and support vector regression are applied.

In this paper, Sect. 2 defines the predictive analysis using machine learning algorithm; Sect. 3 explains the different implementation steps which were concluded at the end of the paper.

2 Predictive Analysis Using Machine Learning Algorithm

Predictive analysis is used to predict unknown events or unobserved events by analyzing the existing data set with the help of machine learning techniques, statistical modeling, and data mining. For predictive analysis, objectives are defined, and then, the data set is prepared. Based upon the prepared data, a model is laid down for deployment and monitoring. Predictive analysis identifies the cause–effect relationship across the variables from the given data set and discovers hidden patterns with the help of data mining techniques. It may apply to the observed patterns to unknowns in the past, present, or the future. The predictive models have a clear focus on what they want to learn and how they want to learn. The models which are used for the prediction of target features of categorical values are known as classification models [4–7]. Predictive models may also be used to predict numerical values of the target feature based on the predictor features. The models which are used for the prediction of the numerical values of the target feature of a data instance are known as

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regression models. There are different types of regression models (linear, logistic, support vector regression). Mainly, they are categorized as linear and nonlinear. In linear regression model, the dependence of the response on the regressors is defined by a linear function, which makes their statistical analysis mathematically tractable. On the other hand, in nonlinear regression model, this dependence is defined by a nonlinear function, hence, the mathematical difficulty in their analysis.

In this paper, we are working on linear regression and support vector regression (SVR).

2.1 Linear Regression

For linear regression, dependent variable (y) is continuous and independent variable (x) may be continuous or discrete. Figure 2 shows the algorithm illustrating the linear regression.

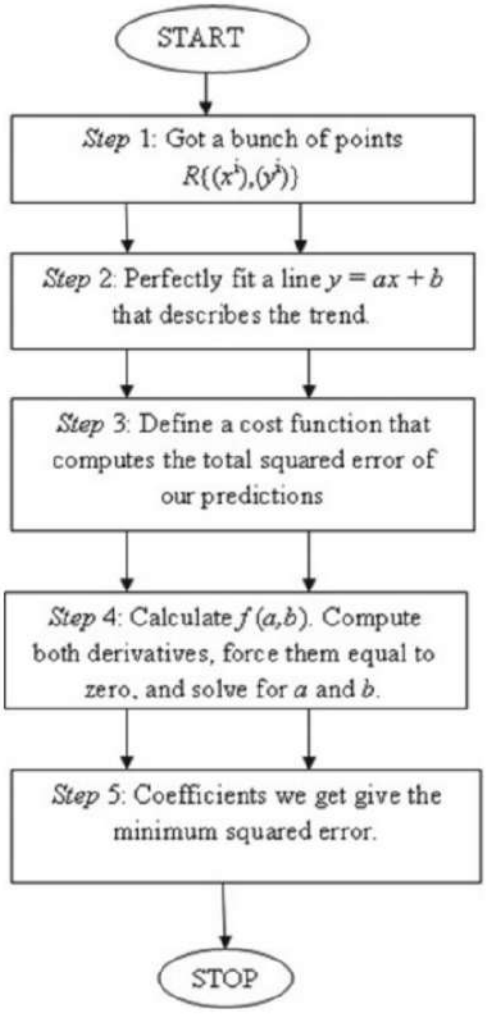

Fig. 2 Algorithm illustrating linear regression model

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For linear regression, the shape of regression line is linear whose slope of line is b and intercept is a. Linear regression is expressed as:

$$\underbrace{y}_{\text{actual (observed)}} = \underbrace{ax + b}_{\text{explained (prdeicted)}} + \underbrace{\varepsilon}_{\text{error}} \tag{1}$$

In Eq. (1), e is the error term. Linear regression can also be expressed by Eq. (2)

$$\underbrace{y}_{\text{observed}} = \underbrace{\hat{y}}_{\text{predicted}} + \underbrace{\varepsilon}_{\text{error}} \tag{2}$$

For predicted values, Eq. (1) can be written as:

$$\hat{y} = \hat{a}\, x + \hat{b} \tag{3}$$

where slope is represented as:

$$\hat{a} = \frac{SS_{xy}}{SS_{xx}} = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sum (x - \bar{x})^2} \tag{4}$$

where $\bar{x}$ and $\bar{y}$ are the sample means and intercept is represented by Eq. (5),

$$\hat{b} = \bar{y} - \hat{a}\, \bar{x} \tag{5}$$

If the independent variable (x) is more than one (i.e. $x_1, x_2, x_3 \ldots$) than regression is known as multiple regression. For multiple regressions, Eq. (1) can be expressed as

$$y = a + b_1 x_1 + b_2 x_2 + b_3 x_3 + \cdots b_n x_n + e \tag{6}$$

Methods like partial least square analysis (PLS) and OLS are used for calculation of linear regression, while methods like stepwise approximation (SWA), forward selection (FS), and backward elimination (BE) are used in multiple regression analysis.

2.2 *Support Vector Regression (SVR)*

A nonlinear function is leaned by linear learning machine mapping into high-dimensional kernel-induced feature space containing all the main features that characterize maximum margin algorithm. The system capacity is controlled by parameters that are not affected by the dimensionality of feature space. The main idea is to optimize the generalization bounds and rely on defining the loss function that

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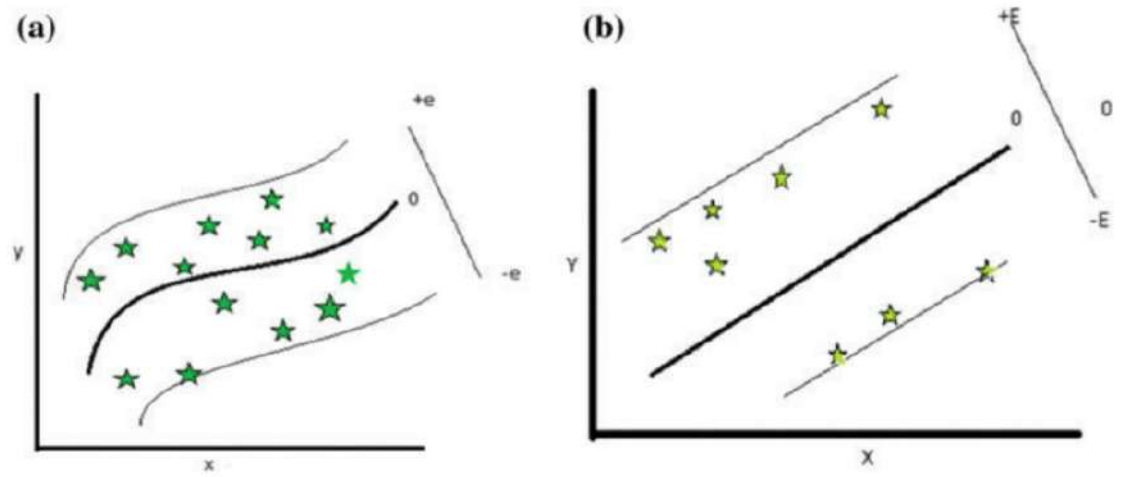

Fig. 3 SVM **a** nonlinear and **b** linear hyperplane

ignores errors that are located within the certain distance/range of the true value for regression. SVR is also used for making prediction models. Another widely used and powerful learning algorithm is a support vector machine (SVM). In SVM, the objective is to maximize the margin which is defined as the distance between the separating hyperplane and training samples that are closest to hyperplane. SVM can be applied as regression and not limited to classification only. SVR works on same principle as SVM works with only a few differences. Figure 3a shows the nonlinear plane of SVM, and Fig. 3b shows linear plane of SVM.

The main idea is to maximize the margin by individualizing the hyperplane. The results of linear regression and linear SVR are mostly similar. The main focus of linear regression is to maximize the conditional likelihoods of the training data from the source, which makes it more susceptible to outliers as compared to SVM. Furthermore, linear regression models can be easily updated, and the SVM focuses on the points that are closest to the decision boundary (support vectors).

3 Implementation of Predictive Model for Absenteeism

Our aim is to predict the absenteeism for MNCs by the previous recorded data sets. We analyzed the data from online source www.kaggle.com, which is a platform for predictive modeling and analytics competitions. Kaggle is an online community of machine learners and data scientists. It allows users to find, explore, and publish data sets. The availability of advanced machines and special tools has led to the analysis of big data. It also broadened our horizons of looking at an unknown data and trying to find useful features and patterns. We programmed our analysis on Python language. Figure 4 shows the proposed methodology employed in the paper to make a predictive model that helps in predicting the absenteeism. A significant amount of time and effort was spent in organizing, cleaning, and redefining variables in the data.

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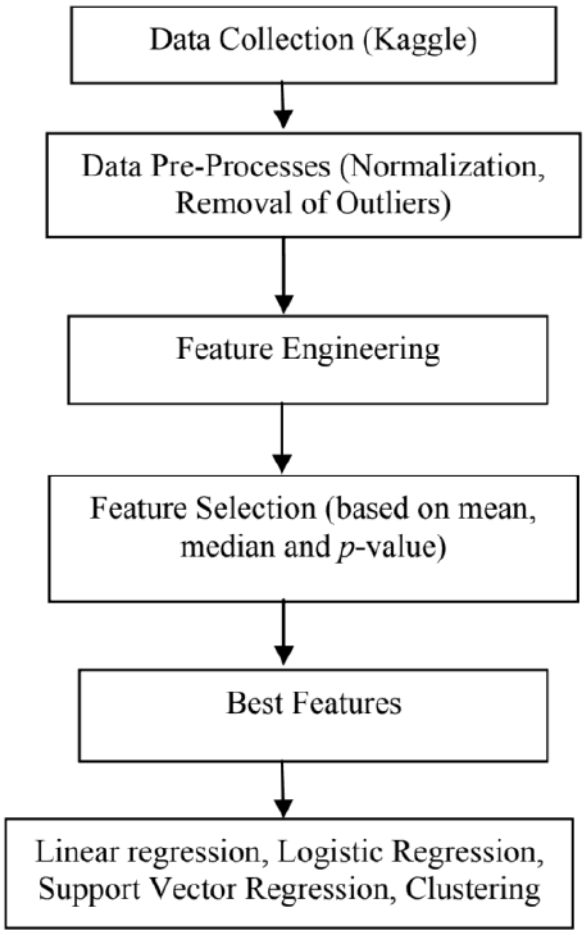

Fig. 4 Proposed methodology

Different steps were followed for implementation of our algorithm:

1. *Data Exploration*: In this section, data set is explored. This is an important step in the machine learning process as firstly we need to know more information about the data we are using and secondly we need to make a few alterations to the data itself. In this paper, we are using 741 observations and 21 parameters before data extraction and selection out of which we are considering the following different parameters: absent (1 = YES, 0 = NO), employee class (1 = 1st, 2 = 2nd, 3 = 3rd), name, age, sex, distance from home, seasons transport, service time, day shifts, workload, hit target, and education.
2. *Data Preprocessing*: Raw data can be transformed into understandable format is called data preprocessing. Data preprocessing is required because real-world data is often inconsistent, noisy, incomplete, or lacking in certain behaviors or trends. The missing values can be identified through data preprocessing. The identification of missing values is important in successful management of data. Missing values, if not handled properly, lead to inaccurate inference about the data. The result obtained will differ from ones where the missing values are present due to improper handling of data.
3. *Feature Engineering*: Since the data can have missing fields, incomplete fields, or fields containing unknown information, a fundamental step in building any

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Table 1 Title from the field Name

Index	Title	No of occurrence
1.	MR	757
2.	MRS	198
3.	MS	2

prediction system is feature engineering. Many times the data set contains highly varying features in magnitudes, units, and range. The field "Name" contained employee's title: Mr., Mrs., Ms. Since name is unique for each employee, it is not useful for our prediction system. However, an employee's title can be extracted from his or her name. In our data set, we found three titles which are shown in Table 1. Title indicates employee's sex (Mr. and Mrs.) and age (Ms. and Mrs.).

4. *Machine Learning Algorithm*: It explains how we have applied different machine learning algorithms (linear and SVR) to our data set in order to build a model. Figure 5 elaborates the machine learning algorithm that we have incorporated in our paper. We have split the data set into training data set and testing data set in the ratio of 70:30, and using training data set, we came up with a model to be deployed. To this model, we applied test data set that yields predictive model.

In this paper, we have used linear regression and SVR to get predictive model. Linear regression requires minimal adjustments to the data provided by Kaggle. We have performed linear regression of all the parameters (shown in Fig. 6) and find that absenteeism is linearly varying with age parameter only.

Figure 7 shows that the *age of the employee* being our predictor variable and *number of days our employee is absent* as our response variable using linear regression.

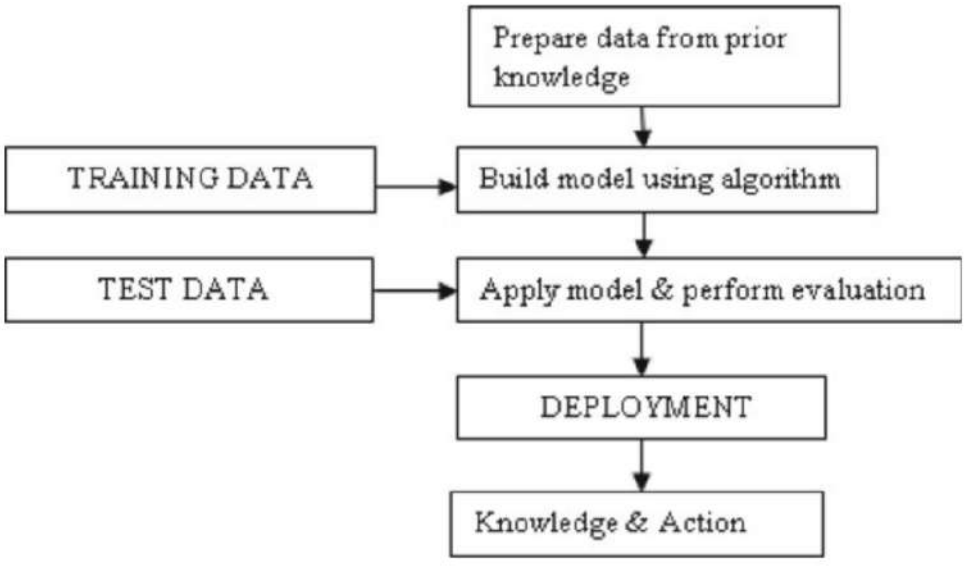

Fig. 5 Machine learning algorithm

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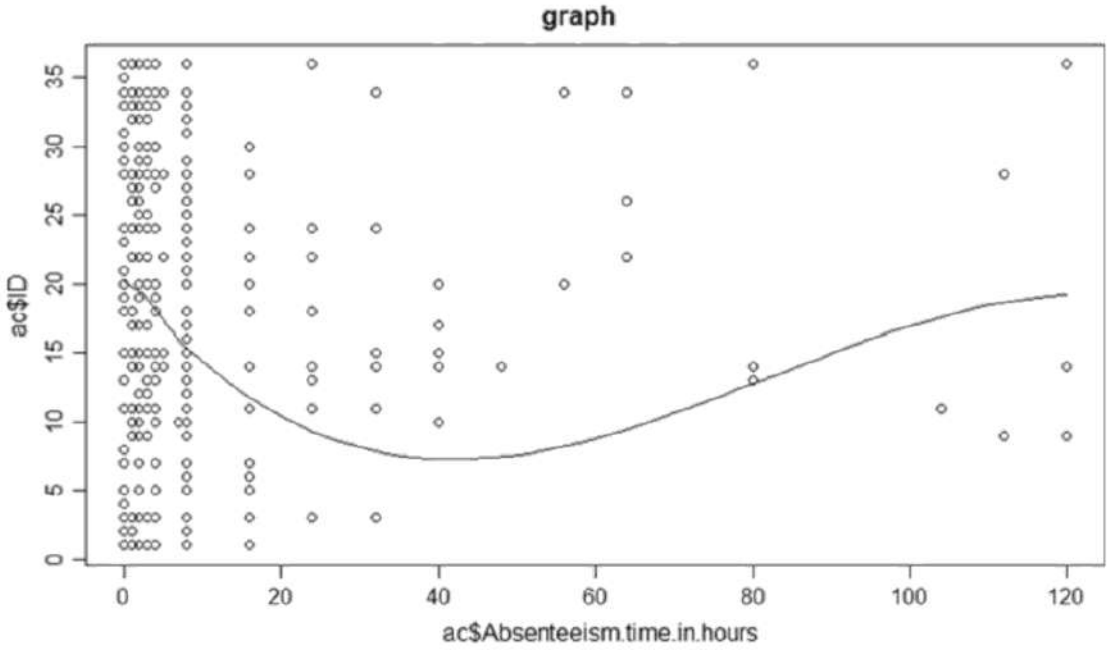

Fig. 6 Linear regression on different variables our data set

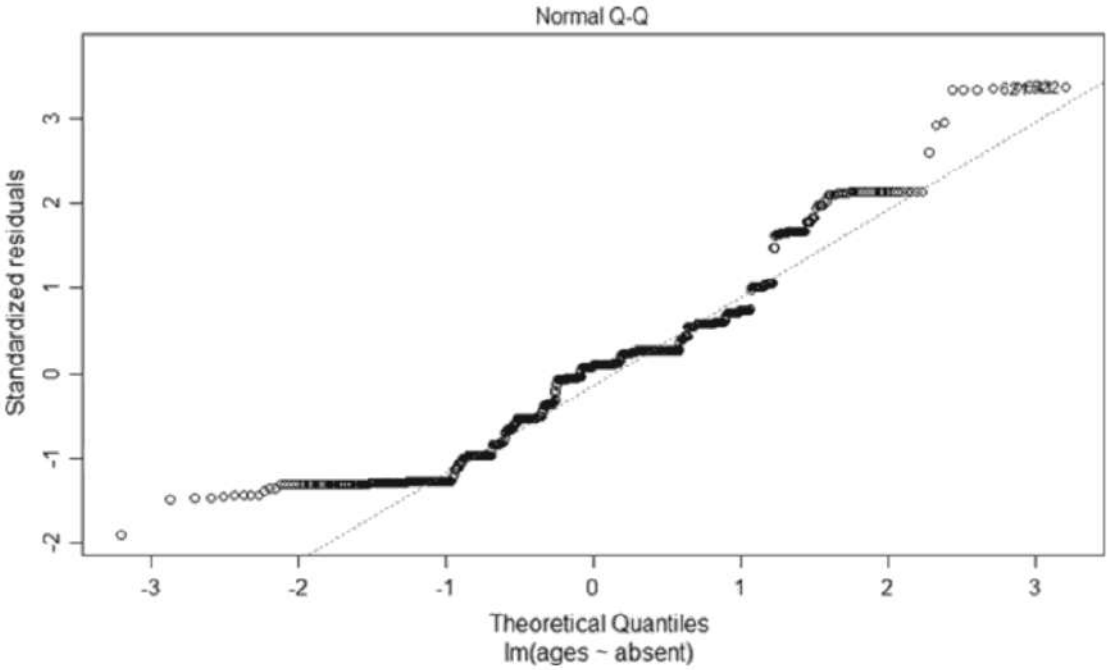

Fig. 7 Residuals versus age using linear regression

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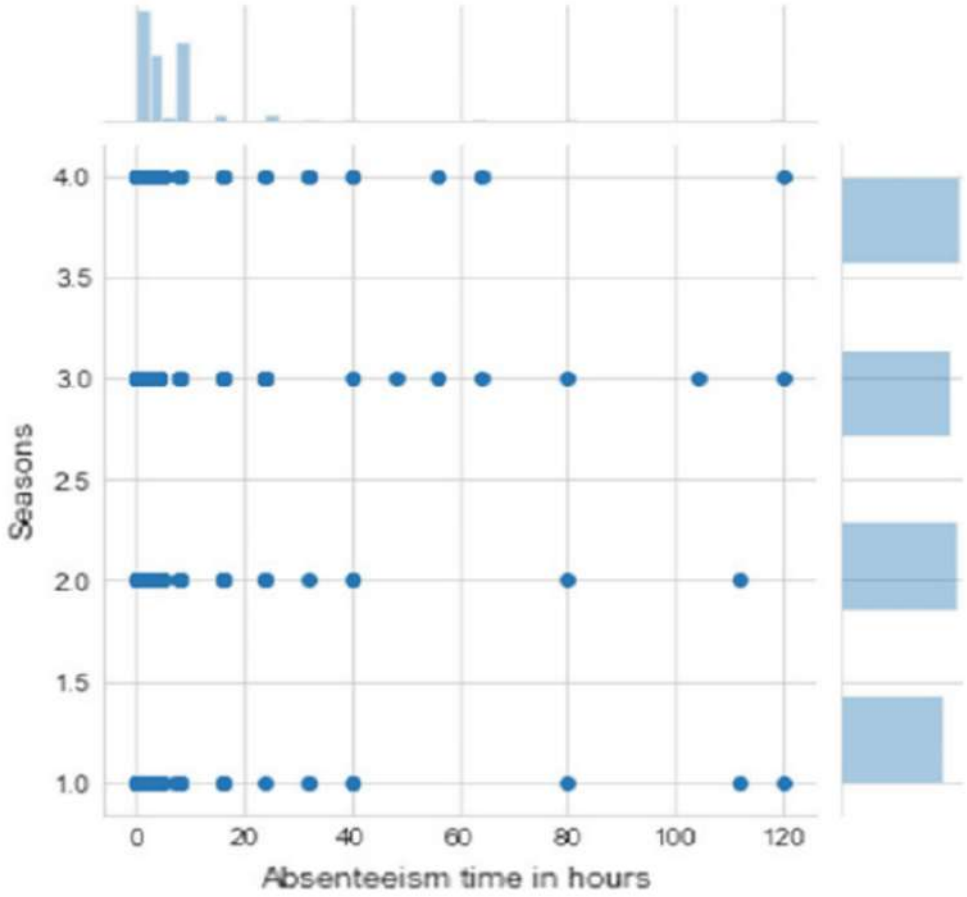

Fig. 8 Graph between seasons of the year versus absenteeism using SVR

We have also applied SVR on our data sets. For SVR, we have considered two parameters age and seasons of the year. Figures 8 and 9 depict the graph for season of the year and age versus absenteeism respectively using SVR.

We have divided the year into four major seasons with an interval of 0.5 but as shown in Fig. 8, we can infer that absenteeism rate does not get much affected by a particular season of the year. The absenteeism rate remains unaffected by this factor as the absenteeism rate is almost equal in all seasons. From Fig. 9, we can infer that the age group of 35–40 years has the highest absenteeism rate as compared to the age group of 50–60. With age parameter, days of the week with hours is also considered.

Figure 10 depicts the absenteeism on different days of the week. Here, each day starting from Monday to Saturday is assigned a different color and the gradual decrease in absenteeism on 2nd day of the week is observed as the age increases, and the absenteeism on the 6th day (Saturday) is fairly high than any other day, reason being the end of the week.

From the experiments, we come to know that age parameter of the age group of 35–40 is linearly related to absenteeism and the maximum absenteeism is on the 6th day of the week, and minimum absenteeism is on the 2nd day of the week. There is no much affect of season on absenteeism.

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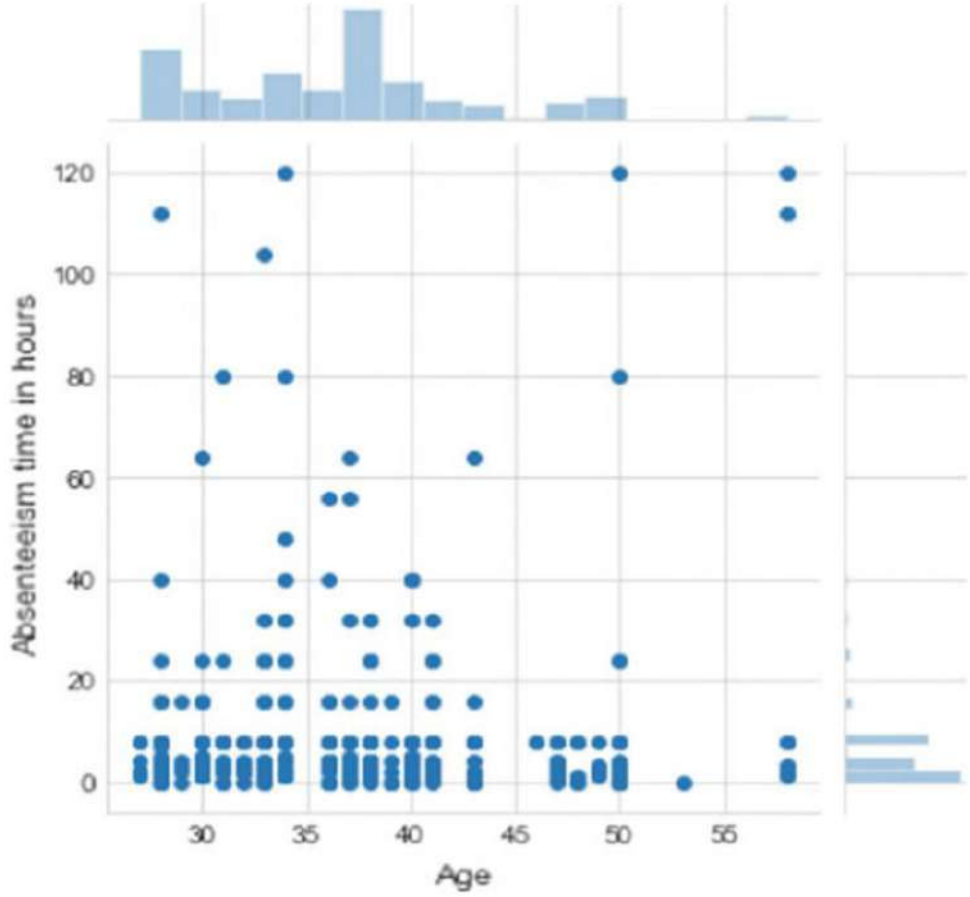

Fig. 9 Graph between age versus absenteeism using SVR

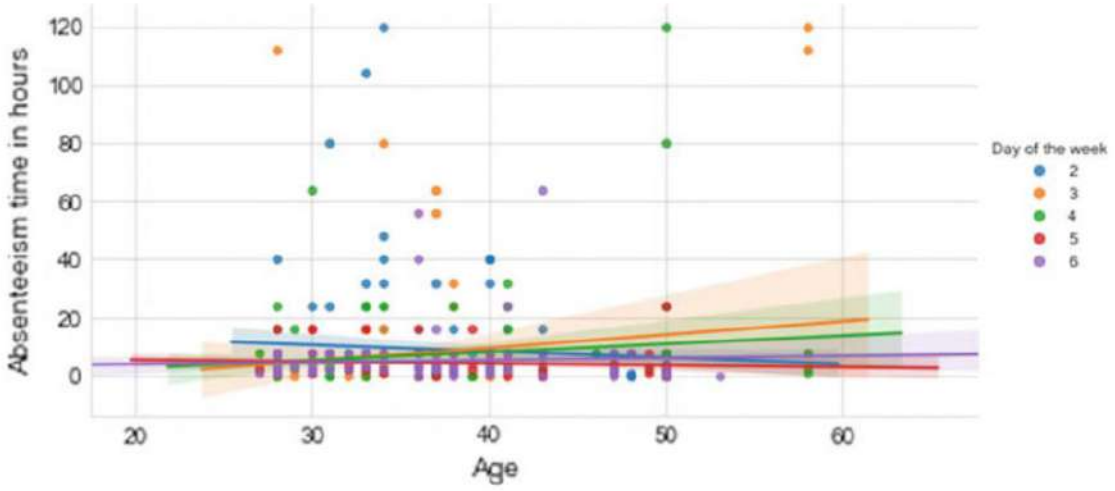

Fig. 10 Age and absenteeism in hours considering days of the week. *Note* 2 defines 2nd day, 3 defines the 3rd day of the week

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4 Conclusion and Future Work

Predictive analysis of absenteeism in MNCs served as a framework for introductory predictive analytic methods. Managers and organizational practitioners need a detailed method for measuring absenteeism loss as well as other measures needed for managerial evaluation to decrease absenteeism rate and compare the effectiveness of absence/attendance policy from period to period. The motivation of this study developed from a desire to learn, understand, and apply linear, logistic, and SVM regression. It is apparent that the effort put forth when working on the absenteeism in MNCs problem has achieved our aims and goal of this study by linear regression and SVR. In the future, we will encode categorical values of parameters such as month of the absence.

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Mutation Testing-Based Evaluation Framework for Evaluating Software Clone Detection Tools



Pratiksha Gautam and Hemraj Saini

Abstract Mutation testing has become a prominent research area in the past few decades. The mutation testing has been basically used in the testing society. It is a type of software testing where we mutate (small change, modification in the program) source code using mutant operators by introducing potential new bugs in the program code without changing its behavior. Analogously, mutant operators generate new clones by copy/paste editing activities. However, several software clone detection tools and techniques have been introduced by numerous scientists and a large number of tools comprises for a perceivable evaluation. Moreover, there have been a lot of efforts to empirically assess and analyze variant state-of-the-art tools. The current abstraction exhibits that various aspects that could leverage the legitimacy of the outcome of such assessment have been roughly anticipated due to lack of legitimized software clone benchmark. In this paper, we present a mutation testing-based automatic evaluation structure for valuating software clone detection tools and techniques. The proposed framework uses the edit-based taxonomy of mutation operator for assessing code clone detection tools. The proposed structure injects software clones in the source code automatically, and after that, we evaluate clone detection tools. The clone detection tools are evaluated on the basis of precision (number of corrected clones) and recall (total number of clones). We visualize that such a framework will present a valuable augmentation to the research community.

Keywords Mutation analysis · Software clone · Mutation techniques · Mutation operators

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1 Introduction

The experiential estimation of testing techniques plays a vital role in software testing as well as in software clone detection research. One frequent usage is inserting flaws, either manually or by using mutation operators [1]. Generally, empirical evaluations are used to actuate two or more approaches, which are exclusive for complying with some detection-related activity. Testing experiments usually entail a set of subject programs with known faults or errors. Furthermore, in software clone detection, it also requires some faulty version or duplicated code, to evaluate software clone detection approaches. Many researchers consequently have taken the methods of introducing bugs into the correct program to generate faulty variants. These bugs can be pioneered by hand or generated automatically through a faulty version of program text. Typically, we view an automatically generated version as an outcome of employing some editing activities in the source code. However, these editing activities are performed according to well-defined rules which are called mutant operators, and the resulting flawed variants are called mutation generation [2]. The mutation operators are identically used to generate potential bugs in software code clones so as to change the original source code [3, 4]. Reusing source code segment by copying and pasting is a common practice in software development. As a consequence, similar copied code fragments are called software clones, and the process is called software cloning [3]. Earlier study exhibits that a major portion (20–59) of program code in the software code was duplicated [5–10]. An error detected in one segment of code, and then, all segments of source code should be checked for the same error [11]. Copied code can also considerably augment the effort to be thorough when intensifying or complying source code [8]. However, several software clone detection approaches have been anticipated, and there have been a number of comparisons and valuation abstractions relating them in different contexts [12–16]. Nonetheless, it is ambitious to analyze different software clone detection tools, due to software clone detection techniques having specific features, and thus, these researches present considerable contributions to the software clone detection research [17]. Typically, insufficient assessment is aggravated as there are no universal evaluation benchmarks. It is thorny to find such a general norm as each technique has its own tunable features and is designed for distinctive reasons.

In this paper, we present a layout of mutation testing-based evaluation framework. The main objective of our abstraction is to draft a mutation-based evaluation framework which has been used to assess clone detection tools and techniques. The proposed framework is still under implementation and is manifested for quantifying and expanding various software clone detection tools. In this paper, we start off by abstracting the basic introduction of software code cloning and mutation testing from which an editing taxonomy of mutant operators can be derived. Moreover, on the basis of these mutation operators, we assert a framework for valuating code clone detection tools.

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2 Background

Copying source code fragments from one section of source text and reusing them into another section with or without minor adaptation are frequent activities in software development process [5]. Software clones can be classified on the basis of their attributes as textual similarity and functional similarity. Further, the textual similarity-based clones are also categorized into three types such as (1) type 1(identical code segment except some variations in whitespace and comments), (2) type 2 (structurally similar code segments except some modifications in variable names, white spaces and comments) (3) type 3 (similar code segments with further alterations as statements deleted, inserted). Functional similarity-based clones are type 4 which have similar functionality but different structures.

3 Mutation Testing Overview

Mutation is a type of white-box testing, which is mainly used for unit testing where we transform (mutate) certain statements of a program text and verify if the test cases are able to find the fault. The adaptation in a mutant program is kept enormously small, so that it does not change the overall intention of the program. The perception of mutation testing is to introduce a syntactic transformation into the original source code, to create a flawed variant (termed as a mutant) as stated by well-defined rules (mutant operators) [18]. The mutation testing first time emerged in the 1970s by [19], in a class term paper. The first research paper was published by the authors 1 [20–22]. The author [23] conducted a survey work on the subarea of mutation testing, which was a weak survey, while the firm mutation provided by [24–27] and they gave an introductory chapter on mutation testing in their books. In 2000, [28] carried out a survey work on mutation testing as well as they recapitulated the history of mutation testing and presented an outline of the existing optimization techniques for mutation testing. Authors [29] defined mutation testing as a fault-based testing, which presents a testing standard known as "mutationcompetence score." The potency of test set can be quantified by using this score in terms of its facility to detect flaws. A recent review was accomplished [30]. They provide a methodical literature survey on application perception of mutation testing. The mutation testing approaches are classified into three types, and mutant operators can be assorted into two types which are shown in Fig. 1. Figure 1a depicts the classification of mutation testing techniques such as (1) the value mutation testing, which alters the key parameter's value as well types of mutation operators. (2) The decision mutation testing, modification in the control statement of the source code using and, or, not. (3) The statement mutation testing method, reorder statements of the program. Figure 1b demonstrates types of mutant operators. The mutant operators can be categorized as traditional mutation operators and class mutant operators. (1) The traditional mutant operators are further classified as arithmetic, logical, relational, conditional, etc. (2) The class mutant operator as

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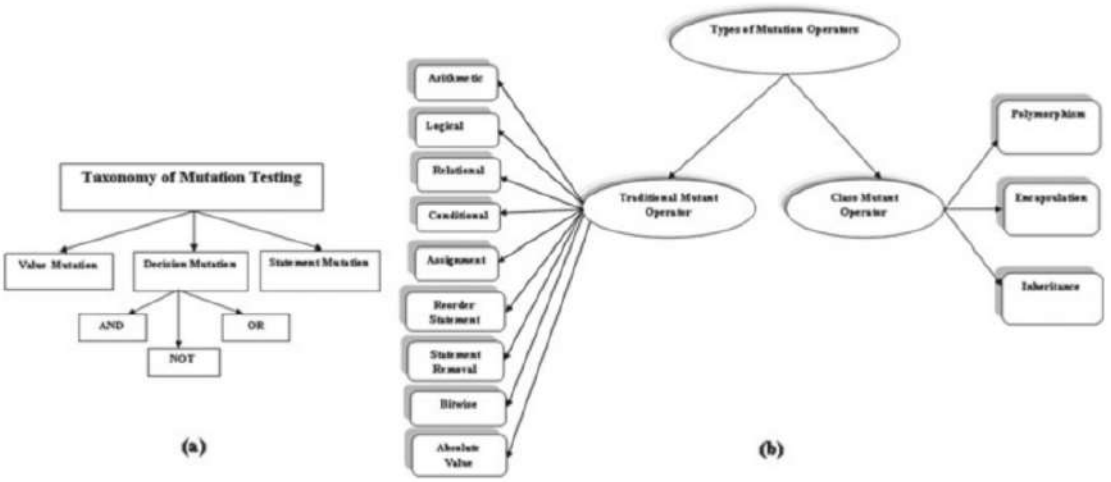

Fig. 1 Taxonomy of **a** mutation testing, **b** mutation operators

inheritance (delete a hidden variable), polymorphism (to check methods have the same name) and encapsulation (transforms, delete and insert instance variables for generating mutants).

The mutation testing is used to create flawed variants from an original program. Further, we used mutation operators for creating various types of software clones which are shown in Fig. 2. Figure 2 shows the mutation operators for software clones. Software clones can be classified into four types. Type-1 clones can be generated by using several mutation operators as mCW removes white space, mCW—changes in blank spaces, mCC—changes in comments, mCF—changes in formatting and mCNWs—changes in new line spaces. Type-2 clones can be generated by using mutation operators as mARV—arbitrary renaming variables, mRPE—replacement of parameters with expressions, mARDT—renaming data types and mARL—arbitrary renaming of literals. Type-3 clones can be generated by mSDL—small deletions within a line, mSIL—small insertions within a line, mMLs—modification in the whole line, mAOR—changes in arithmetic operators and mDSV—variation data statements. Type-4 clones can be created by using mROS—reorder the statements, mCR—replaces one type of control statement with another type of control statement, mCSS—constant substitution.

4 Related Work

The basic idea behind mutation testing is creating exactly similar variants from original program. Each mutant contains at least one artificial modification [31]. There is no mutation testing-based assessment structure presented in the literature; however, there are a number of experiments that contrast and valuate software clone detection

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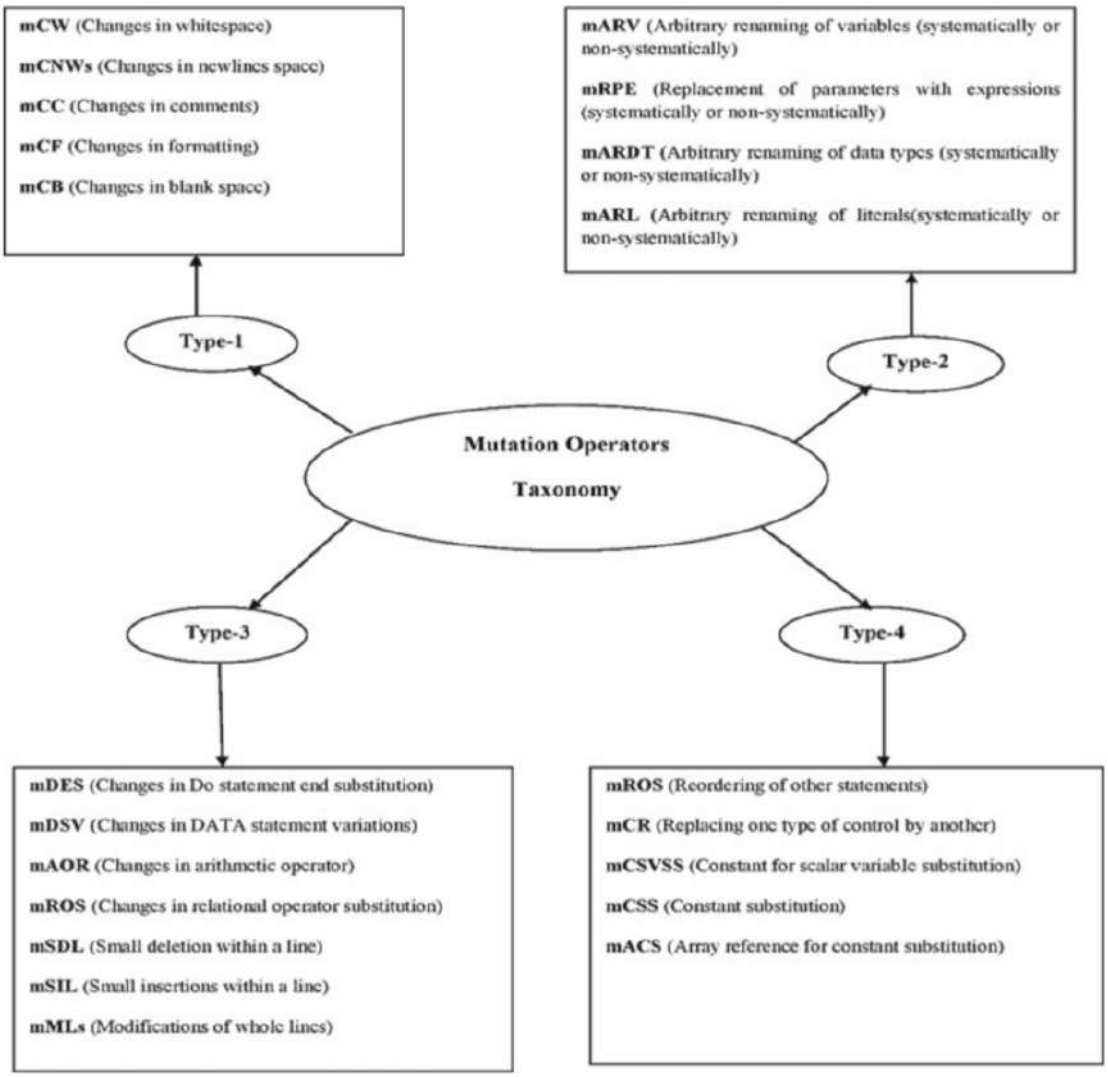

Fig. 2 Taxonomy of mutation operators for software clones

techniques/tools. We present an outline of the existing tool assessment experimentation from the literature. The first experiment was accomplished [14] on two plagiarism detection tools and three state-of-the-arts clone detection tools to evaluate their performance. The first thing they did was verifying the entire duplicated code clones using all the techniques of their experimentation. Various techniques were then compared against various parameters by a human oracle, which in turn uses several metrics that are responsible for measuring different facets of the detected code clones. Though they efficiently identified all the candidate clones, the main constraints of this case study are in terms of size and system quality. The primary objective of their study was to help in a preventive maintenance task which had leverage in validating the candidate clone. Authors have [12] accomplished tool comparison which was invented after considering the limitations of [14] experiment. Further, the authors [12] conducted this experiment with similar three software clone detection tools which are used [14] in their experiment, and they also used three additional clone detection tools in their experiments. The system software [14] had used a diverse set,

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accounting to four Java and four C. Moreover, when the authors' [14] studies were taken under consideration while validating the candidate clones, a human oracle was then used for the same. Although being the most comprehensive study till now, the clone candidate being oracled was only a small proportion considering that other factors might have affected the results [17]. However, authors [15] extended this study with a prototype application of several tools, but without addressing anything to conquer the shortcomings of Bellon et al.'s study. The three envoy software clone detection techniques valuated [16], and they presented relative fallouts in perspective of portability, types of replication addressed, scalability, a number of false test matches and the number of ineffectual matches. Nevertheless, the little size cases and paradigm implementation were used by them instead of the actual tools. They intended to conclude appropriateness of the detection technique for a meticulous task as a substitute to the perceptible evaluation of the detection approaches. The researchers [13] carried out an interesting study; they evaluated numerous clone detection techniques in respect of detecting crosscutting apprehensions.

Recently, various researchers proposed number of techniques for mutation testing. Author [32] proposed an efficient mutation testing framework for multi-threaded code which can reduce time required for mutation testing of multi-threaded code. They proposed a tool named as MuTMuT which is based on four optimizations and one heuristic. The mutation testing method used mutation testing in safety-critical industry using high-integrity subsets of C and ADA [33]. They recognized most adequate mutant types and analyzed main reasons of failure in test cases. Moreover, they also provided a practical evaluation of the application of mutation testing to airborne software system. One of the main issues regarding mutation testing was high cost, due to the creation of mutants, execution of mutants and calculation of their scores. Mateo and Usaola [34] proposed a mutant schema with extra code (MUSIC) which reduces the mutation cost through uncovered mutants. Though this technique defines the statements enclosed by the tests in the original system, in order to out the mutant executions, because tests are only executed against the mutants whose mutated statement is covered by tests. Authors [35] measured the complexity of mutants and prioritized them on the basis of how easy or hard to manifest them. The mutation testing is presented in perspective of Python program [36]. They showed how mutation testing can be effectively handled in Python environment. A mutation reduction method is proposed in terms of program structure [37]. Although they used two path-aware heuristic rules named as loop-depth and module-depth rules and combined these two rules with operator-based selection and statements for the development of four mutant reduction approaches. In addition to this, the researchers [38] have also evaluated mutation at the class level while the existing method analyzes mutation at the traditional level. Further, they proposed a MuCPP system which is based on the class mutation operators of C++ programming language. An improved genetic algorithm is presented [39] which is a search-based approach to reduce the computational cost of mutation testing. However, they used state-based and control-oriented fitness function in their tool eMuJava and compared it with other standard fitness functions. However, aforementioned mutation-based testing approaches have been presented in the literature. All these approaches were focused on mutation

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testing, while mutation word first time was used [3, 4] in clone detection research field in a brief way. Although they provided an editing taxonomy for various types of clone generation and also proposed a mutation/injection-based framework for evaluation clone detection tools.

As per the authors' best knowledge, there is no thorough work on mutation testing operators in perspectives of software clone detection tools. Yet, there is no standard benchmark available for evaluating clone detection, and there is no empirical evaluation, which explicitly determines the utilization of mutants in clone detection research field. The author contribution in this manuscript is summarized as follows:

- We used mutation testing concept in clone detection research area.
- We used mutation operators for generating various types of software clones.
- Proposed an evaluation framework using mutated code clones.

We evaluated clone detection tools on the basis of mutated code.

5 Proposed Evaluation Framework

This section presents details of our proposed framework which is based on mutation testing as shown in Fig. 5. We start with the basic components of the proposed framework and then thrash out clones terminology, precision and recall of the tools. Although, this framework is based on mutation testing and it acts in accordance with the principle of mutation testing.

Figure 5 illustrates conceptual layout of the proposed framework. The proposed framework is categorized into two main phases. Firstly, Clone Generation Phase, in this phase, software clones are generated from original code with the help of mutation operator-based editing taxonomy. The second phase is Tools Evaluation Phase, in which mutated codes are used to evaluate the software clone detection tools performance. The detailed discussions of the proposed framework are shown below.

5.1 Validation Study

Input Original Code Base: At the primary step of the framework, we input the target code base which is shown in Fig. 3. To find out which tool would be significant for such a valuation in terms of recall and precision.

Figure 3 shows an example of code base which is taken as input in the proposed framework. The original code is retrieved from an open-source project named as wet lab [40] which is an open-source project of C++ language.

Figure 4 depicts an illustration of duplicated code which is generated using mutation operators-based editing taxonomy as well as original source code.

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```
//Date: Oct 4 Start :5:23PM End :5:30PM
//Find The Pair With Given Sum
//Complexity : O(n)
#include<iostream>
#include<vector>
using namespace std;
int main()
{
vector<int> v = {1,2,4,5,6,7};
int sum ,left =0 ,right=v.size()-1;
cin>>sum;
while(left<right)
{
 if(v[left]+v[right]==sum)
 break;
 else if(v[left]+v[right]>sum)
 right--;
 else
 left++;
}
if(left<right)
cout<<"Pair Having Sum  "<<sum <<" found at location "<<left+1<<" and "<<right+1<<" value
s are "<<v[left]<<" and "<<v[right];
else
```

Fig. 3 An example of original code base

```
//Date: Oct 4 Start :5:23PM End :5:30PM
//Find The Pair With Given Sum
\\Testing Comment Inserted//Complexity : O(n)
#include<iostream>
#include<vector>
using namespace std;
int main()
{
vector<int> v = {1,2,4,5,6,7};
int sum ,left =0 ,right=v.size()-1;
cin>>sum;
while(left<right)

{
 if(v[left]+v[right]==sum)
 break;
 else if(v[left]+v[right]>sum)
 right--;
 else
 left++;
}
if(left<right)
cout<<"Pair Having Sum  "<<sum <<" found at location "<<left+1<<" and "<<right+1<<" value
s are "<<v[left]<<" and "<<v[right];
```

Fig. 4 An illustration of code clone (type-1)

Random Selection of Code Segment

Once the source code is elected, then any preferred fractional number of accessible source code segment is either selected automatically or randomly from the code base for clone mutation.

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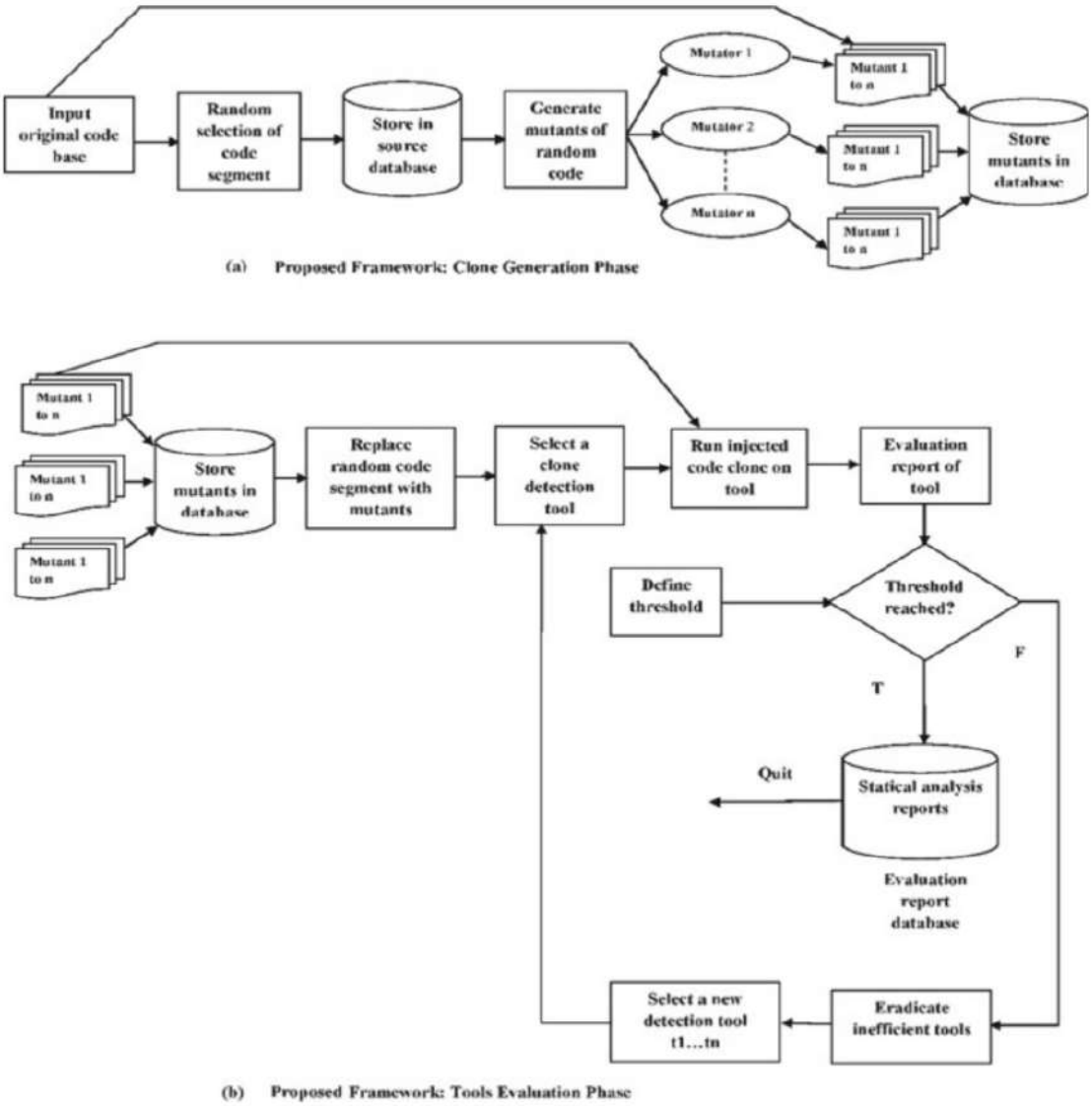

Fig. 5 Proposed mutation-testing-based automatic evaluation framework **a** Clone Generation Phase **b** Clone Tools Evaluation Phase

Stored in Source Database

Randomly selected code segments are stored in the source database, and then, mutants will be created by using these randomly selected code segments.

Generate Mutant of Random Code Segment

The edit-based taxonomy of mutation operators is used for generating mutant versions of randomly or sequentially selected code fragments which are stored in the mutant source database. An example of mutant-version of original code base is shown in Fig. 4. A number of mutants can be generated for one code segment.

The mutated version of the code base after replacement will be fed as input to clone detection tool. The detection tool will be evaluated on the basis of how many clones it will detect accurately and how fast they detect clones.

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5.2 Tools Evaluation Phase

In this phase, each of the mutated code is stored in the database, and then, each mutated code is fed into clone detection tools as an input for evaluating and comparing clone detection tools. The main key feature of this phase is threshold. We defined threshold for clone detection tools. If a tool does not fulfill the threshold limit, then that will be eradicated and a new tool will be selected for evaluation.

Replace Random Code Segment with Mutants
The mutated code is generated for each of the mutant code variants of the source code. The generated mutated version of the original code base is replaced with the randomly selected code segments in the original code base.

Select a Clone Detection Tool
In this phase, a tool will be selected, and then, mutated code base is given as input into the selected tool.

Run Injected Code Clones on Tool
The mutated version of code base after replacement will be given as input on clone detection tool. The detection tool will be evaluated on the basis of how much clone it will detect accurately and how fast they detect clone.

Evaluation Report of Tool
The evaluation report makes a decision for the tool. It analyzes the performance of the tool on the basis of precision (number of accurately detected clones) and recall (total number of clones), scalability (tool supports large database) and portability (language support).

Define Threshold
The key objective of this phase is to diminish the execution time and cost of this process. A threshold will be defined by a user for a clone detection tool, and the tool crossing the threshold will be eliminated, and it will select a new tool for evaluation. Further, the tool which has low precision and recall will be discarded and the high precision–recall tool will be evaluated. It will be useful for those users who are seeking high precision and recall-based tools.

Eradicate Inefficient Tool
Most of the tools have low accuracy in the sense that they did not detect all clones (recall), as they returned a large number of false positive (precision). This led to the cognizance which is a step of valuating the results of tools that should be saved at the end.

Statistical Analysis Report
Once the experimentation is accomplished, then evaluation database is used to calculate clone detection tools accuracy as precision, recall, portability and scalability for each type of clone.

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6 Clone Terminology

The clone detection tool returns clones in the form of clone pairs (CP), clone classes (CC) or both. The similarity relation between two or more clone fragments is illustrated by these two terms. Further, the clone similarity relation between code segments is an equivalence relation which is described in [41]. The clone relation exists between two segments if they are similar structurally or semantically. A pair of code fragments is called clone pair if there exists a clone relation, while clone class is a union of all clone pairs [42].

Definition 1 (*Code Segment*) A code segment (CS) consists of any subsequence of code string. It is defined by any type of granularity as fixed (predefined syntactic boundary as function, begin-end block) or free (no syntactic boundary). A CS is detected on the basis of granularity in the original program, and it is implied as (CS.Filename, CS.BeginLine, CS.EndLine).

Let $P = \{0, 1, 2, \ldots)$ and $P{+}{=} \{1, 2, \ldots)$. For $p \in P$, denoted by $O\ (p)\ A$ the set of n operations on A and set $OA{:} = Up \in P{+}\ O(p)A$. A subset CS $\subseteq OA$.

Definition 2 (*Software Clone*) A code segment CS2 is a duplicated software clone of another source segment CS1 if they are identical on the basis of some given definition of similarity that is $f(\text{CS1}) = \text{CS2}$, where f is a similarity function (textual or semantic). Further, when two code segments are similar with each other, they are called clone pairs.

$$\text{CP} = (\text{CS1}, \text{CS2})$$

Definition 3 (*Software Clone Types*) Software clones are classified on the basis of their attributes as textual similarity-based or syntactic-based, and other is functional similarity-based or semantic-based [5].

Definition 4 (*Code Segment Encompassment*) If two or more code segments are contained within same file or the boundary of line numbers of CS1 is within the boundary of line numbers of CS2.

File contained (CS CS1, CS CS2)

If((CS1.FileName==CS2.FileName) && (CS1.BeginLine>=CS2.BeginLine) && (CS1EndLine<=CS2.EndLine))

7 Measuring Recall

The main objective of our proposed framework is to automatically inject software clones in the source code which are generated by using mutation operators. Further, we evaluate clone detection tool's accuracy in terms of precision and recall. The proposed framework addresses recall for each type of software clones and for each

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type of mutation operators for all the tools. In this proposed framework, the detectable clones are our injected mutant clone versions of the original source code, and that will be inserted into mutated source code base, randomly or automatically. The mutation testing-based techniques make recall simpler. Moreover, if the mutated code segment as moCS of original code segment oCS inserted into the mutated code base mioCB of original source code base oCB is "killed," oCScs and moCS are detected by clone detector and their threshold level value which returns 1 if detector's minimum threshold value is greater than 1 and maximum value less than 100, otherwise it will return to 0. The main objective of threshold value is to minimize the execution time and complexity. The threshold value depends on user's requirements, and the user can define threshold value between 1 and 100 because recall cannot be less than 1 and cannot be greater than 100.

$$\text{Recall} = (\text{Number of detected clones} * 100)/\text{Total number of clones}$$

R T (oCS, moCs) = {return 1, if (oCS, moCS) is detected by tool T in mioCB → THLV (minimum value>=1 & maximum value<=100) otherwise 0.

Where THLV means threshold level value. The similar code segments can be inserted or injected randomly, any number of times, in the original code base oCB and generate n different mutated variants of oCB as mioCB1, mioCB2, …, mioCBn. The proposed framework used mutation operators for creating various types of mutated versions of source code and then inserting them randomly several times to check the sensitivity of clone detector. However, the random segment selector selects m code base, and each of them will be mutated by mutation operators dmOP for generating mutated versions of code segments as moCS1, moCS2, …, moCSm.

Hence, the recall for mutation operator dmOP for clone detector is given as follows.

$$\text{RTdmOP} = \sum_{i=1} n * \text{mRT(oCSi)}/n * m$$

The type-1 software clones used four types of mutation operators (mCW, mCNWs, mCC, mCF, mCB) and their combination (mCW + mCNWs), (mCC + mCF), (mCF + mCB), (mCW + mCC), (mCW + mCF), (mCW + mCB), (mCNW + mCC), (mCNWs + mCF), (mCNW + mCB), (mCC + mCB) and mCF + mCB) can be applied to the m code segments (if we allow operator repetition, then a number of combination can be generated), and each of which is inserted n times into the code base. Therefore, the recall of clone detector tool T for type-1 can be defined as:

RTdmOP = $\sum_{i=1} n * m * (5 + 11)$ RT(oCSi, moCSi)/$m*n*(5+11)$ = {return H, if (n, m) is detected by clone detector tool T in mioCBTHLV (minimum value>=1 & maximum value<=100) otherwise L.

Where H means high recall, L means low recall and 5 indicates number of operators and 11 indicates number of combinations.

The overall recall of clone detectors can be defined as:

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RTdmOP $= \sum_{i=1} n * m * (S + C)$ RT(oCSi, moCSi)$/m{*}n{*}(S{+}c) = \{$return H, if (n, m) is detected by tool T in mioCB $\rightarrow$ THLV (minimum value>=1 & maximum value<=100) otherwise L.

Where H means high recall, L means low recall and S indicates number clone mutation operators and C indicates number of combinations.

8 Measuring Precision

Precision measures irrelevant items which appeared in the results. Preferably, precision should be high when recall increases, but practically, it is difficult to accomplish. The precision definition is shown below.

Precision = (Number of correctly detected clones $*$ 100)/Total number of detected clones

The precision of a tool can be calculated as a mutated code segment moCS generated by using mutation operators dmOP, and clone detector tool T returning k clone pairs, (moCS, CS1), (moCS, CS2)…(moCS, CSK) in mutated code base mioCB.

PTdmOP = w.r.t. t. single insertion of moCS = a/k {return 1, if (oCS, moCS) is detected by tool T in mioCB $\rightarrow$ THLV (minimum value>=1 & maximum value<=100) otherwise 0.

Where a means accurate detection and k means number of clone pairs returned by a clone detector T.

The overall precision of clone detector tool in terms of number of mutation operators and number of combinations which is applied n times to m code segments is shown below.PTdmOP $= \sum_{i=1} n * m * (S + C) \Big/ \sum_{i=1} n * m * (S + C) = \{$return H, if (n, m) is detected by clone detector tool T in mioCBTHLV (minimum value>=1 & maximum value<=100) otherwise L. Where H means high precision and L means low precision.

9 Conclusion and Future Work

The valuation of code clone detection tools and techniques is an emerging issue in today's scenario. The previous studies for experimentally valuating clone detection tools and techniques had various constraints and hence, cannot present a persuasive comparable survey. Thus, in this paper, we proposed a peculiar mutation testing-based evaluation layout, for valuating code clone detection tools which are used by testing society over the past thirty years. Moreover, this paper encompasses mutation testing, operators and provides insight into related work on mutation testing. However, we have not accomplished the execution of the framework until now; we are assured that such a framework can present truthful analogous outcome for distinct tools, in finding deliberately generated software code clones. In the proposed structure,

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CHAPTER 2

Hazardous Wastes – Types and Sources

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2.1 Introduction

All around the globe, the economic and social status of people is changing very rapidly. Especially in developing countries, the need for a better economic state is a prerequisite for better social status. The economic growth and development of a country result in many adverse effects on the environment, *viz.* waste generation, greenhouse gas emissions, deforestation, land degradation, *etc.* Waste can be described in the most characteristic way as unwanted material generated in any production process. Although the definition of waste and its categorization may vary slightly in different countries, waste and waste management represent a significant global issue. The never-ending race towards urbanization and modern lifestyle to become a developed country has a serious disadvantage, namely the generation of hazardous waste. With a paradigm shift in economy with the goal of industrialization, the number of industries, particularly those which produce

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hazardous wastes, has increased dramatically. During the past few decades, the generation of hazardous waste has increased alarmingly around the globe[1–3] and there is an urgent need to develop comprehensive strategies for hazardous waste management. In order to do so, proper guidelines, classification practices and the promotion of reuse and recycling need to be developed. Hazardous waste accounted for about half of the environmental consultation market worth $8.2 billion in 1991,[4] which makes it very evident that hazardous waste was also of great significance nearly 30 years ago. What makes it so concerning is its toxicity, which is why the scientific and practical definition of hazardous waste and its proper treatment and disposal have been dominant over other environmental issues. This chapter attempts to address these issues and provide a comprehensive strategy for the storage, treatment and proper disposal of hazardous waste.

2.2 Management of Hazardous Waste

Initially, officials around the globe were not concerned about the consequences of hazardous waste for environmental and human health. Gradually, with the advances and developments in science and the advent of many interdisciplinary fields, researchers across the world started to recognize the looming threat of chemicals and the consequences for society. Accident episodes were now increasingly associated with chemicals and these accidents attracted attention throughout the world, hence a need to define hazardous waste became evident.

2.2.1 Identification and Classification

Various countries have their own classification system pertaining to hazardous waste and there are multiple levels of sophistication and complexities involved in the identification of hazardous waste. Therein lies a very basic difficulty for government and industrial organizations engaged in hazardous waste control programs, namely to define hazardous waste realistically within the scientific and practical domains. Correct identification and subsequent classification are essential to ensure that the collection, transportation, storage, and treatment of waste and its proper disposal are carried out in a manner that not only protects human health but also provides protection for the environment, and in compliance with legal requirements. This chapter presents the classification system adopted by United States Environmental Protection Agency (EPA) and also by the European Union Environmental Protection Agency, which is accepted across the European Union.

First, correct classification depends mostly on correct identification, and to address this issue the Resource Conservation and Recovery Act (RCRA) describes the four steps necessary for preliminary identification of hazardous waste.[5] These steps are summarized in Figure 2.1. Moreover, the RCRA[5] defines hazardous waste as ‘‘a solid waste or combination of solid waste, which because of its quantity, concentration or physical, chemical or

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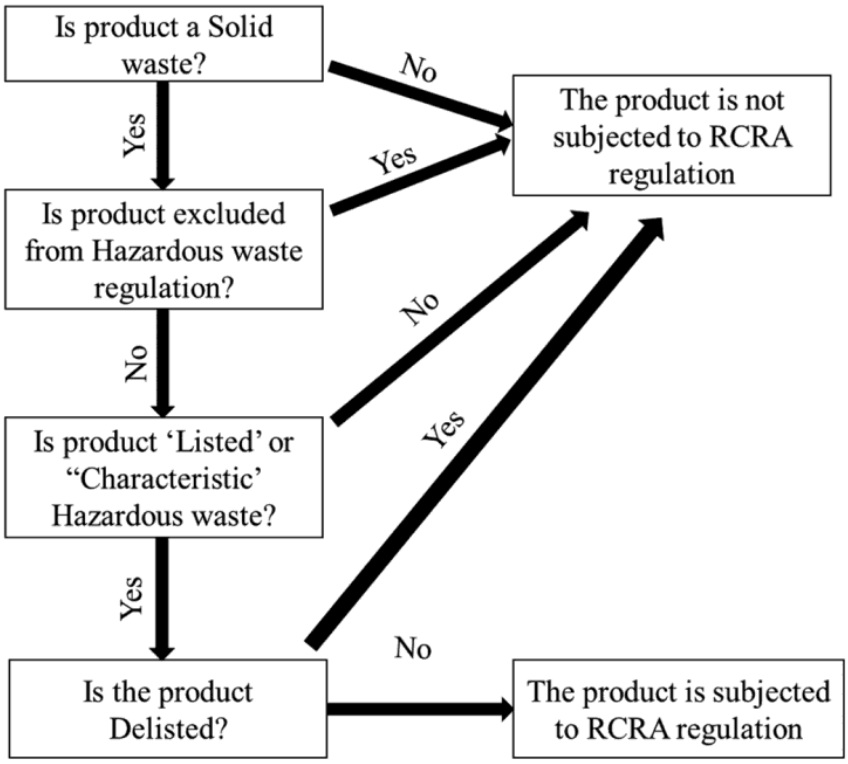

Figure 2.1 Identification process for hazardous waste. See also ref. 5.

infectious characteristics may (a) cause, or significantly contribute to, an increase in mortality or an increase in serious irreversible or incapacitating reversible, illness; or (b) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of or otherwise managed''. This classification is based on the fact that ''such wastes are non-degradable or persistent in nature or they can be biologically magnified or because they can be lethal or because they may otherwise cause or tend to cause detrimental cumulative effects''.[6]

The definition provided by the RCRA is very broad one and does not clearly indicate the threats posed by the waste(s). This issue was therefore addressed by classifying the waste through (1) listing of hazardous wastes and (2) identification of certain specific characteristics which, when present in a waste, makes it hazardous.

2.2.1.1 Listed Hazardous Waste

Hazardous waste listings by the EPA specifically describe the specific types of waste that are dangerous enough to warrant regulatory action. Hence it becomes very important that, before the final listing, the EPA conducts comprehensive studies regarding threats posed by a particular waste and waste stream to human and environmental health. If a waste or stream is found to be threatening enough, it can be listed in one of the lists and be classified as hazardous. Thereafter, any waste that conforms to the listing criteria is considered hazardous, regardless of its chemical composition or

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any such variable. The four criteria that the EPA may use to list a waste are as follows:

1. The waste typically contains harmful chemicals and other factors indicate that it could pose a threat to human health and the environment in the absence of special regulation. Such wastes are known as toxic listed wastes.
2. The waste contains such dangerous chemicals that it could pose a threat to human health and the environment even when properly managed. Such wastes are known as acutely hazardous wastes.
3. The waste typically exhibits one of the four characteristics of hazardous waste described in the hazardous waste identification regulations (ignitability, corrosivity, reactivity or toxicity).
4. When the EPA has to cause to believe for some other reason that the waste typically fits within the statutory definition of hazardous waste developed by Congress.

The EPA may list any waste using one or more of the criteria mentioned above. Based on these, four lists were prepared by the EPA, with each list designating from about 30 to a few hundred waste streams as hazardous. Each waste is assigned a waste code consisting of the letter associated with the list followed by three digits. For example, the wastes on the F list are assigned the waste codes F001, F002 and so on. The four lists prepared by the EPA are as follows:[5]

- *The F list:* since the processes producing industrial solid waste vary greatly across the sectors, the F list wastes are considered to be wastes from non-specific sources. The list designates particular solid wastes from certain common industrial or manufacturing processes as hazardous. The F list is codified in the regulations at §261.31.
- *The K list:* the K list labels a particular solid waste from certain specific industries. Wastes in this list are known as wastes from specific sources. The K list is found at §261.32.
- *The P and the U lists:* these two lists are similar in the sense that both have listings of pure or commercial grade formulations of certain specific unused chemicals as hazardous. Both the P and U lists are codified in §261.33.

2.2.1.2 Characteristic Hazardous Waste

Successful identification and subsequent classification are mainly governed by some characteristic features and these sets of characteristic feature can very well be used to classify hazardous waste. Even though unanimous definitions of hazardous waste have not been formulated across the globe, there is a universal acceptance towards these characteristic features. According to the EPA,[7] if a substance shows one or many of the following

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characteristics upon self-reaction or reaction with other compounds, it may be classified as a hazardous substance. These characteristic features are defined as follows:[5]

1. *Ignitability:* Any waste product that can create fire under certain conditions, has a flash point of less than 60 °C and shows spontaneous combustible characteristics can be called an ignitable product.
2. *Corrosivity:* All the acids or bases ($2 \leq pH \geq 12.5$) and/or any waste product that are capable of causing corrosion in metal containers (such as storage tanks, drums, *etc.*).
3. *Reactivity:* If any material is unstable under normal conditions, it can be considered a reactive hazardous waste. ''These products may cause explosions, undergo violent reactions, generate toxic fumes, gases or vapors or explosive mixtures when heated, compressed or mixed with water''.[5]
4. *Toxicity:* A waste product is referred to as toxic when its proven to be harmful or fatal upon ingestion or adsorbed. Determination of toxicity is carried out through a laboratory test known as the ''Toxicity Characteristic Leaching Procedure'' (TCLP).

2.2.1.3 Wastes Listed Solely for Exhibiting the Characteristic of Ignitability, Corrosivity and/or Reactivity

The regulation of wastes listed solely for exhibiting the characteristic of ignitability, corrosivity and/or reactivity does not work in the same way as that of other listed hazardous wastes under RCRA. Hence, according to RCRA (66 FR 27266), ''When wastes are generated that meet a listing description for one of the 29 wastes listed only for exhibiting the characteristic of ignitability, corrosivity and/or reactivity, the waste is not hazardous if it does not exhibit a characteristic''.[9]

2.2.1.4 The Mixture and Derived-from Rules

Through the listing of hazardous waste and characterization, most of the bases for identification of such wastes were considered to be covered. However, some key concerns were subsequently raised regarding the identification process. One such concern was ''what if the hazardous waste is changed chemically or physically in some way, will it still be considered hazardous?'' To resolve this issue, the EPA quickly came up with a very simple and strict guideline. This guideline was broadly presented in mixture and derived-from rules. These rules operate differently for listed and characteristic hazardous wastes.

2.2.1.4.1 Listed Hazardous Waste. The mixture rule for listed wastes states that ''a mixture made up of any amount of a non-hazardous solid

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waste and any amount of a listed hazardous waste is considered a listed hazardous waste. In other words, if a small vial of listed waste is mixed with a large quantity of non-hazardous waste, the resulting mixture bears the same waste code and regulatory status as the original listed component of the mixture''. Similarly, the derived-from rule for listed wastes states that ''any material derived from a listed hazardous waste is also a listed hazardous waste. Thus, ash produced by burning a listed hazardous waste bears the same waste code and regulatory status as the original listed waste, regardless of the ash's actual properties''.[5]

2.2.1.4.2 Characteristic Wastes. As mentioned earlier, norms for listed waste and characteristic wastes are different. The EPA decided that since the waste mixture does not exhibit any of the four characteristics, it shall no longer be considered hazardous. Hence ''a mixture involving characteristic wastes is hazardous only if the mixture itself exhibits a characteristic. Similarly, treatment residues and materials derived from characteristic wastes are hazardous only if they themselves exhibit a characteristic''.[5]

2.2.1.4.3 Waste Listed Solely for Exhibiting the Characteristic of Ignitability, Corrosivity and/or Reactivity. It is mentioned that ''if a hazardous waste listed only for the characteristics of ignitability, corrosivity and/or reactivity is mixed with a solid waste, the original listing does not carry through to the resulting mixture if that mixture does not exhibit any hazardous waste characteristics''.[5] Similarly, for derived-from it states that ''if a waste derived from the treatment, storage or disposal of a hazardous waste listed for the characteristics of ignitability, corrosivity and/or reactivity no longer exhibits one of those characteristics, it is not a hazardous waste''.[5]

Another major guideline (valid from 2015) followed across the European Union is given by the Environmental Protection Agency (EPA) Ireland, which mentions two very critical elements for hazardous waste classification:[5]

1. Preparation of List of Waste (LoW): ''The LoW provides a harmonized list for coding all waste. The different types of waste in the list are fully defined by the six-digit entry for the waste including the respective two-digit and four-digit chapter headings''.[8]

   As per the LoW, waste can be categorized in any one of the following three entry types:

   (i) non-hazardous;
   (ii) hazardous (marked with an asterisk);
   (iii) mirror – either hazardous or non-hazardous.

   One very important and notable point here is that, without any prejudice, if a waste has been entered in a non-hazardous category, no further assessment is required and the entry is finalized as non-hazardous. Similarly, if a waste has been entered in a hazardous category, it is hazardous without any further assessment. However,

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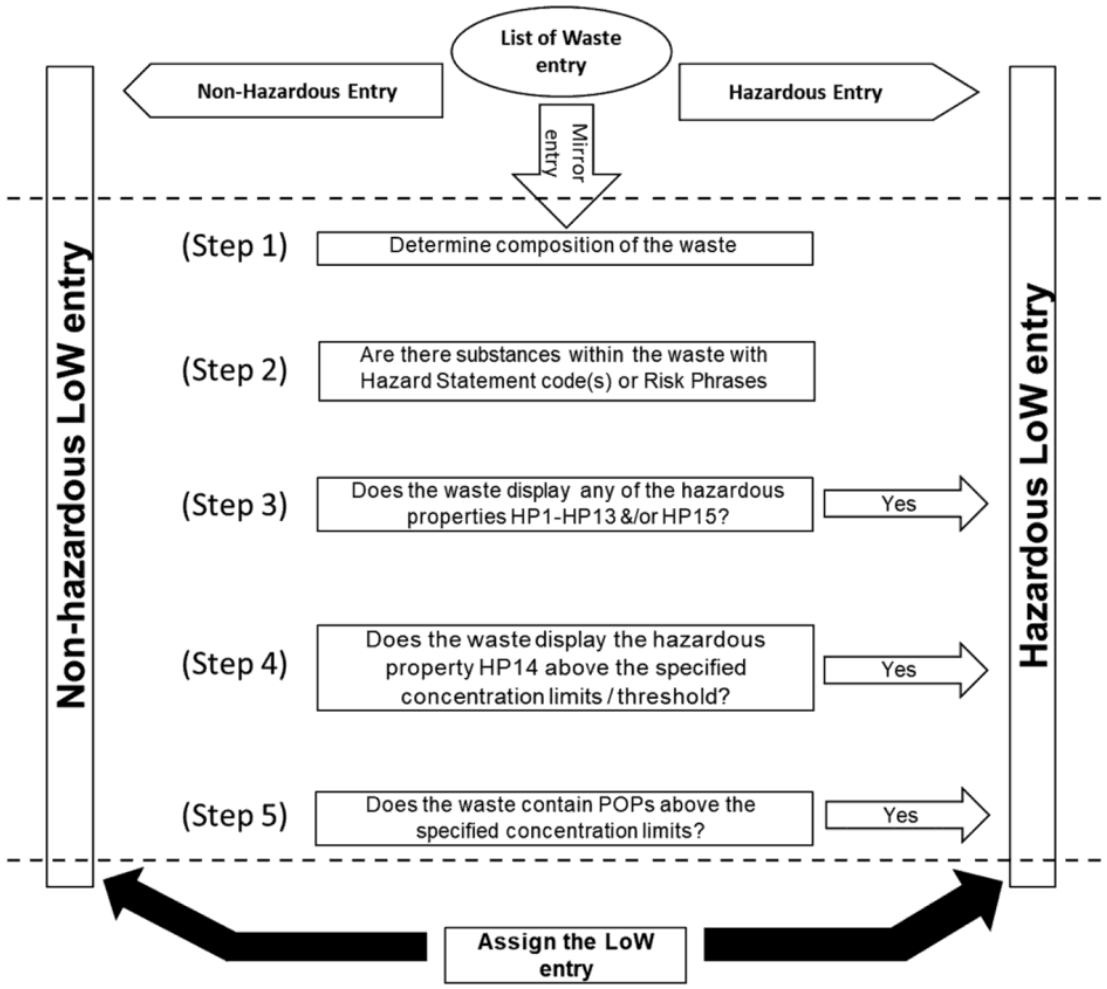

Figure 2.2 Steps for determination of hazardous waste entry. Reproduced with permission from: EPA Ireland.[8]

provisions and directives are in place to rectify any entry based on evidence.

Moreover, if the list has a mirror entry, it is dealt with in accordance with the second element:

2. Determining if waste is hazardous or non-hazardous: ''If the waste has a mirror entry, it must be subject to further assessment to determine if it is hazardous or not''. The necessary steps are outlined in Figure 2.2.

Various classes of hazardous waste and a few examples are compiled in Table 2.1.[10,11] This table illustrates the similarity between UN class number and EPA identification number of hazardous waste classification.

2.2.1.5 Tests for Hazardous Wastes

Various physical and chemical tests are required to identify several waste characteristics so that optimum and efficient treatment and disposal guidelines can be formulated. These test method numbers, listed by the

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Table 2.1 Various classes of hazardous waste with EPA Ireland identification number.

UN class number (1989)	Characteristics	Types	Examples	Similar EPA identification number
1	Explosives	Projection, mass explosion, minor hazard	Ammonium perchlorate, cyclonite, explosive articles	D003
2	Gases	Poisonous, flammable gas, non-flammable gas	Compressed oxygen, butane, ammonia	D001
3, 4	Flammable solids and liquids	Low flash point range, medium flash range, high flash range	Acetone, alcohol, diethyl ether	D001
		Flammable solids, spontaneous combustion, emitting flammable gases when wet	White phosphorus, yellow phosphorus, alkali metals	
5	Oxidizing substances	Oxidizing compounds of all types	Sodium peroxide, potassium permanganate, potassium superoxide	D002
6	Infectious substances	Poisonous agents, infectious agents	Arsenic, clinical waste	D003
7	Radioactive materials	Radioactive compounds of all kinds	Uranium	D003
8	Corrosives	Corrosive in nature	Mineral acids, organic acids, strong bases	D002
9	Toxic	Toxic to the ecosystem or society	Environmentally hazardous chemicals	D004–D043

EPA,[12] are summarized in Table 2.2. The choice of appropriate method depends upon the detail of the information sought for final treatment/disposal. Moreover, to choose the correct method, some basic information is necessary, which includes the following:

1. Physical state of the sample: aqueous, solid, volatile, sludge, multi-phase sample.
2. Analytes of interest: organic (carbon compounds) or inorganic (metals and anions).
3. Analytical sensitivity required.
4. Analytical objective: screening methods/composite sampling, *etc.*
5. Purpose of testing: quantitation or monitoring.
6. Information regarding sample containers and holding time.

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Table 2.2 Applicable method numbers for various tests of hazardous waste.

Applicable determinative method numbers for:		
Organic analyses	Inorganic analyses	Miscellaneous methods
8000D, 8011, 8015C, 8021B, 8031, 8032A, 8033, 8041A, 8061A, 8070A, 8081B, 8082A, 8085, 8091, 8095, 9100, 8111, 8121, 8131, 8141B, 8151A, 8260B, 8261, 8270D, 8275A, 8276, 8280B, 820A, 8310, 8315A, 8316, 8318A, 8321B, 8325, 8330A, 8331, 8332, 8410, 8430, 8440, 8520	6010D, 6020B, 6200, 6500, 6800, 7000B, 7010, 7061A, 7062, 7063, 7195, 7196A, 7197, 7198, 7199, 7470A, 7471B, 7472, 7473, 7474, 7580, 7741A, 7742	5050, 9000, 9001, 9010C, 9012B, 9013A, 9014, 9015, 9016, 9020B, 9021, 9022, 9023, 9030B, 9031, 9034, 9035, 9036, 9038, 9056A, 9057, 9060A, 9065, 9066, 9067, 9070A, 9071B, 9075, 9076, 9077, 9131, 9132, 9210A, 9211, 9212, 9213, 9214, 9215, 9216, 9250, 9251, 9253, 9320

2.3 Waste Generators

A waste generator may be any person who produces a hazardous waste. As the quantity of generated waste may vary, the EPA has categorized generators in three different categories, based on the quantity of hazardous waste generated each month,[13] as follows:

1. very small quantity generators (VSQGs);
2. small quantity generators (SQGs); and
3. large quantity generators (LQGs).

Identification of the generator category is essential for all of the generators. The criteria for determining the category are given in Table 2.3.

There are certain requirements for all waste generators, as described in 40 CFR Part 262,[13] and some of those regulations are as follows:

1. Very small quantity generators (VSQGs):
   - VSQGs must identify all the hazardous waste generated.
   - VSQGs may not accumulate more than 1000 kg of hazardous waste at any time.
   - VSQGs must ensure that hazardous waste is delivered to the authorized person or facility only.
2. Small quantity generators (SQGs):
   - SQGs may accumulate hazardous waste on-site for 180 days without a permit (or 270 days if shipping a distance greater than 200 miles).
   - The quantity of hazardous on-site waste must never exceed 6000 kg.
   - As SQGs are not required to have detailed contingency plans, there must always be at least one employee available to respond to an emergency, who is responsible for coordinating all emergency response measures.

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Table 2.3 Generator categories based on quantity of waste generated in a calendar month. Source: Electronic Code of Federal Regulations.[13]

Quantity of acute hazardous waste generated in a calendar month	Quantity of non-acute hazardous waste generated in a calendar month	Quantity of residues from a cleanup of acute hazardous waste generated in a calendar month	Generator category
>1 kg	Any amount	Any amount	Large quantity generator
Any amount	≥1000 kg	Any amount	Large quantity generator
Any amount	Any amount	>100 kg	Large quantity generator
≤1 kg	>100 kg and <1000 kg	≤100 kg	Small quantity generator
≤1 kg	≤100 kg	≤100 kg	Very small quantity generator

3. Large quantity generators (LQGs):
   - LQGs may only accumulate waste on-site for 90 days. Certain exceptions apply.
   - LQGs do not have a limit on the amount of hazardous waste accumulated on-site.
   - LQGs must submit a biennial hazardous waste report.

Both SQGs and LQGs must manage their hazardous waste in tanks or containers and must comply with the manifest requirements mentioned in 40 CFR Part 262.

2.4 Sampling and Analysis of Hazardous Waste

One of the most basic and important foundations of the RCRA hazardous waste program is the need presented to waste generators for treatment, storage and disposal facilities first to conduct a proper analysis and identification for all the hazardous wastes that are generated, treated, stored or disposed of at their facility, through waste testing and/or acceptable knowledge related to the waste. Waste analysis refers to both testing and application of acceptable knowledge and it involves the identification and subsequent verification of the chemical and physical characteristics and composition of the waste by performing a detailed physicochemical analysis on a representative sample of the waste.[8]

Major stakeholders are (a) waste generators and (b) treatment, storage and disposal facilities (TSDFs), and the majority of the RCRA's waste analysis requirements are applicable to these hazardous waste generators and TSDFs. These clients may pose or have various concerns relating to the quality of waste, which in turn may help in identifying suitable disposal mechanisms,

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etc. The analysis of waste fulfils many such objectives concerning the client. Some such concerns are as follows:

1. Waste producers may want to assess the kind of recovery/disposal that is possible.
2. Managers of waste treatment plants need to know if they can accept and will be able to treat the waste.
3. Authorities are interested in the environmental effects related to a particular waste type.

Hence "waste analysis" and subsequent development of a "waste analysis plan" (WAP) become a pivotal activity which ensures that the treatment and disposal facility complies with the applicable regulations. However, there are certain analytical and other related requirements that must be fulfilled by both the generators and TSDFs. The RCRA generator standards are generally applicable for LGQs and SGQs only.

2.4.1 Waste Analysis Requirements for Generators

Anyone who generates a solid waste is obligated to determine if the waste is hazardous or not. The preparation of a WAP is not mandatory for generators unless they are required to manage and treat the waste or contaminated soil in tanks, containers or containment buildings to meet applicable treatment standards.[13] Figure 2.3 provides a summary flowchart of waste analysis and analytical requirements that are applicable for generators.

2.4.2 TSDF Waste Analysis Requirements

As a TSDF, compliance with the applicable §§264/265.13 requirements for waste analysis and WAPs is a necessity. Part 264 of the CFR covers the requirements for permitted facilities/units, whereas Part 265 covers interim status facilities/units.[13]

If the TSDF relies on generator-supplied information only, it is important for the TSDF concerned to review and verify the supplied information and ensure its adequacy.

Hence the transformation of waste-related information among the TSDFs, the generators and other stakeholders becomes very important. For example, if a generator or TSDF ships out the waste to an off-site facility, it is mandatory to provide the waste profile data (analytical data, source of waste, *etc.*). These data are important for the treatment facility to accept the waste in their facility. One very important stakeholder, other than generators and TSDFs, is "hazardous waste transporters", who also have to have detailed data pertaining to the waste they are handling. It is advantageous for all the stakeholders to provide detailed information among themselves to ensure compliance (Figure 2.4).

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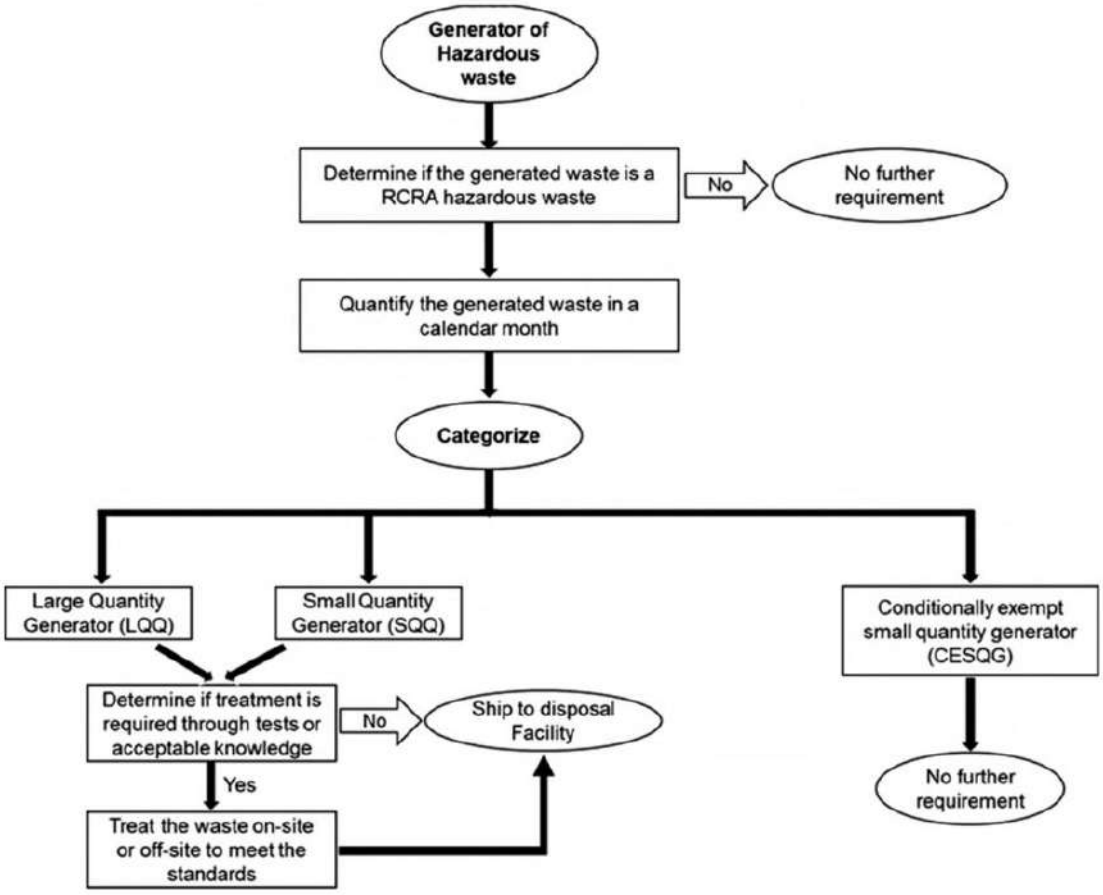

Figure 2.3 Waste analysis requirements for generators.

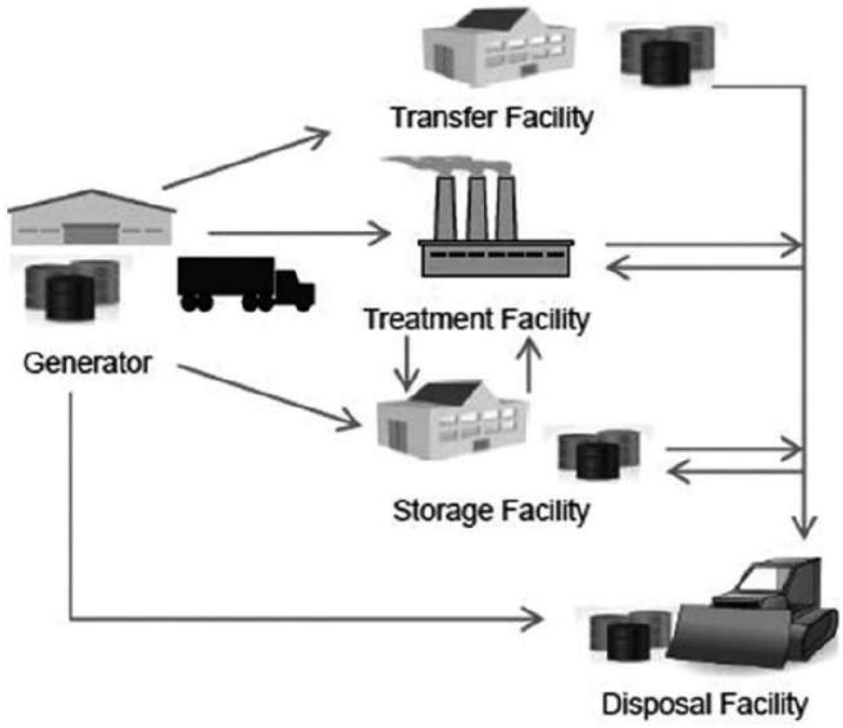

Figure 2.4 Waste analysis data transformation.
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2.4.3 Sampling and Analysis for TSDFs

For a TSDF, all the waste analysis requirements can be satisfied through waste sampling and analysis. Moreover, for a new facility or in the absence of detailed information by the generator, there is a need for frequent sampling and a higher quality of analysis. Sampling and analysis reports may be used to document compliance at the facility.

2.4.3.1 Pre-acceptance Sampling and Analysis

A TSDF receiving waste from any facility must confirm various waste characteristics at the time of pre-acceptance. This will ensure that the TSDF would not accept any waste that it is not permitted to handle. Moreover, this ensures that the TSDF can manage the accepted waste effectively and in accordance with the regulations.

2.4.3.2 Waste Acceptance (Fingerprint Analysis) Sampling and Analysis

Fingerprint analysis can include detailed instrumental analysis in laboratories, may make use of field testing kits and screening instruments or may involve visual observations (as in the case of color identification, *etc.*), although the specific information sought for acceptance of the waste may vary according to the waste type, accuracy and permission required to fulfill the permit requirements and the primary objective of waste acceptance.

There are two vital objectives of all the waste acceptance sampling and analysis:

- making sure that the parameters which are being tested (*e.g.* pH) meet all the permit requirements and are well within the acceptable limits required for effective treatment and management; and
- verifying that the waste that is being shipped in is the same waste that was approved during pre-acceptance.

2.4.3.3 Use of Acceptable Knowledge

There are times when acceptable knowledge proves to be very useful in providing information before pre-acceptance of the waste and also checking the compliance with permit regulations. However, some situations may arise where dependence on acceptable knowledge alone may prove to be fatal. Furthermore, the EPA has recognized that, since accuracy in waste identification is essential, acceptable knowledge may prove to be more economical and convenient than sampling and analysis, it is prudent to go through the rigorous process of ‘‘waste analysis’’.

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2.4.4 Conducting Waste Analysis

Conducting waste analysis and preparing a WAP constitute a very rigorous exercise that helps a facility to conduct and document its analytical methods and procedures. Based on an EPA Ireland document,[8] the various stages involved in waste analysis conduction are summarized in Figure 2.5.

2.4.5 Quantifying the Data Uncertainty

Waste handlers make use of analytical data to make certain decisions and determine if these decisions are supported with sufficient data evidence. For example, if the waste to be managed has elevated levels of a certain pollutant, this could cause potential damage to the managing unit and consequentially may incur regulatory penalties. Hence the unit is likely to minimize the uncertainty behind the decision and increase the confidence level behind the decision taken.[8,14,15]

2.4.6 Need for Re-evaluation and Record Keeping

"The RCRA regulations require that waste analysis performed under 40 CFR 264/265.13(a)(1) be repeated as necessary to ensure that it is accurate and up to date".[8] The important decision to make is determining the re-evaluation frequency and the EPA Ireland document[8] discusses various approaches for this purpose. However, it is important that the facility keeps accurate records of the previous data, which can be accessed whenever necessary for comparison with the present data. Hence "record keeping is an essential aspect of waste analysis, as it documents whether the analyses were done in accordance with required and acceptable procedures".[8]

2.5 Storage, Transport and Disposal of Hazardous Waste

Once the characterization and identification are complete, waste is sent to the storage facility, where it is kept temporarily and subsequently transferred to the disposal or treatment facility.

2.5.1 Storage of Hazardous Waste

The waste resides in the storage facility for a limited time period, after which it is treated and sent to the disposal facility. Generally, the storage facility shall not be provided at the place of generation; however, it might be allowed if the waste is kept in special storage tanks. The primary task of segregation of waste must be carried out with extreme caution and attention. The containers must be kept clean along with the storage facility. Leakages must be

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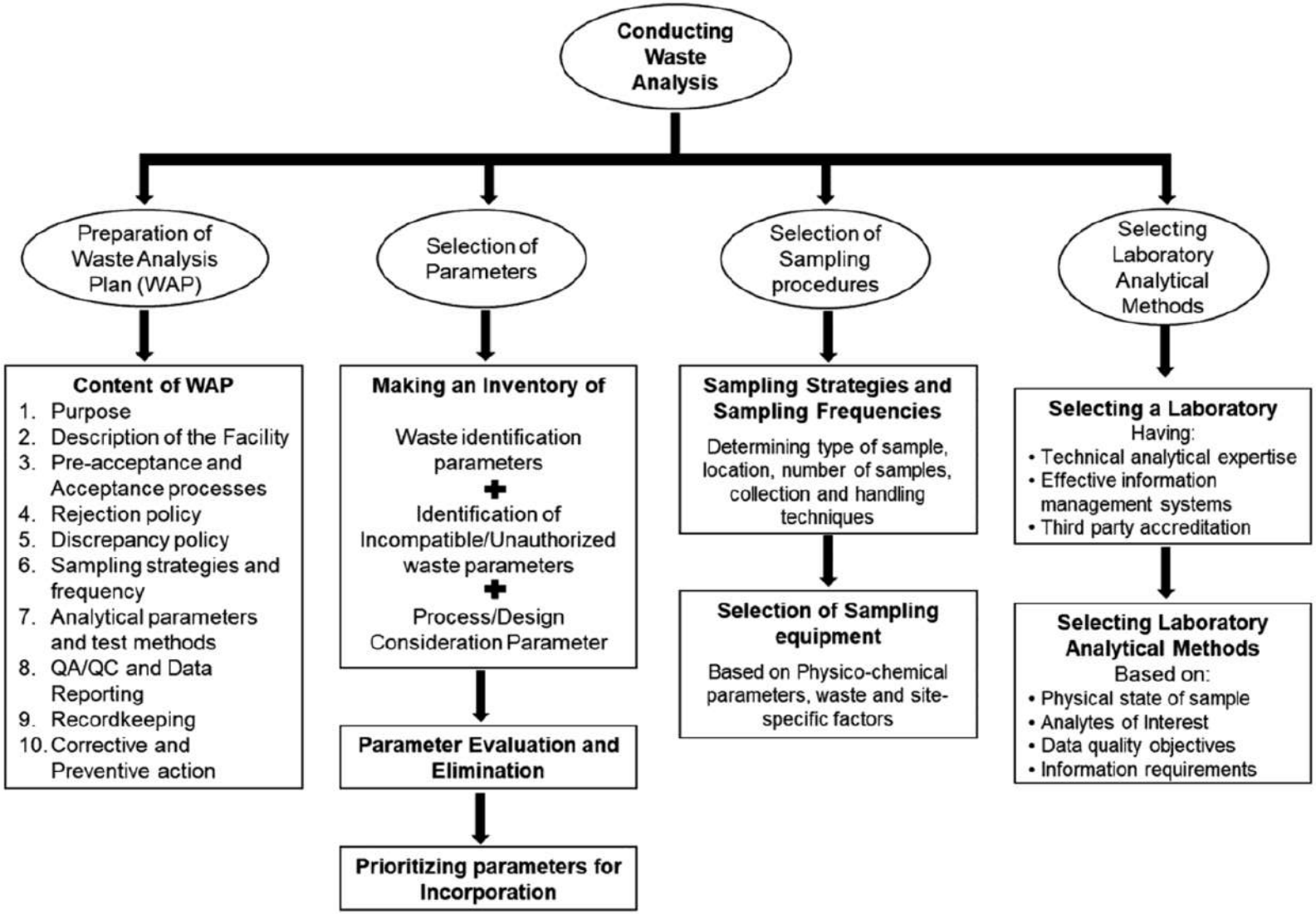

Figure 2.5 Summary of waste analysis procedures and parameters.

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carefully checked for and avoided. Some important points that must be kept in mind are the following:

- Pollution control equipment such as water spray systems, masks, *etc.*, must be kept at the storage facility.
- The storage facility must have all the necessary guidelines in case any accident occurs.
- The facility must be inspected regularly to keep a check on any deficiency and subsequently avoid any potential accidents.
- There must always be additional containers and workers present or kept at standby as an additional safety measure.
- Proper labeling and regular cleaning of containers must be ensured.
- The maximum storage period is 90 days.
- Special care must be taken when storing hazardous chemicals, as they are subject to further reactions and may undergo explosions. The content of containers having hazardous chemicals must be clearly mentioned along with a mention of any special storage or handling requirement, if any.
- The quality of containers must not be compromised.
- Cover to protect against rain must be provided.

2.5.2 Transport of Hazardous Waste

Transportation of hazardous waste is a very important and crucial aspect in the complete hazardous waste management system, since it requires precise practices to ensure safe transfer and disposal of wastes. Hence it is prudent for the transfer facilities to make sure that they have the required level of expertise and conform to the mandatory registration and other licensing requirements of the state authority in question. This would in turn also enable the governing authorities/bodies to ensure safe and secure transport of hazardous wastes. Some key considerations are as follows:

- As a transporter it is prudent to ensure that the waste generators transport their hazardous waste only in the specified transport vehicles.
- Moreover, it is customary to train the drivers and attendants of the transport vehicles to handle any emergency situations.
- The vehicles must be dedicated for transport of hazardous waste only and must be leak-proof and covered.
- Vehicles must have a license and a no-objection certificate from the governing authorities.
- The containers must be sealed, especially if they contain liquid waste.
- It must be ensured that reactions must proceed inside the containers, hence the stability of the base will be maintained.
- The containers should be able to bear the shocks and jerks resulting from vibrations and undulations of the road, *etc.*
- The emptying process must be easy and risk free.

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- Mechanical loading and unloading procedures must be designed to minimize the risks.
- Labels must be waterproof and marked clearly in both English and the regional language. It must also withstand the effects of sunlight.
- The label of the previous contents must be removed to avoid any confusion or mishandling.
- The label must include the waste code number, the type of waste, its origin (basic information of the generator), hazardous properties (*e.g.* flammable, explosive) and the symbol stating the hazardous properties (symbol for biohazard, flammability, *etc.*). Some common labels are presented in Figure 2.6.
- A no-objection certificate for interstate transfer of the waste must be obtained beforehand to avoid any delay.
- For ease of identification of vehicles carrying hazardous waste, they must be painted differently to the regular vehicles, to prevent unfortunate accidents.

2.5.3 Technologies for Hazardous Waste Management

The treatment of hazardous waste can be broadly classified into physical, chemical and biological methods of treatment followed by disposal of waste and residues.

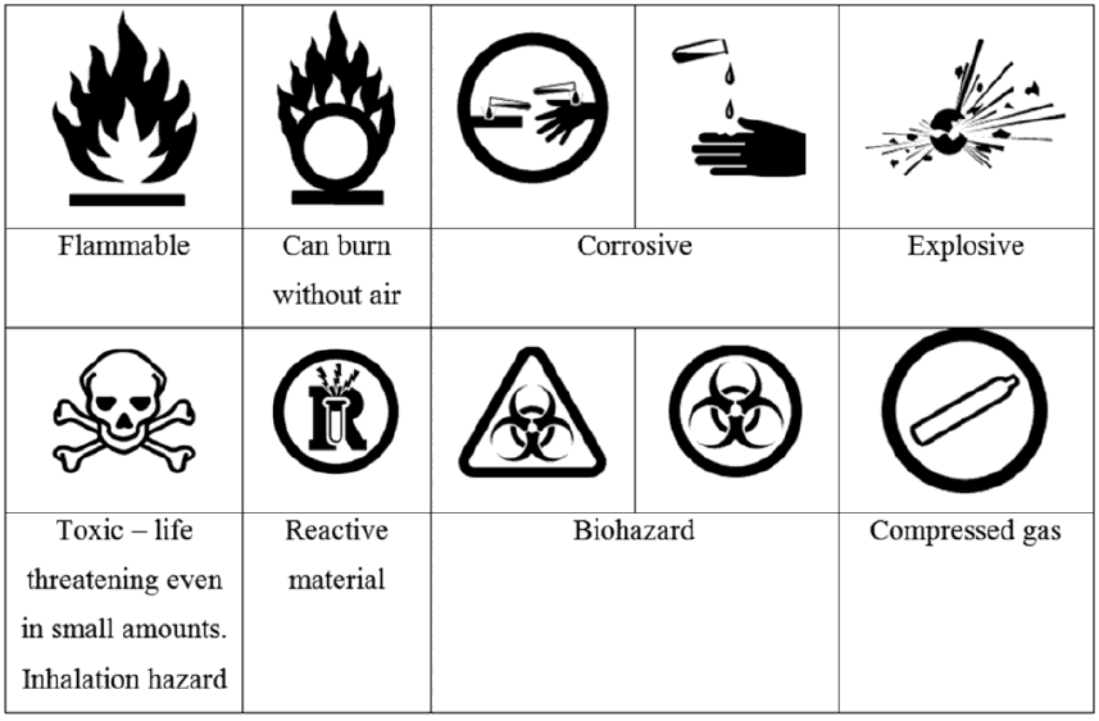

Figure 2.6 Some hazardous waste property symbols. Reproduced with permission from: US EPA.[16]

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2.5.3.1 Physical Methods of Treatment

Physical methods of treatment make use of the physical characteristics of the waste constituents to separate the hazardous constituents in a waste stream, wherein residues are further treated and ultimately sent to ultimate disposal. Some of the key methods are discussed in the following subsections. Table 2.4 presents a summary of physical treatment technologies and processes.

2.5.3.1.1 Separation Through Sedimentation. Sedimentation is a Type I settling process in which gravity causes heavier particles to settle and they are collected at the bottom of the sedimentation tank.[17] Sedimentation can be adopted only when there is a difference in the specific gravities of the constituents in the mix of wastes.

2.5.3.1.2 Separation Through Centrifugation. Components of a fluid mixture can be separated using the process of centrifugation, where the use of centrifugal and centripetal force is used to collect the heavier particles through the center of the equipment. Centripetal forces are much stronger than gravitational forces and hence are better for separating waste mixtures. However, centrifugation is generally limited to dewatering

Table 2.4 Physical treatment operations and processes. Reproduced from ref. 26 with permission of Elsevier. Copyright 2019.

No.	Type of technology	Operations[a]	State of waste[b]	Waste constituents[c]
1	Aeration process	Se	L	1, 2, 3, 4
2	Air stripping process	Se	S, L	3, 4
3	Ammonia stripping	VR, Se	L	1, 2, 3, 4
4	Carbon absorption process	VR, Se	L, G	1, 3, 4, 5
5	Centrifugation process	VR, Se	L	1, 2, 3, 4, 5
6	Dialysis process	VR, Se	L	1, 2, 3, 4
7	Distillation process	VR, Se	L	1, 2, 3, 4, 5
8	Electrodialysis	VR, Se	L	1, 2, 3, 4, 6
9	Encapsulation	St	L, S	1, 2, 3, 4, 6
10	Evaporation process	VR, Se	L	1, 2, 5
11	Filtration process	VR, Se	L, G	1, 2, 3, 4, 5
12	Flocculation process	VR, Se	L	1, 2, 3, 4, 5
13	Flotation process	Se	L	1, 2, 3, 4
14	Ion-exchange process	Se	L	2, 4
15	Reverse osmosis process	VR, Se	L	1, 2, 3, 4, 6
16	Sedimentation process	VR, Se	L	1, 2, 4, 6
17	Steam stripping process	Se	S, L	3, 4
18	Thickening process	Se	L	1, 2, 3, 4, 5
19	Vapor scrubbing process	VR, Se	L	1, 2, 3, 4

[a]Se, separation; St, storage; VR, volume reduction.
[b]S, solid; G, gas; L, liquid.
[c]1, Inorganic chemical without heavy metal; 2, inorganic chemical with heavy metal; 3, organic chemical without heavy metal; 4, organic chemical with heavy metal; 5, radiological; 6, biological.

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of sludge, separation of oils from water and clarification of viscous gums and resins.[18]

2.5.3.1.3 Coagulation and Flocculation. Coagulation and subsequent flocculation aid the sedimentation process, wherein a coagulant (polymer, alum, *etc.*) is added, which helps with the agglomeration of particles and a floc is formed that becomes heavy and settles. Flocculation is used primarily for inorganics. Various studies have reported the use of coagulants to remove the characteristic wastes successfully. Peng and Wang[19] successfully treated pulp mill effluent with a hydraulic retention time of 16.3 min. Fox *et al.*[20] made use of ferric salts with cactus mucilage as a coagulant and removed up to 96% of arsenic within 30 min.

2.5.3.1.4 Filtration. Filtration is another suitable technique for physical treatment and many advanced filtration methods have evolved over the years. Abdullah *et al.*[21] achieved the successful removal of lead using a polysulfone–hydrous ferric oxide nanoparticles ultrafiltration mixed-matrix membrane. Mondal and De[22] used hollow-fiber nanofiltration membranes and successfully treated textile plant effluent for dye removal.

2.5.3.1.5 Adsorption. Adsorption is used for the removal of pollutants in many environmental systems. Grover *et al.*[23] studied the uptake of arsenite by layered double hydroxides, hydrotalcite and hydrocalumite and achieved a removal efficiency of 80%. Xu *et al.*[24] achieved a removal efficiency of 99% under optimal conditions to remove copper using ZnS nanocrystals. Similarly, Cheng *et al.*[25] reported a removal efficiency of 99% of As(III) using an Fe–Al bimetallic composite.

2.5.3.2 Chemical Methods of Treatment

The basic principle behind the chemical treatment process is alteration of the chemical structure of the constituents, which produces residues that are less hazardous than the original waste. Various operations and processes are summarized in Table 2.5 and are discussed in the following subsections.

2.5.3.2.1 Neutralization. Neutralization is a pH adjustment procedure to make a balance between hydrogen ions (H^+) and hydroxyl ions (OH^-). Some of the applicable wastes are pickle liquors, plating wastes, mine drainage and oil emulsion breaking.[27] It is the least expensive form of chemical treatment.

2.5.3.2.2 Chemical Precipitation. This is also a pH adjustment process, in which acid or base is added to adjust the pH such that the constituent that needs to be removed is at its lowest solubility and is precipitated out. This method is mostly used for dissolved metals.

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No.	Type of technology	Operations[a]	Waste constituents[b]
1	Alkali metal dechlorination	De, Se	1, 2, 3, 4
2	Calcination	VR	1, 2, 5
3	Neutralization process	De	1, 2, 3, 4
4	Oxidation process	De	1, 2, 3, 4
5	Chemical precipitation	VR, Se	1, 2, 3, 4, 5
6	Reduction process	De	1, 2, 3, 4
7	Solvent extraction process	Se	1, 2, 3, 4
8	Sorption	De	1, 2, 3, 4, 5
9	Ozonation	De	4, 6

[a]De, detoxification; Se, separation; VR, volume reduction.
[b]1, Inorganic chemical without heavy metal; 2, inorganic chemical with heavy metal; 3, organic chemical without heavy metal; 4, organic chemical with heavy metal; 5, radiological; 6, biological.

2.5.3.2.3 Chemical Hydrolysis. Hydrolysis can be achieved through adding chemicals (acid hydrolysis), irradiation (photolysis) or biologically (enzymatic bond cleavage) where cleavage of bonds takes place, in a molecule that is generally insoluble in water such that it goes into ionic solution with water. Special care must be taken that the heavy metals are not mobilized.

2.5.3.2.4 Ultraviolet Photolysis. The process of detoxification or destruction of hazardous chemicals in aqueous solutions with the help of ultraviolet (UV) radiation is known as UV photolysis (*e.g.* degradation of dioxins in waste sludge). However, since UV radiation cannot penetrate soil or opaque solutions, this method cannot be used for pollutants in such media.

2.5.3.3 Biological Methods of Treatment

Biological degradation of hazardous constituents is one of the most practicable and feasible options in a comprehensive waste management process and makes use of microorganisms to degrade and detoxify the hazardous wastes from water and soil. In recent times, a large number of studies have been focused mainly on identifying new such species and re-engineering the processes.

2.5.3.3.1 Aerobic Treatment. Generally, microorganisms break down hydrocarbons into simpler compounds through aerobic respiration, anaerobic respiration and fermentation. However, aerobic degradation processes are preferred as they are rapid and more complete and hence do not produce a large quantity of by-products. Amanatidou *et al.*[28] found low solid accumulation while observing the degradation of particulate organic chemicals. In a study by Chamorro *et al.*,[29] it was found that more than 85% of BOD_5 and 100% removal of stigmasterol took place in Kraft mill effluents.

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Such methods, however, are limited to low levels of halogenated organics (BOD $<10\,000$ mg L^{-1}).

2.5.3.3.2 Activated Sludge. There are number of modifications along with the conventional process. In this process, activated sludge (one with aerobic microorganisms) is recirculated back into the aeration tank to achieve higher degradation of organic compounds. This process is not suitable for streams containing highly chlorinated organics, amines and aromatic compounds. Moreover, volatile hazardous compounds may also escape during the process.[18]

2.5.3.3.3 Rotating Biological Contactors. This is another aerobic treatment method especially used for waste streams containing alcohols, phthalates, phenols, ammonia and cyanides. Solids are also removed in this process as part of the primary treatment. Similarly to the activated sludge process, streams containing highly chlorinated compounds are not suitable for treatment by this method.

2.5.3.3.4 Bioreclamation. This process makes use of aerobic microbial degradation to treat contaminated areas, easily adopted through *in situ* treatment (either through injection/extraction walls or an excavation process). The applicability of this process is limited by the site geology and hydrological conditions.[18]

2.5.3.3.5 Anaerobic Digestion. The primary end products of all anaerobic digestion processes (achieved through bacteria that survive in an oxygen-free environment) are methane and carbon dioxide. Systems operating with this process generally require long retention times. Many variants of this technology are commercially available but the basic principle remains the same. The applicability is limited by the concentration of organics.

It can be seen that almost all the bioremediation methods work with liquid waste that does not have high heavy metal concentrations and are generally detoxifying processes.

2.5.3.4 Thermal Treatment

Thermal treatment methods are generally applicable to all kinds of wastes and are considered to be a good energy recovery option compared with other methods. Some of these methods are discussed in the following subsections.

2.5.3.4.1 Incineration. Combustion is one of the non-hazardous and energy recovery options pertaining to the management of hazardous waste. The various such processes include liquid injection incineration (special nozzles introduce the liquid waste into the incineration chamber), rotary kiln incineration (rotation is used to cause agitation in the solid waste to

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achieve maximum burning) and fluidized bed incineration (use of an inert granular bed material for efficient transfer of heat). Among these, the fluidized bed reactor requires high maintenance and frequent cleaning and is not ideal for bulky materials, whereas most types of waste can be incinerated in a rotary kiln. In addition, industrial kilns are also used but require much longer times due to lengthy retention durations. Blast furnaces use very high temperatures (~1649–1872 °C) and hazardous waste with a high heat content acts as a fuel for these furnaces. Infrared radiators are also used for the destruction of hazardous waste, which results in low particulate emissions and low fossil fuel usage. The end product of most of the incineration processes is ash, which can be used in filling of low-lying areas and is also being used as a replacement for sand, soil, cement, *etc.* by many researchers across the globe.[30–32]

2.5.3.4.2 Pyrolysis. When the waste is chemically decomposed by heating the material under anaerobic conditions, the process is called pyrolysis. Direct and indirect methods of heating are practiced, with temperatures ranging between 500 and 800 °C; the direct methods produce a combination of combustion gases and volatiles from the waste and the indirect methods allow product recovery, but it is more complex and expensive. The limitation of this process is that the input waste capacity is small and it requires an auxiliary fuel.[18,26]

Advanced electric reactors also pyrolyze waste using electrically heated fluid walls, which results in thermal radiation causing pyrolysis of the organic constituents of the waste fed into the system. The primary advantage with this type of reactor is its portability.

2.5.3.4.3 Wet Air Oxidation. This process uses elevated temperature and pressure to oxidize dissolved or finely divided organics that are too dilute to be incinerated economically. Off-gas treatment is also necessary in this process and it cannot be used to treat large volumes of waste. A modification to this process is supercritical water oxidation, where supercritically heated water (above 500 °C), which acts as an excellent solvent for organic materials, is used.

2.5.3.4.4 Molten Salt Destruction. This method simultaneously burns the organics while sorbing the objectionable by-products from the effluent stream, accomplished through mixing air and waste in a pool of sodium carbonate. It is used in the treatment of wastes with low ash or high chlorine contents.[18]

A molten glass pool is also used as a mechanism to transfer heat for the destruction of organics while capturing ash and inorganics. Most wastes can be treated using this technology and a significant volume reduction is obtained. However, waste with a high ash or soil content cannot be treated by this method and it also requires off-gas treatment.

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2.5.3.4.5 Plasma Torch. In this process, the waste is brought into contact with a gas, energized to its plasma state by an electrical discharge. The temperature in the centerline of the torch reaches up to ~5000 °C, which ionizes the gas and subsequently the ionized gas molecules transfer the energy to the waste and cause pyrolysis. This method can destroy refractory compounds.[18]

2.5.4 Disposal of Hazardous Waste – TSDF

The final and most vital step in any hazardous waste management plan is the suitable and efficient disposal of the waste. However, efficient disposal is very dependent on other stages since its effectiveness depends largely upon the process of collection, transfer and treatment. Based on the disposal pathway suggested by fingerprint analysis, the waste is taken for its final disposal. In general, the easiest and most practiced option for disposal is to dump the waste in landfills. However, in recent years many countries have started to think along the line of ''zero landfill''. Incineration is also a disposal practice that is safe provided that there are dedicated waste incinerators. Hence a comprehensive hazardous waste management facility must consist of waste stores, laboratories, dedicated incinerators, reuse/recycling plants, arrangement for transfer and a secure landfill (especially for inert waste).

The selection of a particular disposal option depends upon several factors, such as the capital investment required, operational and maintenance expenses, technical requirements, *etc.* However, it is advisable to adopt more than one disposal option.[33] Since incineration has already been discussed, the other suitable options for waste disposal are briefly considered in the following subsections.

2.5.4.1 Immobilization

When the toxic waste is mixed with certain materials that tend to form an impermeable solid matrix around the waste, it is called immobilization, as the waste is fixed/trapped inside the matrix. This can be achieved through physical, chemical or physicochemical mechanisms. Cement, polymeric sulfur and resins are some of the substances used to immobilize wastes containing organic compounds. Immobilization can be achieved through solidification techniques or stabilization techniques.[33] A comparative analysis of these techniques is presented in Table 2.6.

2.5.4.2 Landfills

A secure landfill is one that contains hazardous waste, but without any seepage/percolation of leachate into the ground. To fulfill this requirement, the basic design considerations involve the following:

- a layer of natural mineral liner followed by synthetic liner;
- a well-designed drainage system to collect leachate;

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Table 2.6 Comparison of immobilization techniques.

	Cement-based solidification	Lime-based solidification	Organic polymer technique (urea–formaldehyde process)	Thermoplastic encapsulation
Brief description	Formation of a monolithic, rock-like structure around the waste using Portland cement and additives (fly ash, *etc.*)	Mixing of inorganic sludge with lime and additives (fly ash, kiln dust, *etc.*) to form pozzolanic concrete	Mixing of an organic monomer with the waste using a catalyst resulting in a hardened polymerized mass that entraps the solids while permitting some liquid to escape	Dewatered solid waste is mixed with a thermoplastic polymer (asphalt. bitumen, *etc.*) and heated followed by cooling, allowing the formation of a coating over the waste
Applicable waste	Waste sludge contaminated with heavy metals or traces of radioactivity is present	Commonly used for inorganic hazardous compounds	Both wet and dry sludge	
Advantages	• Cost-effective • Simple operation • Tolerant of chemical variations	• Cost-effective • Simple operation • Ease of availability	• Drying of polymer mass is not necessary	• Sludge is completely isolated • Secondary container is not required
Limitations	• Increased bulkiness • Organic matter hinders the settling process • Low-strength cement may cause leaching	• Bulky products • Increased chances of leaching	• Catalyst is a strong acid, hence waste may escape with liquid because of increased solubility	• Expensive materials • Polymers used are flammable, hence special care is required

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- provision for a layer of some impervious material (*e.g.* clay) blanketing the landfill and its slopes (this results in minimizing infiltration, permits adequate runoff and avoids spooling of water in the surrounding areas).

Moreover, there must be provision for surveillance or monitoring bore wells, which must be constructed in both the upstream and downstream directions of the landfill used to monitor the quality of groundwater. However, the leachate collected from the landfill and other areas such as waste storage units and laboratories must be treated and disposed of in a ''leachate treatment facility'' using one of the following options:

- solar evaporation;
- forced evaporation;
- treatment in common effluent treatment plants.

Landfills can have different standards, such as having a single liner, double liner, above the ground or below the ground (based on the groundwater table). Consequently, the site selection for secure landfill must include identifying the soil strata, soil and rock characteristics, groundwater profile, flood levels and access to transportation, *etc.*

2.6 Monitoring Procedure for Treatment, Storage and Disposal Facility/Prevention of Environmental Hazard Risks

In this section, various potential environmental hazard risks at disposal sites are discussed. These hazards emphasize the need for frequent monitoring procedures at TSDF facilities.

2.6.1 Fire

There may be several natural reasons that may cause fire at a landfill site that may not always be monitored. However, the primary anthropogenic reasons may involve following:

- disposing of two or more non-compatible wastes together;
- wastes having high ignitability and calorific value;
- wastes having high reactivity with water, air, acids and bases.

The chances of fire due to other operations are very small.

2.6.2 Rain/Storm

Rains or storms create the potential for leachate generation and subsequently may hamper the drainage and leachate collection efficiency.

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Hence, if the landfill is located in areas with heavy or frequent rainfalls, provision of temporary or permanent cover arrangements must be made. Moreover, storm water drains must be constructed and must be efficiently maintained to keep them operational. Waterlogging in the surrounding areas must be avoided, especially in areas with high groundwater levels.

2.6.3 Air Emissions

The major problem emanating from air emissions is the management of ''dust'', which can be managed through spraying of leachate over the landfill and surrounding areas (especially in the summer season), which not only suppresses the dust but also helps in evaporation of leachate. Moreover, depending upon the stack height and the presence of a geologically sensitive site, the locations to install air-quality monitoring stations must be decided. These stations will monitor the total volatile organic compounds (VOCs), suspended particulate matter (SPM), respirable suspended particulate matter (RSPM), NO_x, SO_x, *etc.*, in the ambient air. Moreover, unpleasant odors may be controlled through (a) restriction of the organic content in the wastes and (b) proper compaction and cover. This will also enhance the esthetic appeal of the landfill.[34]

2.6.4 Groundwater and Surface Water Quality Monitoring

In the worst-case scenario of failure of the landfill liner system, the seepage may leach into the groundwater or reach the surface water, which would degrade the quality of the groundwater and surface water. Hence proper care and attention must be exercised during the design, construction and operation of a landfill site. Moreover, activities that may damage the liners must not be allowed at the landfill or nearby areas. It is strongly recommended that the quality of groundwater (through hand pumps, tube wells or monitoring wells) and surface water (through drains and rivers) is regularly monitored. Parameters to be analyzed must include pH, color, electrical conductivity, turbidity, solids concentration, total organic carbon, biological oxygen demand (BOD), chemical oxygen demand (COD), chlorides, nitrates, sulfates, total Kjeldahl nitrogen, total alkalinity, total hardness, pesticides and heavy metals.[34]

2.6.5 Soil Quality Monitoring

Soil samples must be regularly monitored, the recommended parameters being pH, electrical conductivity, color, total dissolved solids, total organic carbon, polycyclic aromatic hydrocarbons (PAHs) and heavy metals. It is strongly recommended that this monitoring is performed on a seasonal basis, *i.e.* in each season through the year. Moreover, any spillage on the roads must be immediately disposed of into the landfill and surrounding areas must be continuously monitored for effective functioning.[34]

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Analysis of Factors Affecting Cost and Time Overruns in Construction Projects



Shubham Sharma and Ashok Kumar Gupta

1 Introduction

Cost overrun and delay in projects is a foremost challenge associated with nearly all projects in the construction industry. Inclination of construction projects towards overruns is because of risk and uncertainties involved in these projects. In developing countries, this problem is more severe as in some projects cost and time exceed double the amount than anticipated [1]. Construction plays an important role in economic growth of a country and also considered as largest generator of employment opportunities. Despite of its importance in development of a country, it has to face many challenges. In construction industry, a project is considered as successful if it meets both the criteria of budget and deadline [2]. Construction projects that fail to meet these criteria will have to face losses in terms of cost and time. To complete the project within budget and deadline, generally quality of project delivered is sacrificed. The major reason for these overruns is the lack of knowledge regarding the factors affecting cost and time. A construction project mainly consists of two major phases, namely pre-construction phase and construction phase. There is a need of applying risk management process in both the stages of the project. Both the stages play an important role in successful completion of project objectives. First stage is mainly about planning, scheduling, deciding budget, etc. Pre-construction is considered an important stage if managed precisely ensures more profits and less uncertainties [3]. Second stage consists of implementation of the things that was planned and scheduled in first stage with continuous monitoring and controlling. Overruns can affect the project objectives in terms of cost, time, quality and productivity [4]. In

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this research for identification and management of overrun in construction projects, we will use framework consisting of three steps, namely identification of factors responsible for overruns, assessment of identified factors and providing mitigation measures [5]. The aim of this research is to identify critical overrun factors present in construction industry and to manage them such that it has minimum negative effects on the project cost and time.

2 Background Study

A number of factors are responsible for cost and time overruns in construction projects. Previous studies have defined cost overrun in a project as the difference between total cost required for completion of project and the estimated/budgeting cost at time of agreement or contract [6, 7]. According to the literature, time overrun is defined as difference between time required for completion of the project and time agreed in agreement or contract for delivering the completed project [8]. The results of past studies clearly state that cost and time overrun badly affects the project as well as the associated construction companies. In some case, even companies go bankrupt due to these overruns [9]. So, there is need of systematic study of these overruns which can provides clarity about the critical overrun factors involved. The first step suggested by literature is identification of factors involved in construction projects. This is an important step as without knowing what factors are involved, we cannot proceed further [10]. Next step is assessment of the identified overrun factors. This step will help us in identifying critical factors having maximum impact on overruns. Last step is suggesting mitigation measures and continuous monitoring over the construction process. For positive results, monitoring and control are important as new overrun factor can emerge at any time during the construction process.

3 Research Methodology

3.1 Overrun Factors Identification

Starting with the identification of cost and time overrun factors involved in construction projects. A total of forty-four overrun factors were identified through a detailed literature review related to cost and time overruns. Then, these factors were categorized into four major categories, namely project scope, management related, legal constraints faced and site-resource related. Project scope category consists of eight factors, management category consists of six factors, legal-constraint category and site-resource-related category consist of fifteen factors each.

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Table 1 Role and years of experience of respondents

Category	Range	Number of participants
Role of participants	Project manager	19
	Site supervisor	32
	Engineer	41
	Contractor	9
	Consultant	4
Years of experience	<5 years	18
	5–10 years	32
	10–15 years	25
	15–20 years	17
	>20 years	13

3.2 Questionnaire Survey and Respondents

A questionnaire was prepared from the identified overrun factors. It consists of three parts—first part was about respondents' profile and second part was explaining the Likert scale. A five-point Likert scale (1 = very less impact and 5 = very high impact) was used for assessing the impact of overrun factors. A total of 155 survey forms were distributed, out of which 105 completely filled survey forms were collected and used in this research. Data obtained from Likert scale was assessed in Minitab. The survey was conducted in two states of India, namely Punjab and Himachal Pradesh. This survey was filled by respondents involved in dealing with cost and time overruns. The respondents were having different roles like engineer, site supervisor, project manager, contractor and consultant. These survey forms were filled by respondents having experience of working in different parts of India. So, the results of this study can be generalized for all the construction projects. Fifty-five (52.38%) respondents were having experience of more than ten years in construction industry. Number of respondents along with their roles and years of experience are shown in Table 1.

4 Analysis of Data and Results

4.1 Analysis for Reliability of Questionnaire

Internal consistency of overrun factors and questionnaire survey reliability are important aspects to judge whether the survey results are appropriate or not [11, 12]. This was done by using a statistical software named Minitab to check Cronbach alpha. Generally, Cronbach alpha has a value between 0 and 1. Higher the value higher is

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Table 3 Ranking of overrun factors using RII

Overrun ID	Overrun factor	$\sum W$	RII	Rank
OR19	Delay in obtaining permission from authorities	429	0.8171	1
OR10	Poor supervision and site management	418	0.7962	2
OR2	Unrealistic time schedule	416	0.7924	3
OR35	Unforeseen ground conditions	413	0.7867	4
OR31	Lack of skilled professionals	409	0.7790	5
OR3	Change in scope of work	401	0.7638	6
OR12	Poor leadership and management qualities	400	0.7619	7
OR36	Extreme weather conditions	398	0.7581	8
OR7	Rework due to error in execution	397	0.7562	9
OR15	Penalties resulting from low qualities	396	0.7543	10
OR9	Slow decision-making from owner	393	0.7486	11
OR44	Design changes	387	0.7371	12
OR1	Poor preliminary estimates and understanding	383	0.7295	13
OR30	Poor labour productivity	381	0.7257	14
OR11	Improper planning during bidding stage	380	0.7238	15
OR32	Use of improper construction methods	373	0.7105	16
OR16	Conflict between owners and other parties	371	0.7067	17
OR28	Inadequate experience of contractor	369	0.7029	18
OR43	Unrealistic inspection and testing methods	368	0.7010	19
OR4	Disputes in contract documents	367	0.6990	20
OR13	Poor means of contracting	365	0.6952	21
OR17	Changes in government regulations and laws	362	0.6895	22
OR42	Delay in inspection and testing	359	0.6838	23
OR23	Slow response by the consultant's engineers to inquires	357	0.6800	24
OR33	Shortage of manpower	355	0.6762	25
OR21	Working on multiple projects at same time	352	0.6705	26
OR18	Delays in contractors claims settlements	351	0.6686	27
OR40	Change in material prices or price escalation	348	0.6629	28
OR41	Inefficient use of equipment	344	0.6552	29
OR20	Financial constraints of contractors	343	0.6533	30
OR22	Lack of motivation for contractor, e. g. Incentives	342	0.6514	31
OR24	Bribes and corruption	340	0.6476	32
OR37	Inaccurate specification	339	0.6457	33
OR5	Lack of similar work experience	338	0.6438	34
OR14	Poor organizational structure for client or consultant	335	0.6381	35
OR6	Frequent change of sub-contractors	334	0.6362	36

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Table 3 (continued)

Overrun ID	Overrun factor	$\sum W$	RII	Rank
OR29	Consultant or architect's reluctance for change	332	0.6324	37
OR34	Site accidents due to negligence	330	0.6286	38
OR39	Delay in handing over of site	329	0.6267	39
OR26	Theft of material	324	0.6171	40
OR27	Knowledge on construction regulations	321	0.6114	41
OR38	Site accidents due to lack of safety measures	317	0.6038	42
OR25	Hostile political conditions	309	0.5886	43
OR8	Improper knowledge of materials required	297	0.5657	44

Table 4 Categorization of top 15 critical overrun factors

Critical overrun factors categorization	RII	Overall ranking	Ranking within category
Project			
Unrealistic time schedule	0.7924	3	1
Change in scope of work	0.7638	6	2
Rework due to error in execution	0.7562	9	3
Poor preliminary estimates and understanding	0.7295	13	4
Management			
Poor supervision and site management	0.7962	2	1
Poor leadership and management qualities	0.7619	7	2
Slow decision-making from owner	0.7486	11	3
Improper planning during bidding stage	0.7238	15	4
Legal and constraints faced			
Delay in obtaining permission from authorities	0.8171	1	1
Penalties resulting from low qualities	0.7543	10	2
Site and resource			
Unforeseen ground conditions	0.7867	4	1
Lack of skilled professionals	0.7790	5	2
Extreme weather conditions	0.7581	8	3
Design changes	0.7371	12	4
Poor labour productivity	0.7257	14	5

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before it can negatively affect construction project. Poor management and execution of tasks in project will require extra resources to get back on track. So, overrun factors should be managed as soon as they emerge. Site-resource-related category was found to be most critical with five overrun factors in top fifteen. The top five factors recognized with highest value of RII were delay in obtaining permission from authorities with RII value of 0.8171, poor supervision and site management with RII value of 0.7962, unrealistic time schedule with RII value of 0.7924, unforeseen ground conditions with RII value of 0.7867 and lack of skilled professionals with RII value of 0.7790.

For different construction projects, overrun factors may slightly vary. Further scope of this study is similar identification and ranking of critical overrun factors can be done project specific, i.e. considering a particular project like building project, infrastructure project, energy project, etc. Region of project can also be considered as sometimes factors change according to the location of the project. So, this research is significant for engineers, project managers, construction practitioners, risk managers, etc. as they have to deal with cost and time overrun in construction projects.

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Microbial Exopolysaccharides: An Introduction



Kuttuvan Valappil Sajna, Swati Sharma, and Ashok Kumar Nadda

Abstract Microbes secrete high molecular-weight polysaccharides of diverse structures into the surrounding environment termed exopolysaccharides (EPSs). EPSs serve multifarious roles which aid the microbes to thrive at different ecosystems. Many EPSs are industrially/clinically relevant polymers owing to their biocompatibility, biodegradability, non-toxic nature and distinct physicochemical properties. Considering their past success for various applications ranging from hydrocolloids to biomedical applications, microbial EPSs still hold considerable attention of biotechnologists. They are high-value products, and their market value will grow in the coming years due to their potential nutraceutical, therapeutic and industrial potential. The objective of the chapter is to update the readers with recent findings on microbial EPSs. This chapter also gives interesting insights into physiological roles and biosynthesis of microbial EPS. The chapter also discusses the recent advances in applications of microbial EPSs and their commercial prospects.

Keywords Microorganisms · Polysaccharides · Hydrocolloids · Polymers · Biomedical application

1 Introduction

Microbes are the source of many biotechnological products due to their metabolic diversity and ease of cultivation. One such product-exopolysaccharides (EPSs) are widely used as the polymers in various industries owing to distinct physicochemical

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properties, non-toxic nature, biocompatibility, biodegradability and the ease of production. Microbial polysaccharides are of two types—intracellular polysaccharides and extracellular polysaccharides. Extracellular polysaccharides are further classified into capsular polysaccharides that encapsulate the microbes (exocellular polysaccharide) and exopolysaccharide (EPS) which secreted into the surrounding environment [1]. Intracellular polysaccharides are the storage polysaccharides serving as a rapid carbon source under nutrient deprivation [2]. Capsular polysaccharides play a significant role in microbial pathogenesis. The immunogenic property of capsular polysaccharide makes them a good target for vaccine development [3]. EPSs play diverse roles from biofilm formation to pathogenesis.

The first EPS discovered was dextran by Louie Pasteur in the nineteenth century as a microbial product in the wine industry [4]. The contribution by Allene Jeanes in the mass level production of dextran and discovery of xanthan revolutionized the industrialization of microbial EPS. EPSs are high molecular weight compounds with the molecular weight ranging from 0.5 × 106 to 2 × 106 daltons. EPSs may be of homopolymeric or heteropolymeric in sugar composition and can be linear or branched, structurally [5]. Apart from the monosaccharide composition and structural complexity of EPSs, EPSs may contain functional groups such as acetyl, carboxyl, sulfate, phosphate, pyruvate and uronic acid groups, which all determine the physicochemical and biological properties of EPSs.

Microbial EPSs are inevitable for modern human lifestyle as the ingredient in food and personal care formulations. They have immense clinical applications including emergency medicine or an ingredient in pharmaceutical formulations. They are also used extensively in the petroleum industry, household product formulations and construction applications. Considering the current R&D scenario in microbial EPS, their clinical, lifestyle and other implications will be accentuated in the near future. Table 1 summarizes commercially available microbial EPS with potential industrial/clinical applications.

2 Novel Exopolysaccharides with Therapeutic/Industrial Significance

Considering the past success of EPSs for various applications ranging from hydrocolloids to biomedical applications, exopolysaccharide still holds considerable attention of biotechnologists. Many novel EPSs with significant clinical/industrial applications have been reported in the last decade (Table 2). Some of these microbial sources are already known for EPS production. Novel variation in EPS can be pinpointed by investigating the monosaccharide composition of EPS. Strain-specific EPS is encoded by unique EPS biosynthetic genes. Diversity of epsE gene in *Lactococcus lactis* strains result in strain-specific EPS production [25]. Some of the most common sources for the isolation of EPS producing microbes are dairy products, fermented products and plant parts. Identification of lactic acid bacteria

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Table 1 Summarizes commercially available microbial EPS with potential industrial/clinical applications

EPS	Microbial strain	Structure	Industrial/ clinical uses	References
Dextran	*Leuconostocmesenteroids*	α-1,6-Glucan with branching of α-1,3-glycosidic linkage	Clinical applications—plasma volume extender, antithrombotic agent, blood substitute, vascular surgery, drug delivery agent, clinical management of iron deficiency anaemia, preservation solution for organs, and wound healing agent. Other uses—food packaging, photographic uses, separation technology, cell culture techniques and cryoprotectant agent	De Belder [6], Bhavani and Nisha [7], Abir et al. [8], Debele et al. [9], Rutherford et al. [10], Aman et al. [11], Candinas et al. [12], Zhu et al. [13]
Xanthan	*Xanthomonas campestris*	A polymer of D-glucose, D-mannose and D-glucuronic acid	Additive in food, medical and personal care formulations; used as drilling fluid in oil field drilling and building materials for construction applications	BeMiller [14], Akpan et al. [15, Plank [16]
Pullulan	*Aureobasidium pullulans*	Glucan of α-(1-6) and α-(1-4) glycosidic linkage	Food and pharmaceutical additive; oral care ingredient	Singh et al. [17]

(continued)

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Table 1 (continued)

EPS	Microbial strain	Structure	Industrial/ clinical uses	References
Gellan	*Sphingomonas elodea*	A polymer of tetrasaccharide units comprised of D-glucose, D-glucuronic acid, D-glucose L-rhamnose	Food, pharmaceutical and personal care formulation; an additive in household products; also used in tissue culture media preparations	Iurciuc et al. [18]
Curdlan	*Agrobacterium* sp.	(1-3)-β-glucan	Food additive; used in pharmaceutical formulation and drug delivery system	Zhang and Edgar [19]
Scleroglucan	*Sclerotium rolfsii*	β-1,3-β-1,6-glucan	Petroleum recovery; used in nutraceutical and pharmaceutical industry; in food and personal care formulations; construction applications	Castillo et al. [20]
Schizophyllan	*Schizophyllum commune*	β-1,3-β-1,6-glucan	Therapeutic application, cosmetic application	Leathers et al. [21]
Bacterial cellulose	*Acetobacter xylinum*	β-1-4 glucan	Hydrocolloid dressing; cosmetic and textile industrial application	Wang et al. [22–24]

secreting a novel EPS composed of unusual monomer like *N*-acetylglucosamine from a fig leaf highlight the importance of bioprospecting of environmental source such as these for EPS producers [26]. Exploring the ecological hotspots and extreme environments can lead to the discovery of the microbes producing novel EPS with significant biotechnological implications. Delbarre-Ladrat et al. [27] that the majority of bacterial species inhabiting deep-sea hydrothermal vents has the potential of producing structurally diverse high-value EPS, which emphasized the bioprospecting of marine environment for EPS producing microbes.

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Table 2 Novel EPS of therapeutic/industrial significance

EPS	Source organism	Monomeric composition	Potential application	Reference
EPS-NA3	*Lactobacillus coryniformis*	α-rhamnose, α-mannose, α-galactose, and α-glucose	Antioxidant and antibiofilm agents	Xu et al. [28]
α-mannan	*Pseudoalteromonas* SM20310	2-α- and 6-α-mannose	Cryoprotection	Liu et al. [29]
EPS-1 and EPS-2	*Bacillus amyliliquefaciens C-1*	Glucose, mannose, galactose and arabinose (EPS-1); Glucose and mannose (EPS-2)	EPS-1 as an antioxidant agent	Yang et al. [30]
Neutral EPS	*Lactobacillus paracasei* IJH-SONE68	*N*-acetylglucosamine	Anti-inflammatory agent	Noda et al. [26]
Acidic EPS	*Lactobacillus plantarum* SN35N	Glucose, galactose, and mannose	Anti-inflammatory agent	Noda et al. [31]
Pseudozyma EPS	*Pseudozyma* sp. NII 08165	Glucose, galactose, and mannose	Emulsifying and suspending agent	Sajna et al. [32, 33]
DM-1 EPS	*Bacillus licheniformis* strain DM-1	Proteoglycan	In situ microbial enhanced oil recovery	Fan et al. [34]
EPS	*Lactobacillus fermentum* R-49757	D-glucose and D-mannose	Not investigated	Do et al. [35]
EPS-S3	*Pantoea* sp. YU16-S3	Glucose, galactose, *N*-acetyl galactosamine and glucosamine	Wound healing applications	Sahana and Rekha [36]
EPS	*Lactobacillus paraplantarum*	Glucose, galactose and mannose	Emulsifying and texturing agent	Sharma et al. [37]
EPS-SN-1	*Bacillus velezensis SN-1*	Glucose, mannose and fructose	Antioxidant agent	Cao et al. [38]
EPS	*Bifidobacterium breve* Iw01	Rhamnose, arabinose, galactose, glucose, and mannose	Anticancer activity	Wang et al. [22–24]
Nat-103	*Natronotaleasambharensis* AK103^T	Mannose, glucose and glucuronic acid	Antioxidant activity	Singh et al. [39]
EPS	*Lactobacillus mucosae* VG2	D galactan	Not investigated	Fagunwa et al. [40]

3 Physiological Roles and Ecological Aspects of EPS

EPS serve multifarious roles which aid the microbes to thrive in different ecosystems. EPS plays a varying role from biofilm formation, quorum sensing to pathogenesis and the functions depend on ecological niche of host organisms. Physiological roles of EPS are unravelled using the approach of knocking out EPS biosynthetic genes to create mutant deficiencies in EPS production. Pullulan

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produced by a desert isolate *Aureobasidium melanogenum* confers adaptation for living in the harsh desert environment by protecting from various abiotic stresses [41]. EPS produced by an arctic sea isolate *Pseudoalteromonas* strain SM20310, plays a significant role in environmental adaptation of strain in sea ice by providing high salinity tolerance and cryoprotection [29]. EPS has implication in the protection of plant growth-promoting *Rhodotorula* sp. from adverse environmental conditions [42]. Similarly, pH buffering property of cyanobacterial EPS matrix protects the dryland cyanobacteria from acid damage [43].

On solid surfaces, EPS facilitates the growth of bacterial communities as biofilm by leading bacterial cell adhesion and bacterial cell aggregation. Caro-Astorga et al. [44] revealed that each EPS produced by *Bacillus cereus* serve distinct roles. EPS1 contributes to bacterial motility, while EPS2 is involved in biofilm formation and gut colonization, thus playing a role in host-pathogen interaction. Being an integral part of biofilm, EPS makes the bacterial colonies recalcitrant to a wide range of antimicrobial agents. During the biofilm formation by *Pseudomonas aeruginosa*, production of matrix EPS 'psl' and the intracellular signalling molecule 'c-di-GMP' that stimulates the synthesis of biofilm matrix EPS is in the feedforward control loop. Hence, targeting the biofilm signalling mechanism can be an effective strategy to tackle chronic *P. aeruginosa* infections [45]. Another EPS, pel is cationic and hold the extracellular DNA in the biofilm matrix, apart from being the structural element of biofilm [46].

Studies on EPS produced by *Lactobacillus* species revealed the role of EPS in bacterial surface properties and host interaction. EPS affected the surface properties such as colony phenotypes and bacterial surface charge. Gene deletion studies revealed that EPS plays a significant role in bacterial cell aggregation. Concealing the surface structure with EPS might be one of the tactics to reduce the cell-cell interaction and the role of EPS in host cell interaction is strained specific [47–49]. EPS 1, a major virulence factor of a phytopathogenic bacteria *Ralstonia solanacearum* regulate the feedback loop of quorum sensing [50].

In the case of lactic acid bacteria, EPS protect the bacteria from bacteriophage, nisin and lysozyme [51]. EPS is the major arsenal for microbes to compete with each other for food and space. Toska et al. [52] suggested that EPS is involved in the antagonistic interaction between bacterial species and lead to the successful establishment of bacterial communities. In Gram negative bacteria such as *Vibrio cholerae*, EPS protect bacteria from other bacterial attacks by inhibiting the type 6-secretion system (T6SS). Type 6 secretion system by gram-negative bacteria is used to deliver the toxic protein into adjacent eukaryotic and bacterial cells. Deletion of EPS biosynthetic genes makes the *V. cholerae* more susceptible to T6SS attack by heterologous bacteria. On other hand, the same EPS of *V. cholerae* will not affect its T6SS attack on other bacteria [52].

EPS plays an important role in the establishment of plant microbial symbiosis. Plant root attachment of nitrogen-fixing bacteria *Paraburkholderia phymatum* is determined by the production of an EPS, cepacian [53]. Plant-growth promoting soil-borne *P. aeruginosa*, *P. syringae*, *P. putida*, and *P. fluorescens* produce EPS 'alginate'. Alginate play an important role in Zn^{2+} biosorption and phenazine

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biosynthesis, a biocontrol agent produced by fluorescent *Pseudomonas* strain. Increased alginate production affects the rhizosphere compatibility with improved biofilm formation and enhanced root colonization [54]. EPS helps to maintain the spore physiology and improve spore survival. *pzX* is an eps exclusively produced during sporulation of *Bacillus* species. Composition of amino sugar provides unique properties to *pzX* like lowering the surface tension and inhibiting cell-spore aggregates formation [55]. Metagenomic analysis of biological soil crust showed the presence of EPS and lipopolysaccharide (LPS) producing bacterial species. Here, EPS and LPS act as soil glue for soil aggregate formation that aid the formation of biological soil crust [56].

EPS plays a crucial role in etiology of dental caries. Demineralization of teeth by cariogenic biofilms leads to the formation of the oral cavity. In the presence of carbohydrates, cariogenic microbes produce organic acids that leach calcium from the teeth. A study showed that cariogenic microbes such as *Streptococcus mutans*, *Lactobacillus rhamnosus*, and *Candida albicans* produce EPS that have a high calcium-binding affinity, which attributes to the calcium tolerance of the microbes. Apart from structural anchorage to the biofilm, EPS also serve as a survival tool of cariogenic microbes to defuse high calcium concentration [57]. Targeting EPS can be an effective strategy to control cariogenic microbes [58]. However, in the case of catheter-associated urinary tack infection, EPS secreting *P. aeruginosa* adopt exopolysaccharide independent biofilm formation [59]. Hence, understanding the role of microbial EPS is crucial for developing therapeutic interventions against pathogenic microbes in which EPS production can be targeted. Furthermore, ecological functions of microbial EPSs promote their huge agronomical implications.

4 Biosynthesis and Metabolic Regulations of EPSs

Functional genomics analysis provides valuable information on EPS biosynthesis, export, and regulation. Identifying the gene targets can pave the ways to engineer high EPS producing strains or strains that produce tailor-made EPS [60]. Genomic analysis of microbes can reveal microbial potential to produce unknown exopolysaccharides. Borlee et al. [61] identified a novel EPS biosynthetic gene cluster involved in biofilm formation of *Burkholderia pseudomallei*. Genome annotation of EPS producing thermophilic bacteria *Geobacillus* may improve its prospects as a microbial cell factory for EPS production [22–24]. Padmanabhan et al. [62] studied differential gene expression during EPS biosynthesis by *Streptococcus thermophilus* ASCC 1275 in different sugar-containing media at stationery and log phases. They observed a correlation between high EPS production and upregulation of genes involved in sugar metabolism. A similar observation of increased UDP-glucose and UDP-galactose synthesis associated with a high yield of EPS, by *S. thermophilus* S-3 was reported by Xiong et al. [63]. Proteomic analysis revealed that upregulation of proteins involved in sugar

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transport, EPS assembly and amino acid metabolism was also associated with high EPS production [62, 64].

Availability of whole genome sequence of EPS producing microbes facilitates the metabolic engineering strategies for EPS production [65]. Evaluation of EPS production by gene knockout mutants, gene overexpression mutants and gene complementation mutants of EPS biosynthetic genes can shed light on the role of each EPS biosynthetic genes in EPS production [66]. CRISPR-Cas9 genome editing had enabled researchers to produce EPS variants with different monomeric composition from *Paenibacillus polymxa.* These EPS variants can give insights into the structure-function relationship of polysaccharides and aid to create customized EPS with desirable properties [67]. *Xanthomonas campestris* strains were engineered to produce xanthan gum variants with distinct secondary structure and rheological properties, which may be suitable for application in various industries. Structure-activity relationship of these tailor made-xanthan gums revealed that terminal mannose is one of the major determinants of rheological properties of xanthan gum, while the terminal mannose and internal acetyl group are integral to its double-helical conformation [68]. Genome editing and metabolic engineering could yield tailor-made EPS with improved stability and higher performance, which can have huge commercial potential when compared to native EPS.

5 Applications and Commercial Prospects of EPS

Due to the presence of a large number of hydroxyl groups, microbial EPS have been long used as hydrocolloids, which modify the rheology of the system by altering the flow behaviour and texture. In food and personal care industry, they serve as a thickening, gelling, stabilizing, emulsifying and water-binding agents [69, 70]. Xanthan gum is a widely used thickener in food formulation. In food and confectionary, xanthan gum has become more prominent in recent years due to its status as vegan-friendly. In gluten-free baking, xanthan gum provides structure and elasticity to dough or batter, and as an egg substitute, it emulsifies and thickens the food preparations. Xanthan gum based thickened fluid appears promising for treatment of patients with oropharyngeal dysphagia. Apart from safety and efficacy, it is resistant to α-amylase and preferred by patients, when compared to starch-based thickener [71, 72]. The concentration, type and setting time of xanthan gum-based food thickeners are the main factors in designing the infant food formulation used for paediatric dysphagia [73]. Gellan gum exhibit excellent gelling properties. To overcome the limitation of the gellan gum such as low mechanical strength and high gelation temperature, blending with natural or synthetic polymer has been employed [74]. Synergistic hydrogels of xanthan gum and gellan gum with other natural polymers are promising for the preparation of food packaging materials [75].

Antioxidant property and water-absorbing/retention properties are some of the features of EPS attractive for cosmetic applications [76]. 'Lubcan' an EPS with

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remarkable skin lubricating property produced by *Paenibacillus* sp. ZX1905 could be a low-priced replacement of hyaluronic acid in cosmetic formulations [77]. Extremophilic microbes may provide EPS with excellent keratinocyte protective ability from temperature or radiation-induced damage. An EPS of momomers-*N*-acetyl glucosamine, mannose and glucuronic acid produced by an artic marine bacterium *Polaribacter* sp. SM1127 could be an excellent cosmetic ingredient as it is dermatologically safe, possess better moisture retention properties than hyaluronic acid and good antioxidant activity, and protect human dermal fibroblast from low temperature-induced damage [78]. Radiation-resistant *Deinococcous radiodurans* derived EPS (deinopol) protect keratinocytes from radiation-induced ROS damage [79].

Potential bioactivities reported for EPS include antitumor, antioxidant, immunomodulatory, antiviral, antibacterial, anti-inflammatory, and cholesterol-lowering properties. Consumption of bioactive EPS can have potential health benefits [80]. Antitumor property of EPS stems from its ability to modulate oncogenic pathways. EPS produced by many lactic acid bacteria can induce apoptosis and cell cycle arrest in tumour cells, without any toxicity to normal cells [81]. EPS secreted by probiotic yeasts-*Kluyveromyces marxianus* and *Pichia kudriavzevii* were reported to induce apoptosis in colorectal cancer cells by inhibiting AKT-1, mTOR, and JAK-1 pathways [82]. Though many studies demonstrated the antitumor potential of EPS, the viability of EPS as a coadjuvant for cancer therapy needs to be addressed by in-depth in vivo studies. Some researchers observed that the sugar composition of EPS primarily determines its antitumor property. For instance, Tukunmez et al. [83] observed that the apoptotic induction by *Lactobacilli* EPS was related to the mannose content of EPS. The mode of action of *Lactobacilli* EPS is by upregulation of Bax, Caspase 2 and 9 and downregulation of Bcl-2 and Survivin leading to caspase-mediated apoptosis [83].

EPSs have been commonly used in pharmaceutical formulations for controlled and sustained release of drugs, coating of pills or as suspension stabilizers. Presence of hydroxyl groups and free carboxyl groups in EPS enables the structural modification of EPSs, improving the biostability and mechanical properties or impart novel functionality to EPSs, thus broadening their applications [84]. Adding hydrophobic moiety to xanthan gum reduces its solubility and porosity, and modified its rheology. The resulting amphiphilic xanthan gum reduced the surface tension/interfacial tension and stabilized the emulsion, which improves its prospects for pharmaceutical applications, in comparison to native xanthan gum [85]. Du et al. [86] reported an antibacterial hydrogel made of hydrophobically modified chitosan and oxidized dextran with improved wound healing properties than that of traditional gauze. Similarly, a thermoreversible hydrogel made with xanthan and konjac glucomannan appear promising for in situ would healing [87].

Non-immunogenicity, biocompatibility and biodegradability determine the applicability of EPS in biomedical application. Dextran is the most clinically used bioabsorbable EPS. Dextran has been used as a plasma extender and an antithrombotic agent. Dextran is neutral in charge, exhibit excellent pharmacokinetics and is easily degraded by dextranase enzyme in our body [88]. Acetalated

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dextran (Ac-Dex) is modified dextran with hydrophobic nature. It can be easily formulated to micro/nanoparticle, which can encapsulate a diverse payload. Its pH-sensitive nature makes it an effective drug delivery system for protein, miRNAs and chemotherapeutic drugs [89–91]. Studies with natural compound ganothalamine revealed promising application of Ac-Dex as an encapsulating agent for the sustained release of the anticancer drug [92]. Wannasarit et al., [93] synthesized a conjugated dextran-based polymeric nanoparticle which can mimic viral entry to the cell. Adapting a viral mode of delivery of therapeutics to the cytoplasm is a good approach to bypass the lysosomal degradation that happens after the internalization of the drug. The prepared poly(lauryl methacrylate-comethacrylic acid)-grafted acetalated dextran carrying the payload of asiatic acid showed improved therapeutic efficacy than treatment with asiatic acid alone. Pinho et al. [94] prepared a dextran-based photocrosslinked membrane which shows potential as implantable devices for biomedical application. In vivo studies using rat models indicated that the developed dextran-based membrane is biocompatible.

With the aim to restore or regenerate the damaged tissue, tissue engineering comprises of cells and growth factors in a biomaterial that acts as the scaffold for cell growth. Biocompatibility, gelation and mechanical properties are the attractive properties of EPSs for their use as biomaterials in tissue engineering [95]. Microbial EPS containing hexosamine and uronic acid as monomers and acetyl/sulfate groups as functional groups hold great therapeutic potential due to their structural resemblance with mammalian glycosaminoglycans (GAG). Using bacterial GAG-like polymers over mammalian GAG have the following advantages. Bacterial EPSs are produced by fermentation that is more feasible when compared to strenuous extraction of GAG from animal tissue. Bacterial EPSs are free of prions and viruses as in the case of mammalian GAGs. EPS produced by marine isolated *Vibrio diabolicus* and *Alteromonas infernus* are promising candidates for tissue repair and remodelling. Chemical modifications of these depolymerized polysaccharides using *N*-deacetylation and sulfation can yield heparin-like polymers [96–98]. Cross-linked dextran is an effective injectable hydrogel for cartilage regeneration [99]. Capsular alginate extracted from *Azotobacter agile* exhibit lower cytotoxicity on mesenchymal stem cells than algal alginate. Moreover, tailor-made alginate with attractive properties to serve as a biomaterial can be produced by metabolic engineering of host bacterium [100].

The petroleum industry has been using EPS as a viscosifier for the drilling purpose. In situ EPS production by *Pseudomonas stutzeri* XP1 isolated from oil reservoir could enhance the oil recovery that demonstrated the potential of EPS for enhanced oil recovery [101]. EPS can be a potential bioadsorbent for heavy metal removal. They are environmentally friendly, cost-effective, and require milder conditions to operate. Metal adsorption by EPS depends on ionic nature of metal, its size and charge density. Positively charged heavy metals can be sequestered using anionic charged EPS [102]. When arsenic degrading bacteria was cultivated in arsenic-containing media, they produced EPS that can effectively sequester arsenic. These EPS are rich in polyanionic functional groups, which result in electrostatic to

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covalent binding with arsenic [103]. Similarly, studies also demonstrated the excellent flocculating activity of microbial EPS [33, 104].

EPS can be effective and sustainable soil strength improver. Using EPS as the soil stabilizer can alleviate the negative environmental impact associated with traditional soil stabilizers such as lime and cement. Improvement in soil shear strength and soil fabric was noted on addition of xanthan gum to the organic peat matrix, due to the hydrogen and electrostatic binding between xanthan gum and clay particle [105, 106]. Xanthan gum and sodium alginate could alleviate soil erosion and reduce the collapsible potential of soil material [107, 108]. Water adsorption and moisture-retention abilities of soil can be greatly improved by the addition of xanthan gum [109].

Exopolysaccharide-derived oligosaccharides can be considered for sustainable agricultural practices. Plant growth-promoting biostimulants can greatly benefit agriculture by stimulating the nutrient uptake, enhancing the photosynthetic activity of plants and protect the plants by mitigating abiotic stress [110]. Low molecular weight oligo-gellan prepared by depolymerization of gellan gum is promising as a biostimulant, which improved the plant growth and survival of Red Perilla plants under normal and stress conditions. Biostimulatory activity may be due to elicitation of plant polyphenol content and other secondary metabolites, leading to high antioxidant activity [111]. Though gellan gum also confers some biostimulatory effects on plants, the oligo-gellan exhibited better performance [112].

6 Conclusions

Microbial EPSs are one of the industrially significant microbial products, which are used as the functional ingredient in the food, pharmaceutical, personal care and other industries. Functional application of EPS is correlated to their structural complexity, which determines their physicochemical properties and bioactivities. Besides, the structural modification of EPS and synergistic manipulation with natural or synthetic polymers to broaden the applications of EPS, researchers are actively searching for novel EPS with versatile physicochemical properties or unique bioactivities which can have industrial/therapeutic applications. For that, they pursue the bioprospecting of EPS producing microbes from different environmental samples, specifically extreme environment. The ability of microbes to produce unknown exopolysaccharide is also being studied by genomic analysis.

Some latest studies shed light on the role of EPS in host-microbial symbiosis and pathogenesis. Understanding the physiological roles of EPS secreted by pathogenic or opportunistic microbes is quite crucial for developing novel therapeutic strategies against these microbes. Employing multiple omics techniques and metabolic engineering strategies in the field of microbial EPS can greatly expand the knowledge in EPS biosynthetic pathways and also, leads to the generation of tailor-made EPS with superior properties.

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Microbial EPS possess excellent rheological, emulsifying, and water-retention properties, which makes them highly sought-after industrial polymers in food, personal care, pharmaceutical and oil-drilling industry. In addition to this, they possess stability in a wide range of temperature and pH that heighten their commercial prospects. Furthermore, EPS may possess biological activities such as antioxidant, antitumor, immunomodulatory and antimicrobial properties and are promising for therapeutic and nutraceutical applications. Structural modified EPS with natural or synthetic polymers make an effective hydrogel with implications in clinical and biomedical field as wound dressing and tissue engineering applications. Growing researches demonstrate the potential use of EPS for bioremediation, soil conservation and sustainable agricultural practices.

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Urban Solid Waste Management

Issues and Challenges of Sustainability







Edited by:

Sudipto Ghosh
Amit Bhandari

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Foreword

I was delighted when my erstwhile colleague Sudipto Ghosh asked me to write the Foreword to this book which has been edited by him and Professor Amit Bhandari. As a Municipal Urban Planner Sudipto Ghosh gathered close practitioner experience in the problems of waste management in a municipal town and I am aware that he was associated with Bansberia Municipality trying out several innovative approaches in waste management. Professor Bhandari has been intellectually active in finding out sustainable solutions to waste management in India. The subject of this book is close to my heart. During my tenure as Principal Secretary, Environment Department, Government of West Bengal, I have seen how crucial effective waste management is to providing a good enough healthy environment for the citizens and especially children in our cities and towns. The theme of the book i.e., sustainable waste management practices is the need of the hour. As Municipal Commissioner of Kolkata, I have experienced all the problems of big city waste management and seen how the adoption of good practices along with sincerity of implementation can bring about positive changes. This book comes at the right time when the country is moving forward towards adopting better practices in waste management and will be useful to practitioners, academics and citizens at large.

Over the past few decades, the scope, expanse and complexity of waste management practices in India have increased manifold. What started out as the collection and disposal of kitchen waste in a few cities has now expanded into the collection, transportation and effective disposal of organic waste, liquid waste, plastic waste, construction and demolition waste, biomedical waste and e-waste in cities, towns, and rural areas. New challenges call for new solutions and technology. This book provides a window to new thought, approaches and technology. Some of the articles discuss examples of good practices in tackling waste management. Recycling of wastes

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has been tried in many places but most have been short-lived. Some articles in this book provide newer ideas on the recycling of wastes and inform about practices that can be sustainable in the long run. The informal sector comprising of kabadiwallas, ragpickers and others have for long been a significant player in waste management in India. Yet they are mostly ignored and left out of the stakeholders when policies on waste management are framed. Regulations and enforcement have lagged behind international best practices and this is an area which will become more important in the coming years. Putting all together to make for an effective waste management system is the policies that are taken up for addressing it. Shri Anjor Bhaskar in his article on sustainable municipal solid waste has reviewed the practices and policies and points out the improvements needed. Overall, the editors of this publication have chosen the articles with care and have addressed important aspects of waste management

This book is a compilation in one place of various experts in the field presenting their studies on most of the facets of waste management. Readers who are stakeholders or interested persons can be acquainted with new ideas and thoughts and also get a broad idea of the whole spectrum of waste management in India. I am sure the articles will provoke thought and discussion and will inspire several readers to become advocates for better waste management. I was excited to go through the ideas presented by several distinguished contributors. It has been an honour to be invited to write this foreword and I thank the editors for the opportunity.

Arnab Roy, IAS
Principal Secretary
Consumer Affairs Department
Government of West Bengal

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Chapter 5

Risk Assessment of Biomedical Wastes Generated in Hospitals of Chandigarh and Shimla, India

Rajiv Ganguly, Prachi Vasistha and Ashok Kumar Gupta

1. Introduction

Rapid globalization and urbanization have to lead to increased production of wastes including biomedical wastes generated from different health care services (Denboss and Izapanah, 2002; Oweiss et al., 2005). Biomedical wastes generated are of prime importance as they can severely affect the surrounding environment and consequently human health due to the transmission of pathogens (Patwary et al., 2009; El-Salam, 2010). The problem has been further compounded due to inappropriate legislations and management techniques of such biomedical wastes particularly in developing countries (Narendra et al., 2013). The amount of biomedical waste generated is quite small in comparison to the total amount of solid wastes generated but are highly significant due to its potential health risks (Cheng et al., 2009). The quantities of biomedical waste generated depend on numerous factors including patient intake of the healthcare facility, the different treatment specializations (Pruss et al., 1999; Debere et al., 2013). In the general context, about 85% of medical wastes generated in hospitals are non-hazardous in nature, about 10% are classified as infectious wastes and about 5% as non-infectious but hazardous waste (Liao et al, 2014). Advancement in health care facilities around the world has led to serious improvement of biomedical waste

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management in developed countries with strict regulations and guidelines. In Indian context, strict regulations were put forward by the Ministry of Environment and Forest (MOEF) notifying the Bio-medical Waste Management and Handling Rules in 1998 (amendments in 2003 and 2011) under the Environmental Protection Act 1986 (MOEF, 2011) and was one of the first countries to successfully implement these rules (Gupta et al., 2009; IPEN, 2014). However, despite strict regulations and legislative guidelines, in an Indian context the paradox of the situation is that the healthcare facilities often themselves pose health risk due to improper management of waste, and often lack of awareness of the existing regulations (Narendra et al., 2013).

Since medical wastes consist of pathogens, they need to be handled carefully to minimize risks to all personals present in the healthcare facility (doctors, nurses, administrative personals, patients, etc.) (Rao,2009). The problem is further compounded as often the risks associated with handling of biomedical wastes are unknown to workers in healthcare facilities (Nema et al., 2011). Research studies have shown that several injuries and infections arise due to such mismanaged biomedical wastes in and around healthcare facilities including infection of nurses in Operation Theatres (OT) (Rao et al., 2004, due to indisposed medicines and broken syringes and general medical wastes which become toxic when remain exposed over very long time (Bokhoree et al., 2014).

In the above context, it is important to identify the risk associated with the different waste types generated in a healthcare facilityto take appropriate and necessary follow-up actions to avoid any mishap. The paper presents the results of risk assessment analysis conducted over four hospitals in two cities obtained using the PHA methodology and evaluated further using a matrix methodology.

Preliminary Hazard Analysis (PHA) is a semi quantitative analysis which is generally performed to identify the potential hazards that may lead to any accidental event that may be large or small, to rank these accidental events according to their severity and likelihood so that appropriate hazard controls and necessary follow-up actions can be taken (Rausand, 2008). PHA applications have been utilized for conducting vast

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number of different studies including assessing risk management in pharmaceutical industry (Charoo and Ali, 2013), reliability for fractional column in refinery (Ibrahim and Nafaty, 2016), risk management study in medical device industry (Dumbrique, 2010). However, very limited literature is available on application of PHA for risk assessment of biomedical wastes. In one such study carried out in Batna city of Algeria reported by Sefouhi et al.,2013.PHA was used to identify and assess the risks that occur in the hospital due to the presence of hazardous elements in hospital waste in terms of severity associated with these waste types. The main categories of waste that represented most possible and acute hazards were Sharps, Infectious Waste and Anatomical Waste (Sefouhi et al.,2013). The conclusion drawn from the study was that all necessary steps were followed in the hospital at Batnacity for proper management of biomedical wastes however there was a significant scope for attention and improvement (Sefouhi et al.,2013). The PHA analysis carried out in the study helped the identification of various hazards that could take place in the hospital and plan the necessary follow-up actions relevant to the hazard (Sefouhi et al.,2013).

Different healthcare facilities produce different types of wastes dependent on different factors including type of healthcare facility, patient intake etc. (Komilis et.al, 2011), hence the techniques of risk assessment varies from hospital to hospital due to difference in waste characteristics. However, it is important to note that Risk causing Healthcare Waste or Risky Healthcare waste (RHCW) production percentages are almost same for all hospitals. The general production of Risky healthcare Waste in a hospital is considered to be about 10-25% (Shinee et.al. 2008; Srivastava et al., 2012)

The major RHCW generated in hospitals are Waste Sharps, Pharmaceutical and Chemical Waste, Infectious Waste and Anatomical Waste (Gupta et al., 2009; Kumar et al., 2014). The severity of these wastes varies from minor effects to catastrophic effects. In this study, we have used the PHA technique to determine the risk assessment from such RHCW.

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Site Locations

The study areas were selected keeping in view of the different biomedical waste practices in major hospitals located within 100 km radius. The nearest cities were Shimla (2 hospitals considered) and Chandigarh (2 hospitals considered) wherein these hospitals were located. (Distance between Shimla and Chandigarh is 100 km's). Further both public and private sector hospitals were considered in Shimlaand only private hospitals in Chandigarh to evaluate the risks associate with the management of biomedical waste and their compliance with Indian guidelines. Brief descriptions of these hospitals have been mentioned in the next few paragraphs.

In Shimla the two hospitals that were chosen were IGMC Hospital (Public sector hospital) comprising of 33 departments. The biomedical waste management is handled by a team of 3 members headed by medical superintendent who looks after the entire management of healthcare wastes from generation to disposal (Personal Communication with IGMC Hospital Administration). The average inpatients are 669 with average bed occupancy of 84. According to the annual statistical report of the hospitalthe total number of patients admitted each year were about 31,872 of which 31,771 patients were discharged disposal (Personal Communication with IGMC Hospital Administration). The total number of patient treatment days to be around 2, 44,503 with average length of stay for patient to be 8 days disposal (Personal Communication with IGMC Hospital Administration). The location of the hospitals in Shimla city has been shown in Figure 1.

The INDUS Hospital (in Shimla) is a private hospital with a 6 storied hospital building comprising of eight major departments includingsurgery, medicine, ayurveda, radio diagnosis and imaging, pediatrics, and adolescent medicine, gynecology and maternity, orthopedic surgery, dentistry and oral health, and department of physiotherapy (Personal Communication with INDUS Hospital Administration). In this hospital, the biomedical waste management is maintained by team of 2 main members, one of these being the head of the nurses training department and other person being administrative head

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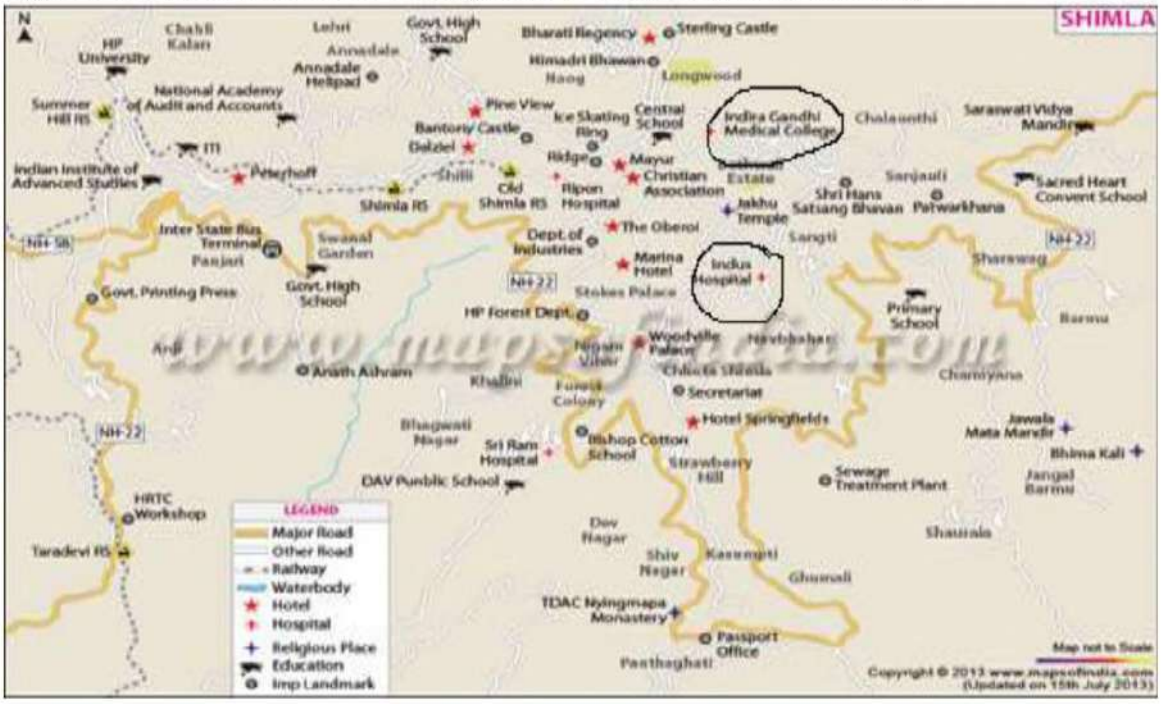
supported by workers for collection and disposal of the waste from hospital wards(Personal Communication with INDUS Hospital Administration).Though the premises of the hospital small but the hospital wards are well equipped with attached washrooms and intercom facilities in general wards and ventilators, defibrillators, piped oxygen, central suction and compressed air in the intensive care units. The hospital is looked by a team of 19 doctors and operates on a 24-hour basis with assigned house physician on duty round the clock (Personal Communication with INDUS Hospital Administration).

Figure 1: Location of two hospitals selected in Shimla city



In Chandigarh the hospitals that were taken for study purpose were MAX Super Specialty Hospital and the IVY both being both large Private Sector hospitals located in Mohali area.The view of Chandigarh City has been shown in Figure 2 below.MAX Healthcare is India's first provider of integrated and comprehensive world class healthcare services. There are 11 facilities for the healthcare services distributed in North India specializing in over 32 disciplines (Personal Communication with MAX Hospital Administration).

The hospital is well equipped with technically advanced equipment's for providing excellent medical facilities to its patients. The Hospital has been renowned with various accreditations from NABH, NABL and

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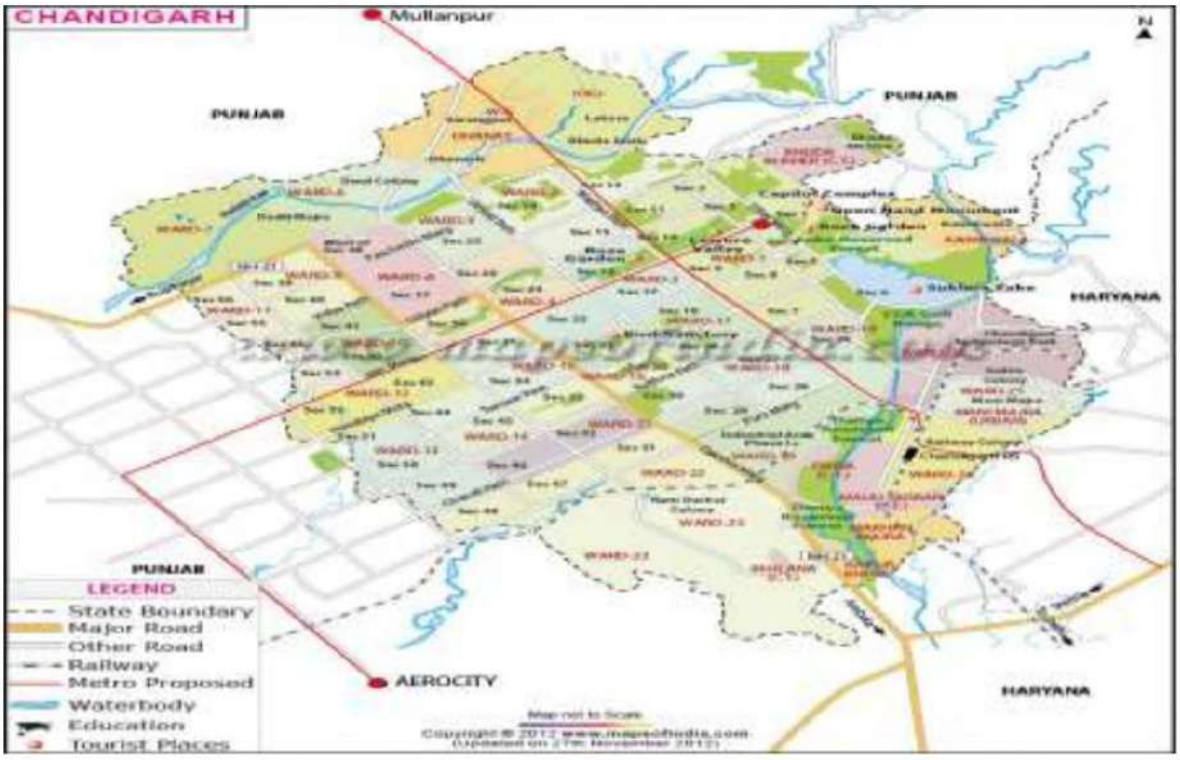
LEED making it highest quality service provider (Personal Communication with MAX Hospital Administration). The various services provided in the hospital includes Obstetrics, Child Birth, Joint Replacement, Orthopedics, Gynecology, OPD facility, Dermatology, Plastic Surgery, Aviation Medicine, Nuclear Medicine, Ophthalmology, Urology, Thoracic Surgery etc. (Personal Communication with MAX Hospital Administration).

Figure 2: A view of the Chandigarh City



IVY Hospital is the largest tertiary Healthcare provider in Punjab. It has a total bed capacity of 205 beds and more than over 25 super specialty departments with more than 125 consultants, 1500 paramedical and nursing staff and 3000 complex surgeries and is NABH accredited (Personal Communication with IVY Hospital Administration). The total number of patients treated annually is more than 1.25 lakhs in number (Personal Communication with IVY Hospital Administration). The hospital provides expertise in Heart, Brain, Cancer, Bones and Joints, Kidney and Bladder, Stomach, Liver and Digestive System, Women Health, Child Care, Diabetes, Lungs, Internal Medicine, Psychiatrist, General Surgery, Skin, ENT etc. (Personal Communication with IVY

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Hospital Administration).The hospital has been providing subsidized and free treatment to people below poverty line and to people with yellow cards. Medical checkup camps are organized every year along with awareness campaigns in nearby schools and villages as a part of social responsibility (Personal Communication with IVY Hospital Administration).

Another reason for selecting these hospitals was that these hospitals are highly reputed in the respective areas and washighly willing to share their information and contribute to the study purpose.

Materials and Methods

The methodology for the study involved a Questionnaire session which was conducted during the research period and which was filled by the doctors and all appropriate personals involved in the process of the biomedical waste handling at these selected hospitals according to their past experiences and observations. The Questionnaire was prepared for ranking of the different risky waste categories according to the severity and likelihood by the doctors and the nurses involved directly in handling and management of the wastes. The result from this questionnaire survey was used for determining the risk assessment using a matrix methodology.

The first section of the questionnaire contains personal information of the person filling the responses including their names, designation, place of work, and years of experience. The second section consists the matrix for quantification of likelihood and severity of the waste categories obtained from the analysis. The likelihood and severity both are indexed on a five point scale with 1 being the lowest and 5 being the highest value. The likelihood is ranked as *very unlikely, unlikely, possible, likely, very likely* whereas the severity is ranked as no effect, minor, major, hazardous and catastrophic with each ranking given a value for the quantification of results. The boxes in the matrix show high, low and medium risk regions where each region is specified with a definite colour i.e., red, green and yellow respectively. This is shown in Table 1and the severity of the consequence criteria in Table 2. The third section contained table with different waste categories with their potential hazardous elements, the probable causes for the accidental events and the accidental events that

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may occur due to mismanagement at the different hospital sites. The table also contains columns for ranking of waste categories in terms of severity and likelihood. The questionnaire has been attached as supplementary document S1.

The PHA methodology is a semi-quantitative method for risk assessment. A matrix method of evaluation was utilized and ranking of the different RCHW was determined so that the hospital could take precautionary measures and prepare the necessary follow-up action plans in case of any hazardous event or outbreak that takes place in the hospital premises. This procedure was repeated for all the four hospitals.

The matrix method of evaluation of the questionnaire analysis is a novel approach and very less literature is available. The method of evaluation has been discussed further in the next few paragraphs. The major indices calculated were Likelihood Index (L.I), Severity Index (S.I) and Hazard Index (H.I).

Table 1: Matrix Evaluation for Risk ranking and follow up actions For Different Categories of Waste.

		Hazard Severity				
		No Effect 1	**Minor 2**	**Major 3**	**Hazardous 4**	**Catastrophic 5**
Likelihood Of Occurrence	***Very Unlikely 1***	Low	Low	Low	Low	Medium
	Unlikely 2	Low	Low	Low	Medium	Medium
	Possible 3	Low	Low	Medium	Medium	High
	Likely 4	Low	Medium	Medium	High	High
	Very Likely5	Low	Medium	High	High	High

The maximum likelihood grading score that could be provided to each waste type was denoted as 'A' and the value was taken as 5 (based on 5-point grading system). The likelihood count for each type of the wastes

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varied from 1-5 and was denoted as ‘a’ and the number of persons referring to particular likelihood count were taken as ‘n’.

Table 2: Severity of Consequence criteria

No effect	Has no effect on health
Minor	Minor injury
Major	Major injury
Hazardous	Serious or fatal injury
Catastrophic	Death

The likelihood Index for each waste type was calculated separately according to formula Likelihood Index (LI) = ∑an/AN. Each likelihood count that could be referred to by personnel filling the Questionnaires at the Hospital was taken in first column of the table (a). The number of persons referring to these particular Likelihood counts was taken in the second column (n). In the third column every likelihood count was multiplied with the number of persons referring to these particular counts. The values were represented as a*n. These values were then added up and the Likelihood Index was calculated according to the formula LI = ∑an/AN where A and N were taken as 5 and 15 respectively. This is shown in Table 3 and is shown as an illustrative example. Hence, likelihood index (L.I) for infectious waste at MAX hospital was 56/75 = 0.75 (75%). Similar calculations were performed for the other three waste types namely Sharps, Anatomical Waste and Pharmaceutical & Chemical Waste for the calculation of Likelihood Indexes.

Similar methodology as described above was performed for the calculation of Severity Index (S.I) for each waste type. The value of the L.I for each waste type was multiplied with its corresponding S.I to obtain the Risk value for each waste type. This process was repeated for all the different waste types and for all the different hospitals.

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Table 3: Calculation of Likelihood Index for Infectious Waste at MAX Hospital.

Likelihood count (a)	No of persons referring to particular count (n)	a*n
1	0	0
2	0	0
3	6	18
4	7	28
5	2	10
	∑an =	56
	L.I. =	0.75

Results and Discussions

The questionnaire was ranked up by group of 15 personals including doctors and nurses and all major personals involved in management of biomedical waste at all the four different hospitals. Likelihood Index (L.I), Severity Index (S.I) and Risk Index (R.I) were calculated for all the different types of the wastes generated and for all the four hospitals. The values of L.I, S.I and R.I for each waste type of each hospital have been tabulated in Table 4 below.

Table 4: Likelihood, Severity and Risk Values for various waste types in different Hospitals.

IGMC Hospital Shimla			
Waste Type	L.I.	S.I.	R.I.
I.W	0.93	0.89	0.83
Sharps	0.83	0.79	0.66
A.W	0.76	0.67	0.51
P&C.W.	0.69	0.61	0.43
Indus Hospital Shimla			
Waste Type	L.I.	S.I.	R.I.
Sharps	0.73	0.71	0.52
P.&C.W.	0.61	0.47	0.29
I.W.	0.56	0.63	0.35
A.W.	0.48	0.47	0.22
Max super Specialty Hospital Mohali			
Waste Type	L.I.	S.I.	R.I.
I.W.	0.75	0.79	0.59
Sharps	0.73	0.77	0.57
P.&C.W.	0.63	0.65	0.41

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A.W.	0.57	0.63	0.36
IVY Hospital Mohali			
Waste Type	L.I.	S.I.	R.I.
Sharps	0.80	0.95	0.76
I.W.	0.73	0.87	0.64
P.&C.W.	0.67	0.76	0.51
A.W.	0.51	0.6	0.30

In Table 4, the waste categories are represented by Sharps, Anatomical Waste (A.W), for Pharmaceutical & Chemical Waste (P&C.W) and Infectious Waste (I.W). It is observed from Table 4 that for the hospitals located in Shimla city, for IGMC hospital, the L.I values is highest for Infectious waste (L.I = 0.93) while it is highest for sharps in Indus hospital (L.I = 0.73). From the L.I values that for IGMC Hospital handling of Infectious waste demands maximum attention because of the infections that may be caused by the waste kind if not handled properly. For Indus Hospital Sharps indicate maximum likelihood and needs to be handled carefully because Sharps can cause cuts and punctures to workers and these wounds may get further infected by pathogens thereby posing a threat of double risk (Sefouhi et al.,2013). Similarly, it was observed that for the hospitals located in Chandigarh city, for MAX Hospital (L.I = 0.75) the value was highest for infectious waste and for IVY hospital (L.I = 0.80) the maximum likelihood was for sharps.

Comparison of the R.I values as observed from Table 4 showed that for IGMC and MAX hospital, the maximum values were observed for Infectious waste (R.I = 0.83 and 0.59 respectively) whereas for INDUS hospital and IVY hospital, the R.I values were highest for Sharps (R.I = 0.52 and 0.76 respectively). Of the four study hospitals, anatomical waste deemed least risk producing category for three hospitals excepting IGMC wherein the Pharmaceutical & Chemical Waste was observed to be less risky. The risk posed by Pharmaceutical & Chemical Waste is highly variable depending on the number of laboratories and the amount of chemicals being used. Infectious Waste and Sharps were found to be higher risk as has been reported in earlier literature (Carvalho and Silva,2002).

A risk matrix was plotted with likelihood on the y-axis and the severity at x-axis therefore showing the different zones in which each

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waste category could fall showing the amount of risk posed by them. The values for the likelihood and the severity were then plotted on the risk matrix. The risk matrix for each hospital has been shown in Figures 3-6 respectively. The matrix shows the waste categories represented by 'S' for sharps, 'I' for Infectious Waste, 'P' for Pharmaceutical & Chemical Waste and 'A' for anatomical Waste.

The values for Likelihood and Severity were plotted for the IGMC Hospital; Shimla to obtain the zone in which risk associated with each category felled the matrix clearly shows that the risk associated with all the different waste categories was high risk category due to the large waste quantities generated at the hospital site thereby imposing a risk of mismanagement leading to a hazardous event. This has been shown in Figure 3.

The risk matrix for the INDUS Hospital has been shown in Figure 4. The matrix clearly shows that the waste category Sharps falls in red region thereby showing High Risk Category whereas the remaining three categories of waste falls in yellow region showing medium risk category. One of the probable causes being that this hospital generates less amount of waste than IGMC.

The risk matrix for the MAX Hospital has been shown below in Figure 5. The matrix clearly shows that the waste category Sharps, Infectious Waste and Pharmaceutical and Chemical Waste falls in red region indicating a high-risk range whereas the Anatomical Waste category falls in yellow region showing medium risk range.

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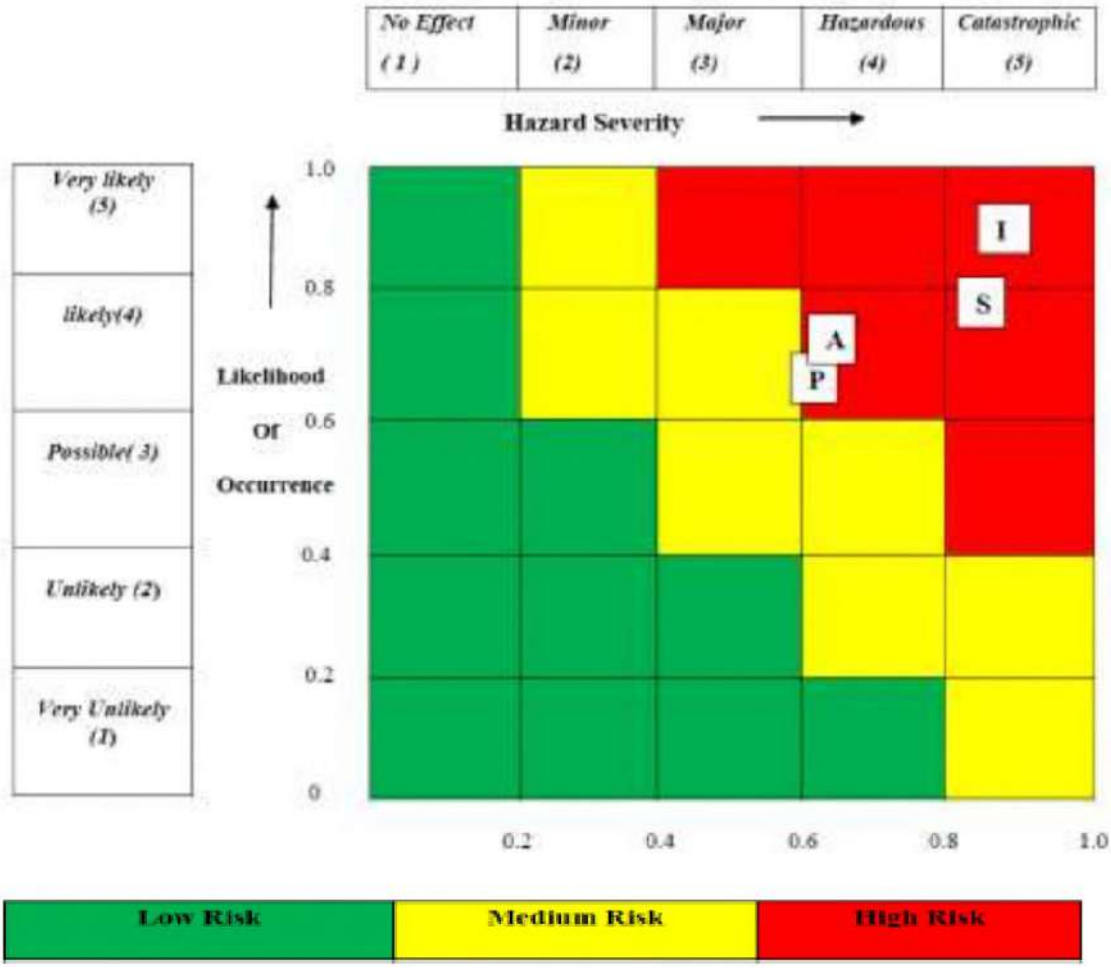
Figure 3: Matrix for Risk Ranking of different waste type at IGMC Hospital



The risk matrix for the IVY Hospital has been shown below in Figure 6. The matrix clearly shows that the waste category Sharps, Infectious Waste and Pharmaceutical and Chemical Waste falls in Red region showing a high-risk range whereas the Anatomical Waste category falls in yellow region showing medium risk range.

The risk matrices above clearly showed the risk associated with different waste categories and the range in which they fall as high medium and low respectively. The risk matrix is also very helpful in quickly identifying the potential risks associated with biomedical waste management process and proper steps needed to control it.

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Figure 4: Matrix for Risk Ranking of different waste types at INDUS Hospital.

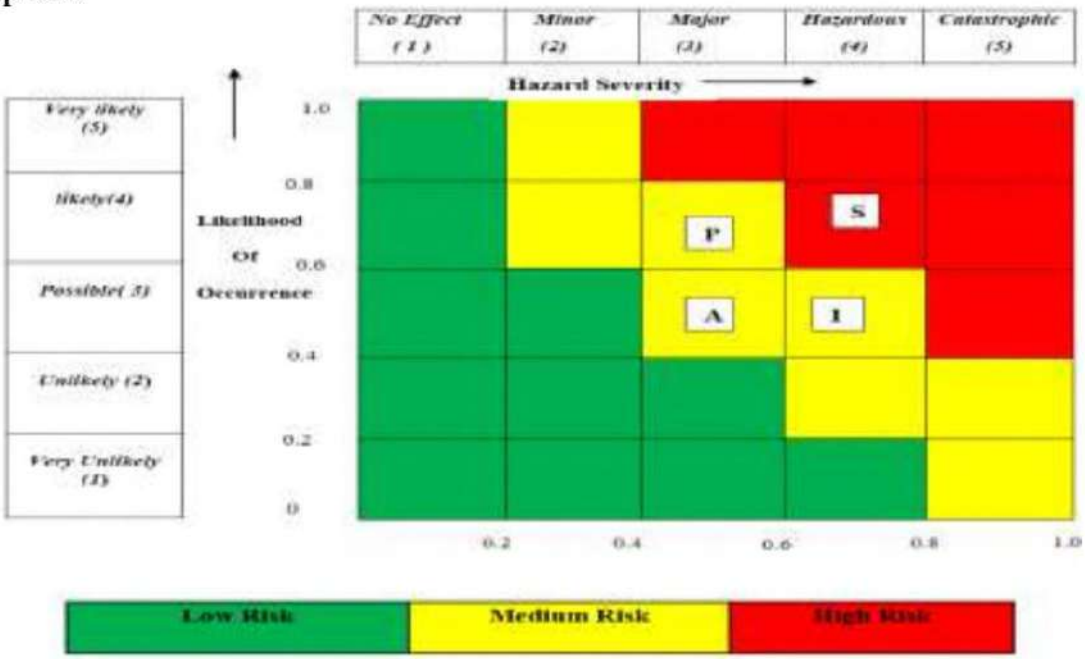

Figure 5: Matrix for Risk Ranking of different waste type at MAX Hospital

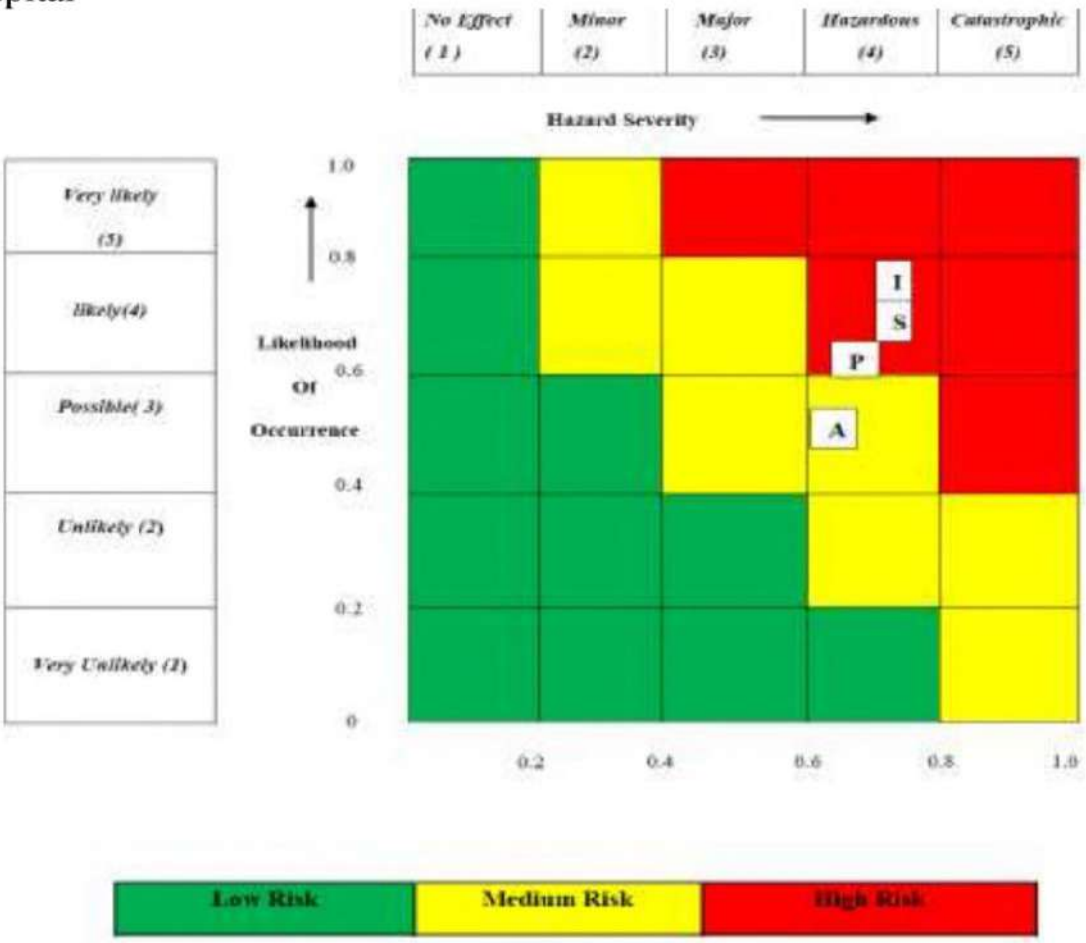

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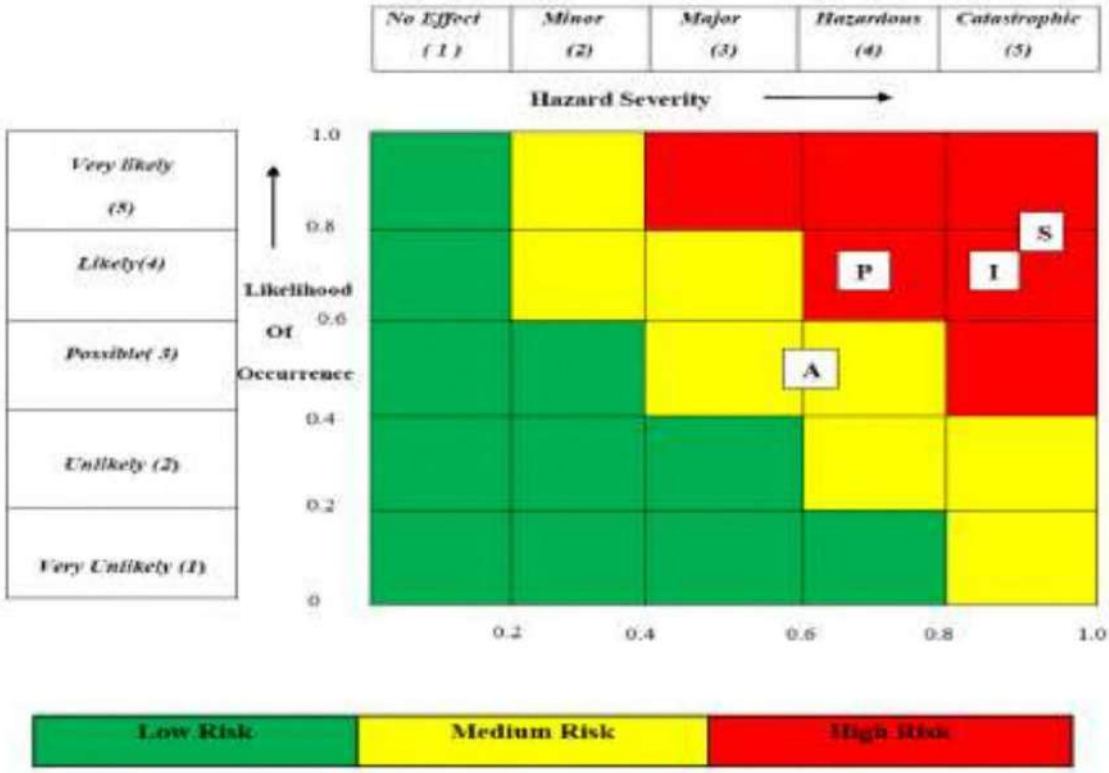
Figure 6: Matrix for Risk Ranking of different waste type at IVY Hospital



Conclusions

The paper analyses the risks of biomedical waste management practices followed by four different hospitals located in two different cities of Shimla and Chandigarh within a 100 km radius using a matrix method of evaluation. The study results showed that the maximum risk was from infectious waste in IGMC in Shimla and MAX hospital in Chandigarh whereas; the maximum risk was from Sharps from INDUS hospital in Shimla and IVY hospital in Chandigarh. Risk matrices were plotted to categorize the risk assessment values being classified as high risk, medium risk and low risk. In general, all the waste types were classified as High Risk for IGMC and only Sharps were classified as High Risk for INDUS hospital, with rest of the categories being Medium Risk. In MAX and IVY hospitals, all the waste types were classified as High Risk with the exception of Anatomical waste which was classified as Medium Risk.

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administration of the Hospital for giving permission to conduct the study in their hospitals providing all necessary information and support and for their valuable suggestions and time for improving the study. The names of the hospitals have been published after taking consent from the suitable authorities.

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Effect of Curing on Compressive and Shear Strength Parameters of Liming Waste Ash Stabilized Expansive Soil

Niraj Singh Parihar and Ashok Kumar Gupta

Abstract The expansive soils are known for their low compressive and shear strength and they present numerous challenges to geotechnical engineers during infrastructural development. The study is an effort to examine the utility of a leather industry waste product known as liming waste ash for enhancement of the compressive and shear strength of the soil. The effects of different curing periods on the relative parameters of strength have also been discussed. It was found that the curing of the soil-ash (LLWA) mix promotes the development of bond strength through formation of pozzolanic cementitious products and augments the shear strength parameters and the unconfined compressive strength (UCS) of the soil. An improvement of 270 and 380% was found in the UCS and cohesion of the soil respectively post 28 days of curing period along with substantial rise of internal friction angle up to 7 days of curing. The influence of LLWA and curing duration on the soil fabric and its relative effect on various strength parameters have also been explained at the microstructural level through SEM analysis on the uncured and cured soil samples.

Keyword Expansive soil · Liming leather waste ash · Chemical stabilization · UCS · Shear strength · SEM

1 Introduction

Expansive soils are one of the most found soils across the globe known through various names such as black cotton, vertisol, udert, etc. and they have been one of the most problematic soils to be used as foundation and subgrade material in building and road construction due to their high expansive mineral content such as montmorillonite. A high proportion of such minerals give rise to high electronegativity and

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water absorption capacity to the soil leading to its reduced bearing capacity and high swell-shrink characteristics. In India, the huge land masses layered with the weathered basaltic plateaus and lava traps have resulted in formation of the black cotton soil which covers more than one-fifth of the geographical area and is abundantly found in central, western and southern Indian states [1, 2]. Such large areas covered by expansive soil when brought under infrastructural development, offer very less alternatives of costly base-soil replacement and soil stabilization proves as one of the best techniques to make these soils fit as a decent bearing material.

Chemical stabilization is a widely practised technique to counter the unwanted characteristics of expansive soils. A number of industrial and agricultural by-products have emerged as useful products in the recent past with capability to stabilize expansive soils. These waste products contain similar pozzolanic or binding characteristics as are found in the conventional chemical soil stabilizers such as lime and cement and their use as a soil stabilizer not only creates an alternative for replacement of the costly and pollution causing conventional construction material but also solves the dumping and environmental related issues related to these wastes. A wide number of researches have been done on the utility of these wastes as chemical modifiers of soil including industry originated wastes such as phosphogypsum [3], cement kiln dust [4, 5], marble dust [6], silica fume [7], fly-ash [5, 8], slags [2, 9], quarry dust [10], lime-soda glass powder [11], lime sludge [12, 13], etc. and silica containing agricultural wastes such as corn ash [14], groundnut shell ash [15], bagasse ash [16], rice-husk ash [12], wheat-husk ash [17], etc. or a combination of both [18, 19].

The leather processing industry is one of the oldest in the world. The leather industry has seen an overwhelming growth in the recent past due to increase in demands for its finished products. It is also among the top export industries in India with Indian leather exports crossing 5.5B USD [20]. With more than 6 million tonnes of leather waste production worldwide, India and China together share more than 25% of this waste produce [21]. It is one of the industries with the highest waste to raw product fraction of 60–80% containing numerous environmental pollutants originating from its chemical processes. However, the waste originating from the industry finds no or little use and has to be either dumped or sent for digestion [22, 23]. The earlier researches have shown their concerns on these methods of waste disposal as this waste dumping is environmentally hazardous and the waste matter is not easily digestible and generates greenhouse gases [24]. The incineration of this waste has therefore been suggested as the adaptable method by many of the researchers due to high calorific value of the waste [25, 26] and the same is practised by many countries nowadays. But despite the volume reduction of the waste after burning, a lot of waste ash still has to be disposed of in the landfills with or without treatment which can promote degradation of land and water table.

Liming waste coming from beam-house operations in the leather processing industry accounts for a sizeable proportion of the total produced waste and is only scarcely utilized for making glue and gelatin-like products. Parihar and Gupta [27, 28] conducted research over the utilization of lime-fleshing or liming leather waste ash (LLWA) for stabilization of expansive soil and established that the residual waste

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3 Experimental Program

The black cotton soil dug from the open field was collected and sealed in airtight containers to conserve its native state till the time of testing. The virgin soil was first subjected to laboratory determination of engineering properties such as unconfined compressive strength (UCS) and shear strength parameters and the same tests were repeated through various soil-LLWA mix proportions under different curing periods. The LLWA was mixed in the proportions of 2, 4, 6, 8 and 10% by weight of the soil. The soil and waste ash were first dry mixed to uniformity until formation of a homogenous mix followed by addition of a requisite amount of water for slurry formation and sample preparation for all tests. All the experiments for plain and LLWA mixed soil were conducted as per the recommendations of Indian standard codes. The samples for UCS and unconsolidated undrained triaxial test were simultaneously prepared by using same slurry mixture in the previously defined mix proportions as per IS: 2720 (Part X)-1991 [30] and IS: 2720 (Part XI)-1993 [31] respectively. The soil samples for both the tests having 38 cm diameter and 76 mm height were derived through sampling tubes driven in the proctor mould compacted under standard proctor compaction procedure recommended by IS: 2720 (Part VII)-1980 [32] for equality in imparted energy levels. The moisture content during proctor compaction of soil-LLWA mixes was kept a little above the optimum moisture level of the mix to compensate for the water required for hydration reaction. The obtained samples were divided into four groups for examining the effects of different periods of curing. The first set was tested immediately after the derivation of samples whereas the other three sets were tested after curing the samples for a period of 4, 7 and 28 days respectively under very high humid conditions as explained by Parihar and Gupta [28]. A strain rate of 1.25 mm/min was followed for all the compressive and shear strength tests. An average value of at least two UCS samples tested for each mix type has been taken as final. The SEM study has been conducted on the readily mixed samples, uncured samples and samples derived after various curing periods to examine the effect of additive proportion and curing time on soil structure at a microscopic level.

4 Results and Discussion

4.1 Uncured and Cured Compressive Strength

The behaviour of soil strength with respect to curing period is accessed through an unconfined compressive strength test. The samples of dimension 38 mm diameter and 76 mm height derived through proctor compaction test were used for the study. Samples of plain black cotton soil were tested immediately after extrusion of soil samples while the LLWA mixed samples were tested both immediately after derivation and also after different curing periods of 4, 7 and 28 days. The curing periods

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were decided on the grounds of time required for electronegative charge stabilization of soil, generation of compounds of cementation and initial gain of strength respectively. The effect of curing on UCS of soil with different LLWA contents is shown in Fig. 2a and the respective increase in UCS(ΔUCS) with respect to the UCS of untreated soil specimen (UCS_i) is shown through a dimensionless ratio ($\Delta UCS/UCS_i$) in Fig. 2b.

It was observed that the strength increase was continuous both with the addition of LLWA and with the progression of the curing period. A nominal strength gain was also noticed immediately after mixing the waste ash which was mainly due to the formation of cohesive matrix and particle packing effect as the soil and the waste ash exhibit different grain size characteristics. Further, with the increment of the curing duration, the calcium silicate compounds (calcium silicate hydrate (CSH) and calcium aluminate silicate hydrate (CASH)) continued to form with the chemical reaction of silica and aluminium in the soil and ash and calcium oxide in the ash in

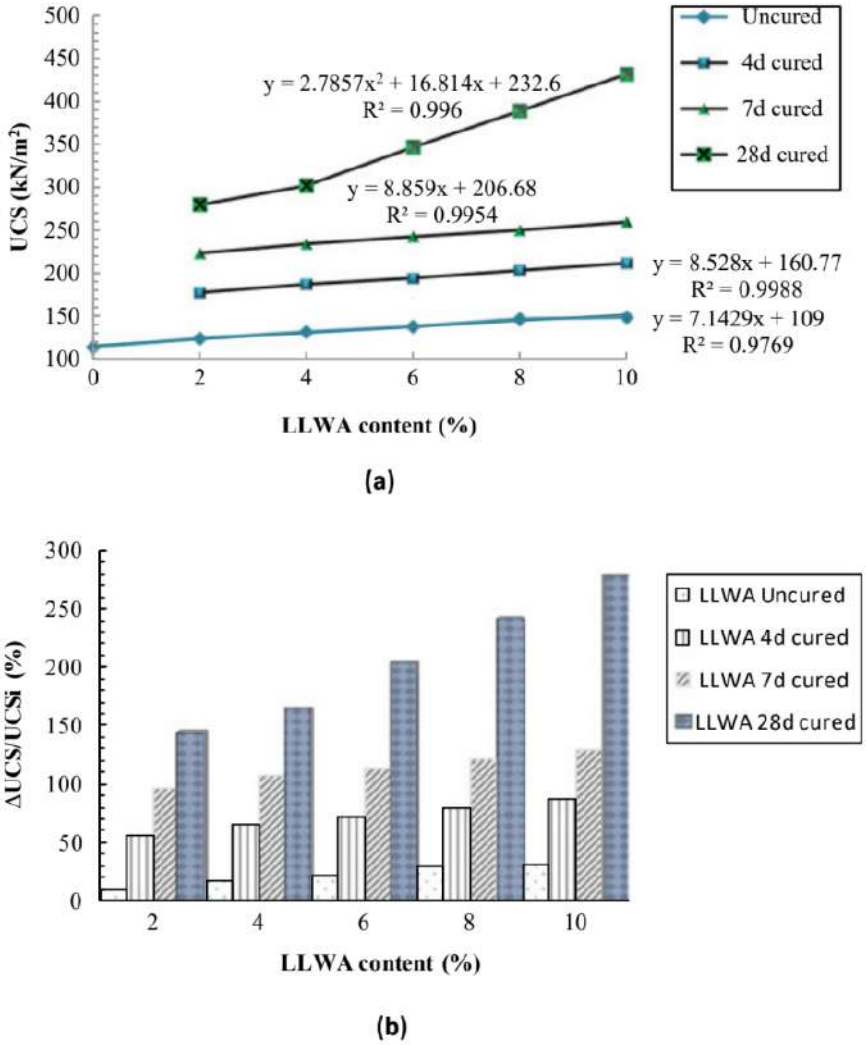

Fig. 2 **a** Relationship of UCS with LLWA content and curing period, **b** % rise in cured UCS w.r.t. untreated UCS

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the presence of moisture which substantially increased the strength, particularly after 7 days of curing. A more than 270% increase in the UCS was observed with highest additive addition post 28 days of curing. It is interesting to note that the behaviour of UCS with LLWA content is almost linear with a high degree of correlation coefficient for uncured UCS specimens and cured specimens of 4 and 7 days whereas a parabolic increase in strength was observed for 28 days cured specimen. The extreme rise in this strength gain is due to complete formation of the silicate gels after 7 days of curing which provided the bonding between particles thereafter.

4.2 Shear Strength Parameters

The undrained shear parameters, i.e. cohesion and internal friction angle for each sample mix and for all defined curing periods were derived from the failure envelope obtained through unconsolidated undrained (UU) triaxial test performed at low confining pressures of 50, 100 and 200 kPa. The effect of waste addition and curing on angle of internal friction and cohesion are shown in Fig. 3a, b respectively. It is clear that the LLWA addition has an incremental effect on both the parameters as a consequence of the combined effects of granular material addition and its capacity to produce agglomeration between particles. This agglomeration is generated on account of the chemical reaction between calcium ions and electronegative silica mineral sheets and the bonding provided by silicate gel which increased both cohesion and internal friction. It can also be noticed that the effect of waste on cohesion is more pronounced as the cementation between particles enhanced progressively with the addition of waste and higher curing time. The rate of cohesion rise also increased after 7 days of curing due to full establishment of strength yielding calcium silicate gel and peak cohesion of 260 kPa was achieved as compared to 54 kPa of untreated soil cohesion post 28 days of curing time. However, the effect of waste on internal friction angle was limited to a certain extent as addition of LLWA beyond 6% concentration decreased this parameter at all curing periods. This may be due to cationic repulsion and lack of frictional effect between the ash particles in case of their excessiveness. It was also observed that the internal friction stabilized after 4 days of curing time and reduced beyond 7 days of curing. This probably has occurred due to the achievement of full electroneutrality till the former period which would have helped coalescence of the particles leading to maximum increase in the internal friction angle. Although, the presence of excessive gel formation between soil and ash particles at the latter period would have led to the reduction of particle to particle contact and hence the internal friction did not experience much appreciation at this curing period and beyond. But overall, cementation and cohesion had a dominating effect at even highest concentrations of additive and at all curing periods which also led to a continuous gain of UCS despite the decrease in the internal friction.

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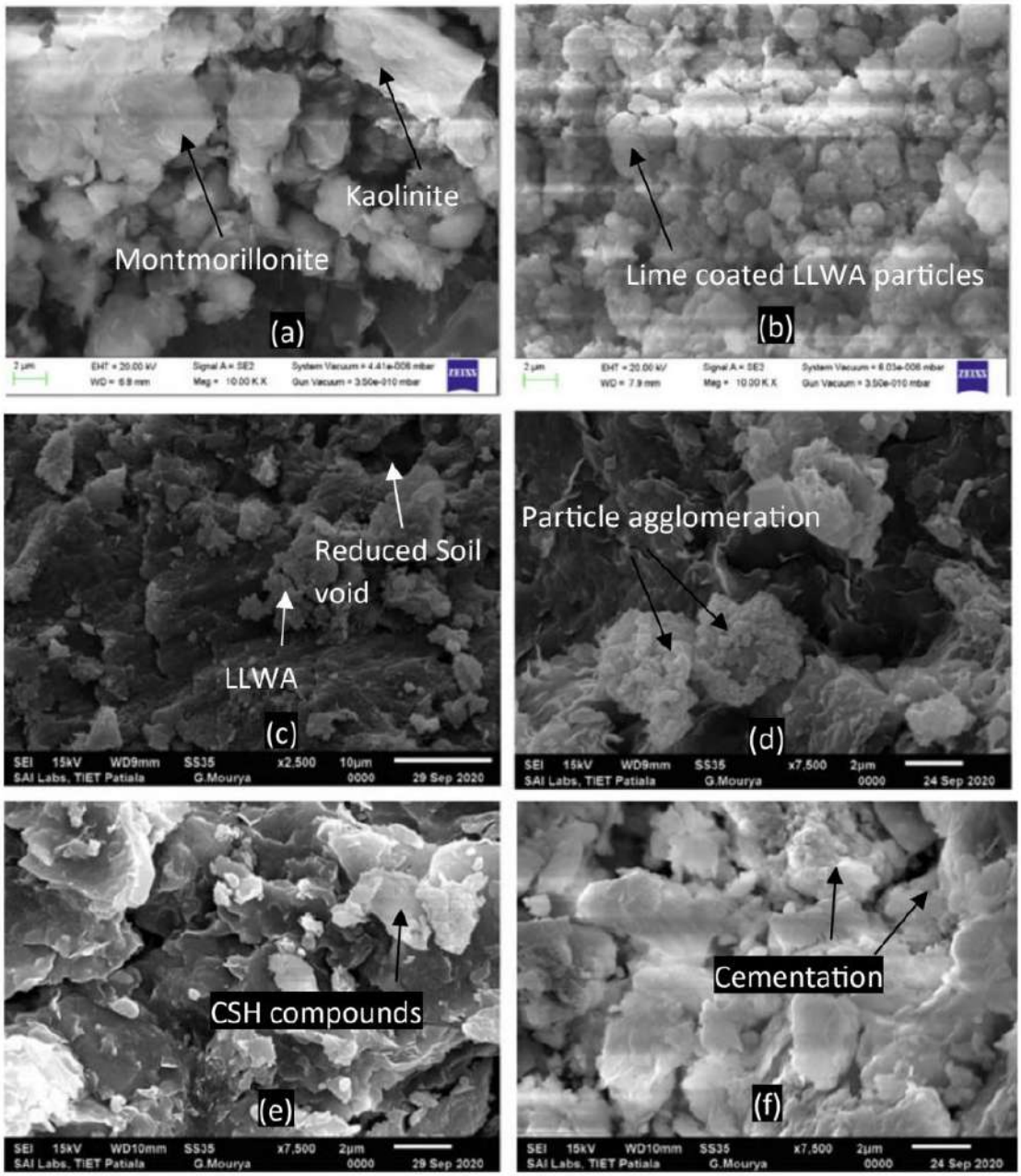

Fig. 4 SEM images for **a** untreated soil, **b** LLWA, **c** uncured mix, **d** 4 day cured mix, **e** 7 day cured mix, **f** 28 day cured mix

particularly beyond 4 days of curing period where the original crystalline structure of the soil was modified and dissolved into the compact cementitious structure of CSH and CASH gel formation. A well-developed silicate gel formation was visible after 28 days of curing period with the particle void spaces completely filled with cementitious compounds. This improved gel formation was the reason behind a sharp increase in UCS and cohesion of the mix at late periods of the curing led by an increased bond strength and cementation between particles. However, the gel structure reduced the particle to particle contact and decreased the overall friction which appeared as a reduced internal friction angle in the UU test results.

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approaches; Identification of molecular cues linked with enhanced metabolites using comparative transcriptomics approach and also have experience on hydro-aero cultivation of medicinal plants for industrial importance. During Doctoral Studies; he (research team) has generated technology at Dr. Yashwant Singh Parmar University of Horticulture & Forestry Nauni, Solan for developing insect pest-resistant transgenic plants in economically important vegetable crops of cauliflower cv. Pusa Snowball, cabbage cv. Pride of India and broccoli cv. Solan Green Head (with *cryIAa* gene) for insect pest resistance. He has been awarded DST INSPIRE JRF/SRF Fellowship, Department of Science and Technology, Ministry of Science and Technology, Government of India for Ph.D. full doctoral program. He has qualified ICAR AICE-SRF (PGS), ICAR ASRB National Eligibility Test (NET). He has published 35 research/review papers in various journals of International and National repute, contributed 13 book chapters and 5 popular articles. Dr. Kumar has received many awards from various societies and scientific organizations for his scientific contribution i.e. Young Scientist Award Biotechnology-2018 by Society for Plant Research, Young Scientist Award -2019 by the Society of Tropical Agriculture, New Delhi, India, Excellence in Research Award -2019 by Agro Environmental Development Society, India. etc.

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3 In Vitro Production of Medicinal Compounds from Endangered and Commercially Important Medicinal Plants

Neha Sharma and Hemant Sood

Abstract

Medicinal plants are known for curing various disorders and ailments throughout the world. The therapeutic properties of these plants are attributed to the medicinal compounds produced by them. Growing demands of these medicinal compounds have urged a necessity to concentrate the research on enhancing their production by engaging different techniques. In this article, we have assessed different plant tissue culture techniques which could be applied for enhancing the production of commercially important secondary metabolites. Here, we have discussed the usage of cell/tissue culture techniques for mass propagation and bioactive metabolite production in endangered medicinal plants under in vitro conditions. Role of hairy root cultures, elicitation and precursor feeding, endophytes, and nanoparticles has also been studied for enhancement of commercially important bioactive compounds. Further, we have also highlighted the importance of metabolic engineering and CRISPR-based approaches for understanding the biology of biosynthesis of medicinal compounds.

Keywords

Secondary metabolites · Medicinal compounds · Micropropagation · Elicitors · Endophytes · Metabolic engineering

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3.1 Introduction

The importance of medicinal plants has been known to humans since ancient times and is also recommended for their medicinal properties by traditional medicinal systems like Unani, Ayurveda, and other ancient texts including Atharva Veda, Charaka Samhita, Rig Veda, Sushruta Samhita, etc. Conferring by World Health Organization (WHO), 65–80% people of developing nations cannot access the expensive modern pharmaceutical products and depend on medicinal plants to endure their prime healthcare needs (Palhares et al. 2015). The herbal medicines are less expensive and safer than synthetic or modern drugs (Karimi et al. 2015). Approximately 25% of modern medicines and 60% of anticancer medicines are obtained from natural resources (Palhares et al. 2015). Medicinal compounds are mainly secondary metabolites, which are the resultant of primary metabolites and involved in directly in the life of plant cells by playing role in their defense, signaling, and chemical adaptations to environmental stresses. These medicinal compounds are obtained from various plant organs like bark, flower, leaves, stem, root, seed, or whole medicinal plant and can vary in a tissue and organ specific way during different developmental stages (Wink 2003). Secondary metabolites are mainly categorized as terpenoids (derived from acetyl coenzyme A or glycolysis cycle intermediates), phenolics (aromatic rings 11 bearing a hydroxyl functional group), and alkaloids (nitrogen containing compounds).

Due to emergence of new products like health care, personal care, and immunity-boosting formulations, industrial demand for herbal products has increased and will further tend to rise in future. Estimates show that the international demand for plant derived drugs is likely to approach ~US$5000 billion by end of the year 2050 (Pan et al. 2014). Currently, majority of herbal collections are obtained from their natural habitat and only 10% are contributed by the cultivated medicinal plants. The escalating demand of herbal products is affecting the dwindling population of medicinal plants in wild. Slow growth rate, complex accumulation patterns, narrow geographic ranges along with unorganized and extensive harvesting of medicinal plants are making them more prone to extinction and loss of genetic diversity. Also, uneconomical chemical synthesis and inaccessibility of quality plant material in adequate amounts hinder in satisfying the increasing industrial demands. Therefore, biotechnological tools offer valuable alternatives for production of desirable medicinal compounds by enhancing their biosynthesis and accumulation. In this chapter, we have reviewed different techniques and approaches used for production as well as enhancement of commercially important compounds in medicinal plants.

3.2 Medicinal Compounds Production Using Cell/Tissue Culture Techniques

In medicinal plants, cell/tissue culture techniques are promising methods for controlled biosynthesis of numerous bioactive compounds. These are environment friendly and act as cost-effective alternative to chemical synthesis of medicinal

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compounds. These techniques enable the in vitro grown plants to biosynthesize particular medicinal compounds analogous to the intact plants and also aid in producing secondary metabolites at large scale without any seasonal constraints. Utilizing cell/tissue culture techniques, various medicinal plants can be established under aseptic conditions using different explants including meristems, leaves, stems, and roots for mass propagation and production of bioactive metabolites. Secondary metabolite accumulation is genotype specific; therefore, high metabolite content producing genotypes or cell/organ lines needs to be selected for induction of in vitro cultures of medicinal plants. Various valuable medicinal compounds are biosynthesized in callus or suspension cultures, while some metabolites are produced in more organized structures like shoots, roots, glands, or somatic embryos. Callus or suspension cultures have been widely utilized for production of secondary metabolites and can be efficiently upscaled for production of important medicinal compounds under in vitro conditions (Kapoor et al. 2018; Kumar et al. 2020). Organ culture under aseptic conditions is required for biosynthesis of some medicinal compounds which need differentiated structure or organ for production of medicinal compound. For example, *Panax ginseng* roots for saponins, foliar glands of *Hypericum perforatum* for hypericins and hyperforins, *Nicotiana tabacum roots for* biosynthesis of lysine to anabasine and its leaves for conversion of anabasine to nicotine (Hussain et al. 2012). Numerous studies have been attempted on medicinal compounds production in medicinal plants using cell suspension or organ/tissue culture techniques and some of these studies have been summarized in Table 3.1. Biosynthesis of bioactive compounds under in vitro conditions is dependent on various factors including culture media composition (carbon source, macronutrients, micronutrients, other organic compounds and plant growth hormones), pH of media, explant or inoculum concentration, and other suitable environmental conditions like light, temperature, aeration, and agitation. Optimization of these factors aids in improvement of metabolite productivity. There are studies where higher metabolite content in cultured cells has been reported compared to native medicinal plants like camptothecin in *Ophiorrhiza mungos* (Deepthi and Satheeshkumar 2017), shikonin in *Onosma bulbotrichom* (Bagheri et al. 2018), and vinblastine and vincristine produced in *Catharanthus roseus* (Mekky et al. 2018). Cell/tissue culture techniques offer various advantages for medicinal compound production such as biosynthesis of secondary metabolites under in vitro conditions is more reliable, simpler, and predictable. Also, the process of extraction of valuable phytochemicals from in vitro grown cell suspensions or tissue culture plants is fast and effective in comparison to isolation from whole plants. Interfering secondary metabolites can also be avoided in cell cultures. However, cost-effective parameters need to be considered for their economic production at large scale.

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3.3 Hairy Root Culture

Hairy roots are comprised of differentiated transformed roots which are produced by infection caused by *Agrobacterium rhizogenes*. T-DNA located in root-inducing (Ri) plasmid of this pathogen is transferred and integrated into the genome of host plant, thereby leading to formation of hairy roots at the wounded site. These proliferating roots show lateral branching, self-regulating rapid growth, absence of geotropism and are genetically stable (Hussain et al. 2012). Unlike natural roots, which are accessible at particular period of the year, these proliferating roots could biosynthesize bioactive compounds throughout the year without the effect of seasonal variations. Attributed to high productivity of secondary metabolites, this technique has become popular tool to produce same medicinal compounds corresponding to the wild type roots. Therefore, hairy roots provide an imperative alternative to natural plant material for biosynthesizing many valuable medicinal compounds. Production of some important medicinal compounds using this technique has been listed in Table 3.2.

3.4 Role of Elicitors and Precursor Feeding for Enhancement of Medicinal Compounds Production

Elicitors act as the signal molecules which can be biotic or abiotic in nature and are capable of inducing or enhancing the production of specific secondary metabolites by initiating defense or stress related responses. Biotic elicitors are partially purified extracts of biological origin like fungus, bacteria, yeast, or the plant itself. Some examples of biotic elicitors include polysaccharides, glycoproteins, inactivated enzymes, alginate, xanthan, yeast extract, fungal homogenate, etc. Abiotic elicitors are substances which are of non-biological origin and are categorized in physical, chemical, and hormonal factors such as UV rays, light, temperature, heavy metal salts, osmotic stress, antibiotics, jasmonates, methyl jasmonic acid, salicylic acid, acetyl salicylic acid, abscisic acid, etc. (Halder et al. 2019). They have been extensively used in cell/organ and hairy root cultures of different plant species to enhance the production of medicinal compounds. Further, they can also trigger the outflow of intracellular products and ease the extraction and purification of the targeted compounds. Application of different biotic and abiotic elicitors for production of various medicinal compounds has been summarized in Table 3.3.

The approach of supplementing the extrinsic precursors to growth medium is also used to enhance the production of bioactive compounds. For production of desired metabolites, if the endogenous levels of certain precursors are low, then supplying the precursors of key biosynthetic steps enhances the production of those metabolites (Bourgaud et al. 2001). Several reports have shown the effect of feeding suitable precursor for increasing the productivity and accumulation of target metabolites in different medicinal plants under in vitro conditions. Exogenous feeding of tryptamine and loganin has enhanced the secologanin production in mutant cell lines of *Catharanthus roseus* (Whitmer et al. 1998). In another study, exogenous

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Table 3.2 Medicinal compounds produced in some plants using hairy root culture techniques

Plant name	Medicinal Compound	Properties	References
Aconitum heterophyllum	Aconites	Anticancer, anti-inflammatory, antimicrobial, pesticidal	Giri et al. (1997)
Agastache rugosa	Rosmarinate	Antioxidant, anti-inflammatory, antimutagenic, antimicrobial, antiviral, astringent	Lee et al. (2007a, b)
Angelica gigas	Deoursin	Anticancer, antibacterial, antinematodal	Xu et al. (2008)
Artemisia annua	Artemisinins	Antimalarial	Liu et al. (2002)
Astragalus mongholicus	Cycloartane saponin	Antimicrobial, antifungal	Ionkova et al. (1997)
Beta vulgaris	Betalains	Antioxidant, anti-inflammatory	Pavlov et al. (2005)
Brugmansia candida	Tropane alkaloids, hyoscyamine, scopolamine Scopolamine and hyoscyamine Scopolamine and hyoscyamine	Anti-asthmatic, anticholinergic, narcotic, anesthetic	Marconi et al. (2008)
Catharanthus roseus	Alkaloids	Anticancer	Hanafy et al. (2016)
Centella asiatica	Asiaticoside	Wound healing, memory improvement, cognition, and mood modulation	Nguyen et al. (2019)
Coleus forskohlii	Forskolin and rosmarinic acid	Anti-inflammatory and antipyretic	Li et al. (2005)
Echinacea purpurea	Alkamides	Immunostimulatory, anti-inflammatory	Romero et al. (2009)
Fagopyrum esculentum	Rutin	Antioxidant, anti-inflammatory, anticancer, antimicrobial, cardioprotective, hypolipidemic, antidiabetic, reno-protective, wound healing, anti-stress	Lee et al. (2007a, b)
Gentiana macrophylla	Gentiopicroside	Antimicrobial	Zhang et al. (2010)
Gingko biloba	Terpenoids	Antioxidant, improve blood flow to brain	Ayadi et al. (2003)
Linum flavum	Lignans	Anticancer	Renouard et al. (2018)
Lithospermum erythrorhizon	Shikonin	Antimicrobial	Tatsumi et al. (2016)
Panax ginseng	Ginsenosides	Neuroprotection, anticancer, antidiabetic, hepatoprotective, immunomodulatory	Murthy et al. (2017)

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Table 3.2 (continued)

Plant name	Medicinal Compound	Properties	References
Papaver somniferum	Morphine, sanguinarine	Analgesic, narcotic, sedative, stimulant	Le Flem-Bonhomme et al. (2004)
Picrorhiza kurroa	Picroliv	Hepatoprotective, anti-inflammatory, anticholestatic, antiulcerogenic, anti-asthmatic, antidiabetic, immunomodulatory	Verma et al. (2015)
Rauvolfia micrantha	Ajmalicine and ajmaline	Neuroprotective	Sudha et al. (2003)
Rubia akane	Alizarin and purpurin	Anticancer, antimalarial, antimicrobial, antifungal, antioxidant	Lee et al. 2010
Silybum marianum	Flavonolignan	Hepatoprotective, anticancer, antihepatitis	Rahnama et al. (2008)
Swertia japonica	Amarogenetin	Antibacterial, antihepatitis, anticholinergic, chemopreventive, anti-lieshmanial	Ishimaru et al. (1990)
Withania somnifera	Withanoloid A	Aphrodisiac, liver tonic, anti-inflammatory	Murthy et al. (2008)

supplementation of geraniol, 10-hydroxygeraniol, or loganin significantly increased tabersonine levels in hairy roots of *Catharanthus roseus* (Morgan et al. 2000). Bemani et al. (2013) have observed that application of phenylalanine to suspension cell cultures of *Corylus avellana* L. has increased the production of taxol along with the antioxidant activity and cytotoxic effects. Lately, Kumar et al. (2016) have found that exogenous supply of precursors like cinnamic acid and catalpol influences the synthesis of picroside-I in shoot cultures of *Picrorhiza kurroa*. Recently, Thakur et al. (2019) have reported enhanced picrosides content via nutrition feeding method in aeroponic and hydroponic system of *Picrorhiza kurroa*. Hence, elicitation and precursor feeding under in vitro conditions can be used as a viable tool for enhancing the production of pharmaceutically important secondary metabolites which are otherwise produced in low quantities.

3.5 Role of Endophytes in In Vitro Production of Medicinal Compounds

Endophytes are microbes that exist inside the plant living tissues without causing any negative effect to them. These microbes have the capability to biosynthesize secondary metabolites similar to that produced by their host plants (Köberl et al. 2013). They produce secondary metabolites due to the horizontal gene transfer between host and endophyte. These secondary metabolites empower them to create supremacy over other invading pathogens or enhance plant defense and consequently securing themselves against various pathogens (Mousa et al. 2016; Naik

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Table 3.3 Different elicitors utilized in production of secondary metabolites in plants

Plant name	Medicinal compound	Elicitor	Culture type	References
Andrographis paniculata	Andrographolide	Methyl jasmonate	Cell suspension	Sharma et al. (2015a, b)
Amni majus	Xanthotoxin	Copper	Shoot	Purohit et al. (1995)
Ambrosia artemisiifolia	Thiarubrine A	*Protomyces gravidus*	Hairy root	Bhagwath et al. (2000)
Azadirachta indica	Azadirachtin	*Claviceps purpurea*	Hairy root	Satdive et al. (2007)
Bacopa monnieri	Bacosides	Jasmonic acid, methyl jasmonate, pH, sucrose, copper	Shoot	Naik et al. (2010), Sharma et al. (2013), Munish et al. (2015)
Catharanthus roseus	Vinblastine and vincristine	Sodium chloride	Embryogenic tissues	Fatima et al. (2015)
Corylus avellana	Paclitaxel	Sucrose	Cell suspension	Sara-Alsadat et al. (2015)
Digitalis purpurea	Digitoxin	Salicylic acid	Shoot	Patil et al. (2013)
Datura metel	Hyoscyamines, scopolamines	Salicylic acid	Root	Ajungla et al. (2009)
	Atropine	Silver, *Escherichia* coli, *Bacillus cereus, Staphylococcus aureus*	Hairy root	Zahra et al. (2015)
Echinacea pupurea	Derivatives of caffeic acid	Gibberellic acid	Hairy root	Abbasi et al. (2012)
Gymnema sylvestre	Gymnemic acid	Methyl jasmonate, salicylic acid, *Aspergillus niger, Escherichia coli, Bacillus subtilis, Saccharomyces cerevisiae*	Cell suspension	Chodisetti et al. (2013), Chodisetti et al. (2015)
Glycyrrhiza uralensis	Glycyrrhizic acid	Salicylic acid	Adventitious root	Li et al. (2015a)
Hypericum adenotrichum	Hypericin and pseudohypericin	Sucrose, polyethylene glycol	Seedling	Omer et al. (2013)
Hypericum hirsutum	Hypericin and pseudohypericin	Salicylic acid	Shoot	Coste et al. (2011)
Hypericum perforatum	Hypericin and pseudohypericin	Chitin, pectin, dextran	Shoot	Sonja et al. (2015)
	Phenylpropanoid and naphtodianthrone	Chitin, *Fusarium oxysporum, Phoma*	Cell suspension	Sonja et al. (2015)

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Table 3.3 (continued)

Plant name	Medicinal compound	Elicitor	Culture type	References
		exigua, Botrytis cinerea		
Melissa officinalis	Rosmarinate	Ozone	Shoot	Tonelli et al. (2015)
Perovskia abrotanoides	Cryptotanshinone and tanshinone IIA	Methyl jasmonate, sorbitol, silver, yeast extract	Adventitious roots	Arehzoo et al. (2015)
Picrorhiza kurroa	Picroside-I	Methyl jasmonate, sodium nitroprusside, abscisic acid, seaweed extract	Shoot	Sharma et al. (2016)
Plumbago indica	Plumbagin	Jasmonic acid	Hairy root	Gangopadhyay et al. (2011)
Plumbago rosea	Plumbagin	Jasmonic acid, yeast extract	Cell suspension	Silja et al. (2014)
Pueraria thomsnii	Puerarin	Ozone	Cell suspension	Sun et al. (2012)
Salvia castanea	Tanshinone	Methyl jasmonic acid, silver	Hairy root	Li et al. (2015b)
Salvia miltiorrhiza	Tanshinone	Methyl jasmonate, salicylic acid, gibberellic acid, *Trichoderma atroviride*	Hairy root	Yuan et al. (2008), Qianliang et al. (2013), Xiaolong et al. (2015)
Salvia officinalis	Diterpenoid	Methyl jasmonate, sodium salicylate	Shoot	Izabela et al. (2009), Kracun-Kolarevic et al. (2015)
Silybum marianum	Silymarin	Methyl jasmonate, yeast extract	Cell suspension	Firouzi et al. (2013)
Stevia rebaudiana	Steviol glycoside	Proline, polyethylene glycol	Callus and cell suspension	Pratibha et al. (2015)
Taverniera cuneifolia	Glycyrrhizic acid	Methyl jasmonate, *Mucor hiemalis, Rhizobium leguminosarum*	Root	Awad et al. (2014)
Vitis vinifera	Resveratrol, trans-resveratrol, stilbene, viniferins	UV radiations, methyl jasmonate, salicylic acid, chitin, silver, cadmium, cobalt	Cell suspension	Taurino et al. (2015), Xu et al. (2015)

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playing role in manipulating metabolic pathways to biosynthesize desired medicinal compounds. CRISPR technology can be employed in different approaches for manipulating the biosynthetic pathways which include controlling transcription factors to trigger or block specific effectors of metabolic pathways, enzyme manipulation, enzyme inhibition, blocking branch pathways, switching path to alien metabolite, removing limited availability to precursor, translational regulation, protein modification, etc. (Sabzehzari et al. 2020a, b). Alagoz et al. (2016) have knocked out benzyl isoquinoline alkaloids pathway gene, viz. *4OMT2* in *Papaver somniferum* and observed reduced morphine, thebaine levels in edited plants. Similarly, in *Salvia miltiorrhizarosmarinic acid synthase* (*SmRAS*) gene of phenolic acid metabolic pathway has been edited using CRISPR/Cas9 technology (Zhou et al. 2018). They have found declined rosmarinate and lithospermic acid B contentsin edited hairy root lines, specifically in the homozygous mutants. Additionally, enhanced level of rosmarinic acid precursor 3,4-dihydroxy phenyl lactic acid was observed. Therefore, the study suggested that the rosmarinic acid synthase enzyme is important for biosynthesis of rosmarinic acid and can be targeted to increase the level of desired metabolites.

3.7 Nanoparticles Mediated Secondary Metabolite Production

Nanoparticles are 1–100 nm sized particles, which can interfere with various signaling pathways and can modulate secondary metabolite production in plants; however, the exact mode of action behind this modulation is yet to be uncovered (Marslin et al. 2017). Zhang et al. (2013) have reported 3.9-fold enhanced artemisinin content by silver nanoparticle treatment in *Artemisia annua* L. hairy roots. In *A. thaliana*, silver nanoparticles have upregulated anthocyanin and flavonoid biosynthetic genes (Garcia-Sanchez et al. 2015). Recently, Jasim et al. (2017) have studied the consequence of silver nanoparticles treatment in *Trigonella foenum graecum* L. and observed a substantial increase in diosgenin concentration. Nanoparticles have potential to increase secondary metabolite production in plants; however, deeper understanding is still required to fully exploit this technique to produce commercially important medicinal compounds.

3.8 National and International Status of Medicinal Compounds in Commercially Important Medicinal Plants

India harbors diverse potential for medicinal plants due to its different climatic zones, geographical variance, and rich biodiversity. Medicinal compounds of these plants are used in modern therapeutic drugs throughout the world, for example, use of berberine from *Coptis japonica* as cardioprotective, hepatoprotective, and renoprotective (Morimoto et al. 1988), reserpine, serpentine from *Rauwolfia serpentina* root in hypertension (Salma et al. 2008), vinblastine and vincristine, from *Catharanthus roseus* for cancer treatment (Mekky et al. 2018). Several types of

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research have been conducted by national and international research community to enhance medicinal compounds production in commercially important medicinal plants. The demand of medicinal plants is constantly increasing around the globe. China, India, Nigeria, the United States of America (USA), and WHO are significantly investing on herbal medicinal research, so that it can contribute to global health (WHO 2002).

3.9 Conclusion

Medicinal plants have been used to cure various diseases since early times. Slow growth rate and threat of extinction of some medicinal plant species along with the inaccessibility of superior plant material in suitable amounts hamper in meeting the increasing industrial demands. Biotechnological approaches provide an additional production system to prevail over inadequate availability of bioactive and commercially important medicinal compounds. Cell/tissue culture techniques aid in multiplication of medicinal plants under in vitro conditions which provide an incessant, reliable source of natural products and thus relieve pressure from their natural habitat. Advances in hairy root cultures and endophytes can lay out new modes for cost efficient, viable production of low volume pharmaceutically important secondary metabolites. Elicitation with various biotic and abiotic elicitors has been broadly practiced for production of medicinal compounds in different species and will further aid in meeting growing demand of these natural metabolites. Metabolic engineering has opened new gateways to produce important metabolites by manipulating endogenous biochemical pathways. The emergence of CRISPR/Cas system has also opened new doors towards next-generation metabolic engineering which can assist in better elucidation of secondary metabolite production in plants.

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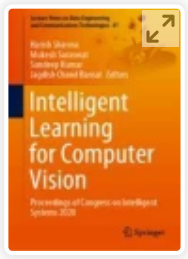

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A Comparative Analysis of Edge-Preserving Approaches for Image Filtering

Niveditta Thakur, Nafis Uddin Khan & Sunil Datt Sharma

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Abstract

Noise removal while sustaining the integrity of important details is a pedantic problem in image enhancement and reclamation. The vital stage to improve image quality which is needed for quantitative imaging study is filtering. Edges preserving filtering techniques are used extensively in computer vision to serve denoising efficiently in

prominent research areas for enhancing the quality of low-level vision images, medical images, industrial images, geological images, and so on. This review paper is presenting the popular edge-preserving approaches for the enhancement of speckle contaminated images and to enhance peak signal-to-noise ratio (PSNR) of images. Various image quality metrics for proving the worth of these approaches are discussed. The main challenges in these filtering approaches are also covered along with how those challenges are inscribed by researchers. This review contributes to research problems to other fellow researchers who are keen to work in this area.

Keywords

Anisotropic diffusion (AD) **Guided filtering**

Image quality assessment (IQA)

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A Comparative Analysis of Edge-Preserving Approaches for Image Filtering

Niveditta Thakur, Nafis Uddin Khan, and Sunil Datt Sharma

Abstract Noise removal while sustaining the integrity of important details is a pedantic problem in image enhancement and reclamation. The vital stage to improve image quality which is needed for quantitative imaging study is filtering. Edges preserving filtering techniques are used extensively in computer vision to serve denoising efficiently in prominent research areas for enhancing the quality of low-level vision images, medical images, industrial images, geological images, and so on. This review paper is presenting the popular edge-preserving approaches for the enhancement of speckle contaminated images and to enhance peak signal-to-noise ratio (PSNR) of images. Various image quality metrics for proving the worth of these approaches are discussed. The main challenges in these filtering approaches are also covered along with how those challenges are inscribed by researchers. This review contributes to research problems to other fellow researchers who are keen to work in this area.

Keywords Anisotropic diffusion (AD) · Guided filtering · Image quality assessment (IQA)

1 Introduction

Real-world limitations lead to image quality degradations including noise, blurring, low contrast, etc. Image filtering [1] is a vital topic in image processing that is used to do denoising. Goyal et al. [2] conclude that lack of expertise of operator, adverse external and environmental conditions at the time of capture, and bad quality of used

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imaging device is the principal cause of noise in medical images which lead to false diagnosis. Speckle and additive Gaussian noise are dominant in ultrasound images (US), remote sensing images, and computed tomography (CT) scans.

Speckle noise is extensively found in the real-world image which has a more consequential result on performance and structural detail. Inaccurate characterization and loss of relevant information during the diffusion process called over-filtering are major problems in speckle reducing filter.

Cardiac US images are used to assess cardiac physiological indicators, coronary heart diseases, and diagnosing heart failure covering a wide range of clinical applications. Detection of a brain tumor using magnetic resonance imaging (MRI) shows the detailed image of the attacked brain position, and noise removal from an image is challenging. Identification of potential tumors on CT images for the early stage oral cavity cancer detection requires suitable filtering algorithms. In biometrics, fingerprint identification using anisotropic diffusion is popular since fingerprint has a systematic texture with well-ordered local inclination and frequency. Mineralogy, surveillance, agriculture, and astronomical areas use hyper-spectral images. Remote sensing image helps in detecting vehicles, buildings, road-linked objects, and the acquisition of transportation data.

In the linear filtering approach, output pixel values are linear combinations of the pixels in the input pixel's neighborhood. Linear filters do well at emphasizing edges, and they have the disadvantage of also emphasizing noise, inevitably blur edges, and fail to protect the details of the image well. Spatial nonlinear filters reduce noise without blur edges and thus conserve edges. But, the generation of factitious features distorts subsisting features of images because meaningful edges in a coarse image would be smudged so much so that it is hard to determine where the real meaningful edge is originally located. Another class of filter is the isotropic diffusion filter where isotropic means the same in all directions and this behaves in the same way as Laplacian filtering. Desirable filtering along with edge preservation is achieved using a guided filter and anisotropic diffusion filter which are discussed in Sects. 2 and 3, respectively. Section 4 is about implementation and observation along with a brief discussion on challenges and future research directions. Section 5 concludes this paper.

2 Guided Filter

Enhancement algorithms inspired by the guided filter possess edge-preserving property. In guided image filter (GIF) [3], each output pixel is computed locally as a linear transform of the guidance image. Low computational complexity and high efficiency make GIF well-liked. But, GIF when applied to edge-aware smoothing results in halo artifacts near edges. Also, the guided filter approach performs inefficiently on structural discontinuities due to lack of anisotropy.

Efficient adaptive guided image filtering (EAGIF) [4] does image sharpening and denoising at the same time. EAGIF algorithm has low computational requirements

in comparison with adaptive bilateral filtering. Weighted guided image filter (WGIF) [5] makes a regularization parameter adaptive by executing edge-aware weighting. Non-consideration of edge direction, in WGIF, leads to blurred edges in the averaging process. Inconsistent structure occurrence in image results in failure of guided filtering due to the lack of anisotropy. Chen and Wu [6] introduced weighted aggregation GIF (WAGIF) to reduce halo artifacts and to get sharp edges. But, the small scaling parameter η makes WAGIF suffer from over-sharpening and gradient reversal artifacts. Sun et al. [7] proposed steering kernel inspired filtering (SKWGIF), by utilizing the steering kernel to fully use edge direction by adaptively learning direction and including the learning results into the filtering process. SKWGIF suppresses halo artifacts better along with edge conservation.

Edge preservation results of SKGIF found better than GIF and WGIF as shown in resulting Fig. 1, and comparative PSNR results are in Fig. 2.

Anisotropic guided filter (AnisGF) [8] is a derivative of a guided filter which has been used in edge-preserving along with noise removal [9–13]. Weighted averaging helps achieve maximum diffusion along with strong edge preservation. Summary of the varying properties of the family of guided filter design is specified in Table 1.

Family of guided filters compared in Table 1 include GIF [3], AGF [4], WGIF [5], GGIF [14], WAGIF [6], SKWGIF [7], and AnisGF [8]. 'P' = Present, 'A' = Absent, 'L' = Low, 'H' = High, 'M' = Medium.

Steering kernel [7] learning process complexity is required to be reduced which is very challenging and needs further surveyed. With AnisGF [8], there is fine extraction

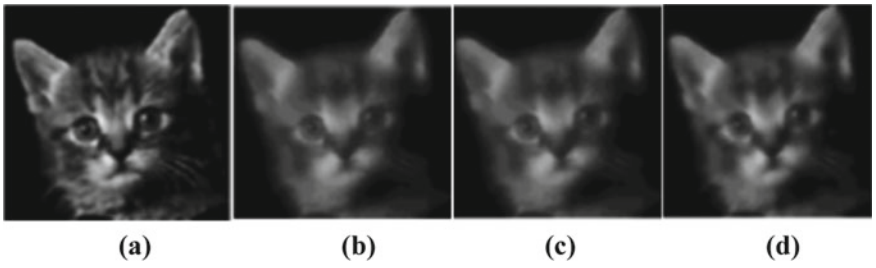

Fig. 1 **a** Reference image. **b–d** Filtered output of GIF, WGIF, and SKWGIF [7]

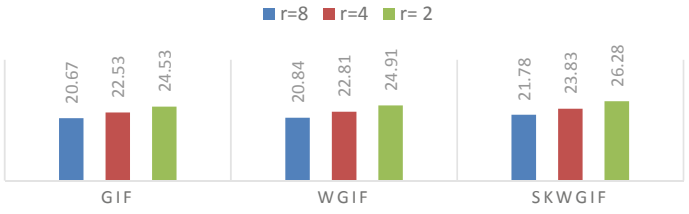

Fig. 2 PSNR values of different guided filters [7]

Table 1 Comparative analysis of guided filter designs

Property	GIF	AGF	WGIF	GGIF	WAGIF	SKWGIF	AnisGF
Adaptive regularization	A	P	P	P	P	P	P
Adaptive weighting	A	A	A	A	P	P	P
Inconsistent structure handling	A	A	A	A	P	P	P
Computational complexity	L	L	L	L	L	H	L
Time consumption	L	L	L	L	–	H	M

of textures, making certain that very little color and structural information are eliminated. But, AnisGF is not found immune to the formulation of density-dependent artifacts, so there is a need to extend this filter to multiple scales.

3 Speckle Reducing Anisotropic Diffusion Filter

Classical divergence-based anisotropic diffusion (AD) has received considerable attention to serving denoising efficiently. Traditional approaches include Weickert's edge-enhancing diffusion (WAD), Cho's dictionary-based anisotropic diffusion (DAD), and extended anisotropic diffusion (EAD) which overcome undesirable effects of linear smoothing filter such as blurring and misinterpretation of meaningful edges, but actual noise present in the image is not considered. A set of parameters that determine the success of anisotropic diffusion-based enhancement are the threshold parameter, conduction function, and stopping parameter [15].

Efficient enhancement of noisy image follows causality, piecewise smoothing, and immediate localization as described by Perona and Malik (PM) [16] along with anisotropic diffusion equations as represented by Eqs. (1) and (2) for filtering along with the preservation of edges. The anisotropic diffusion equation using four nearest neighbors is given by Eq. (1):

$$I_{t+1} = I_t + \frac{1}{4}\sum_{i=1}^{4}[C_t.\nabla I_t] \tag{1}$$

Equation 1 is rewritten as:

$$\partial_t I = \mathrm{div}(C.\nabla I) \tag{2}$$

$$C = \frac{1}{1 + \left(\frac{|\nabla I|}{k}\right)^2} \tag{3}$$

where

t Iteration.
I Input image.
∇I Image gradient.
C Diffusivity coefficient.
k Edge threshold parameter.

Equation (1) shows that the diffusion model is dependent on C. Equation 2 shows that C is a function of the gradient of image and k.

Here, the parameter to be controlled is diffusion coefficient C by changing k for the specific image used in an application and the type of noise present in the image. Regular anisotropic diffusion reaches a steady-state solution for a large number of iterations which result in longer computational time along with loss of sharpness at edges. But for large noise content image and more variation of noise across the image, the scheme proves insufficient to get correct multi-scale segmentation, and it proves an ill-posed problem [17]. Local contrast and noise can be considered for correct enhancement.

The problem of inaccurate speckle statistical modeling and issue of poor formulation of edges in classical filters, e.g., Lee, Frost, Kuan, and Gamma, is solved by using non-homogeneous diffusive heat phenomenon in speckle reducing AD filter (SRAD) [18]. Detail preserving AD filter-oriented speckle reducing AD filter and optimized Bayesian non-local means method came out as an improved despeckling method.

Fuzzy AD algorithm is suggested by Puvanathasan and Bizheva [19], for OCT images specifically, corresponding to various features and biological tissue types, by considering uncertainty in the calculated diffusivity coefficient. This proves the best edge preserver in comparison of Type-I fuzzy AD algorithm, Wiener, and adaptive Lee filter for fairly short processing time. New fuzzy rules can be added further to refine speckle noise reduction performance for different images. Probability-driven OSRAD [20] uses tissue-based statistical models and got good results. But the structural loss of details is still there. Wu and Tang [21] suggested an anisotropic method for speckle noise removal considering two functions, fidelity and speed function based upon ENI (edge, noise, interior pixels). If $p = (i, j)$ is pixel under consideration and $N_P^0(w)$ are neighbor pixels centered at p with window $= (2w + 1) \times (2w+1)$. For each $q \in N_P^0(w)$, $d(p, q)$ is the difference in intensity of pixel p and q.

$$\mathrm{ENI}_P = \sum_{q \in N_P^0(w)} I_p(q) \tag{4}$$

$$I_P(q) = \begin{matrix} 1 & \text{when } d(p,q) \le T \\ 0 & \text{when } d(p,q) > T \end{matrix} \tag{5}$$

Controlling speed function is:

$$g_n(\mathrm{ENI}_P) = \frac{1}{2} + \frac{1}{2}\cos\left(\frac{2\pi \mathrm{ENI}_P}{N}\right) \tag{6}$$

Controlling fidelity function is:

$$\lambda_n(\mathrm{ENI}_P) = \frac{1}{4} - \frac{1}{4}\cos\left(\frac{\pi \mathrm{ENI}_P}{N}\right) \tag{7}$$

where $N = (2w + 1)^2 - 1$.

The value of g_n at edge minimum, at noise intermediate, and at an interior is maximum. The value of λ_n at the edge intermediate, at noise minimum, and at the interior is maximum. There is no explicit formula or method to determine the parameters w and T. Results are checked on standard test images; however, it can be extended to SAP contaminated medical images.

Fabbrini et al. [22] proposed a novel anisotropic diffusion filter, improved edge-enhancing diffusion (IEED) filter to minimize noise on homogeneous regions while keeping weak edges. IEED does not use any noise model, also mathematically less complex, but the method is checked for speckle noise only.

The over-filtering problem of classical filters is resolved by ADMSS [23] by extending the formulation to perform selective diffusion so that diffusion structures and textural regions reduced, and in this way, visibility of important structures is enhanced. K-means clustering-based AD filter [24] uses a cluster-based speckle scale function, and the homogeneous sample region is chosen based on the clustering results. To control and guide the diffusion process, Mishra et al. [25] use the probability density function of edge and pixel relativity information (EPPR-SRAD). Diffusion equation theory is used by the doubly degenerate nonlinear diffusion (DDND) model [26] to promote the denoising process given by:

$$\partial_t I = \mathrm{div}\left(b(\mathrm{I})\frac{1}{\left(1 + |\nabla I|^2\right)^{(1-\beta)/2}}\nabla I\right) \tag{8}$$

$b(I)$ gray level indicator function.

New despeckling diffusion model:

$$\partial_t I = \mathrm{div}\left(\frac{\nabla I}{1 + (|\nabla I|/k)^{\beta(I)}}\right) \tag{9}$$

$\beta(I) = 1 - b(I)$ is the region indicator function.

Gao et al. [27] found that in ADMSS, erroneous pixels appear in homogeneous background, so they developed an improved DDND model (IDDND). Xu et al. [28] suggested Gabor-based AD (GAD-LBM), supporting advantages of GAD on

edge preservation and the advantages of the lattice Boltzmann method (LBM) on rapid parallel implementation. GAD-LBM provides excellent noise reduction, detail preservation, and computational efficiency. Goyal et al. [29] proposed an SGS-SRAD filter for the despeckling of US images which is a combination of Savitzky-Golay smoothing (SGS) filter and SRAD.

4 Image Quality Assessment (IQA)

IQA is used to quantitative and statistical performance analysis which is used to benchmark or to validate the performance of various image enhancement algorithms. Here, IQA techniques for ADF-based enhancement methods are presented.

Despeckling on homogeneous regions is calculated by ENL index [22] given as:

$$\mathrm{ENL} = \left(\frac{4}{\pi} - 1\right)\frac{\mu_{\underset{\sim}{I}}^2}{\sigma_{\underset{\sim}{I}}^2} \tag{10}$$

where $\underset{\sim}{I}$ = despecled image, $\mu_{\underset{\sim}{I}}^2$, $\sigma_{\underset{\sim}{I}}^2$ are mean, and variance of $\underset{\sim}{I}$ on the homogenous region.

Contrast measure [24] is used to check the performance of despeckling algorithms:

$$C_m(i) = \frac{1}{n}\sum_m |c(i)|.\log(1 + |c(i)|) \tag{11}$$

where

n number of pixels,
m number of edge points,
$c(i)$ local contrast at pixels i

where

$c(i) = \sum_p \left(i - i^{'}\right)$, p denotes neighbor pixels around i.

Contrast-to-noise ratio (CNR) [19] is the difference between particular image features relative to the background. Edge preservation (η) which shows edge degradation is occurring in the image.

$$\mathrm{CNR} = \frac{1}{R}\left(\sum_{r=1}^{R}\frac{(\mu_r - \mu_\mathrm{b})}{\sqrt{\sigma_r^2 + \sigma_\mathrm{b}^2}}\right) \tag{12}$$

where $\mu_\mathrm{b}, \sigma_\mathrm{b}^2$ = mean and variance,of background noise. μ_r, and σ_r^2 is mean and variance of rth region of interest that includes Pratt's figure of merit (FOM) [18, 25,

28, 30] calculates edge preservation in denoised images. FOM range is between 0 and 1 where 1 means best edge detection. FOM score decreases with an increase in the noise level.

$$\text{FOM} = \frac{1}{\max\{\hat{n}, n\}} \sum_{i=1}^{\hat{N}} \frac{1}{1 + d_i^2 \gamma} \tag{13}$$

$\hat{n}$ detected edge pixel and
n reference edge pixel.
d_i Euclidean distance between $\hat{i}_{th}$ edge and its nearest neighbor.
γ 0.9.

Perceptual fog density is calculated by fog-aware density evaluator (FADE) [6] where low FADE is desired. Structural degradation-oriented mean structural similarity index (MSSIM), MSE, and PSNR are simple and popular error sensitivity metrics.

5 Discussions and Observations

Image smoothing with edge conservation is a growing field of research. The experiments are performed on standard test images of Lena which are speckle contaminated for different level of noise (10% and 20%) as shown in Figs. 3b and 4b. Implementations are done on MATLAB R2020a software, and then PSNR is calculated. Table 2 summarizes various edge-preserving filtering techniques on the basis of the type of image and IQA method used. Anisotropic and guided filtering is applied on standard test images, and anisotropic techniques analyzed here are Frost [18], PM [16], DPAD [31], OBNLM [32], and ASMSS [23].

From Table 3, it is clear that with an increase in noise, PSNR is decreasing for each method. Guided filter results in Figs. 3h and 4h which is showing the highest PSNR values; however on seeing visual results, this filter fails on speckle noise. However, anisotropic diffusion methods OBNLM and ADMSS result in Figs. 3f, g and 4f, g which show effective filtering of speckle noise. Frost and DPAD result in Figs. 3c, e and 4c, e which show that speckle removal is not achieved properly. PM achieves speckle removal, but edge information is severely affected in Figs. 3d and 4d. DMF which is a directional median filter fails in completely removing speckle noise as shown in Figs. 3i and 4i.



Fig. 3 **a** Original Lena image. **b** Noisy image (speckle noise = 10%). **c** Frost filtered image. **d** PM filtered image. **e** DPAD results. **f** OBNLM. **g** ADMSS. **h** Guided filter. **i** DMF

6 Conclusion

Guided filter and partial differential equation (PDE) based anisotropic diffusion methods are capable of smoothing noise in the image along with edges preservation. Anisotropic diffusion filters are the best option for speckle contaminated images where guided filter does not work effectively. The optimal diffusion coefficient function can be explored to discriminate the isolated impulsive noisy pixels from edge

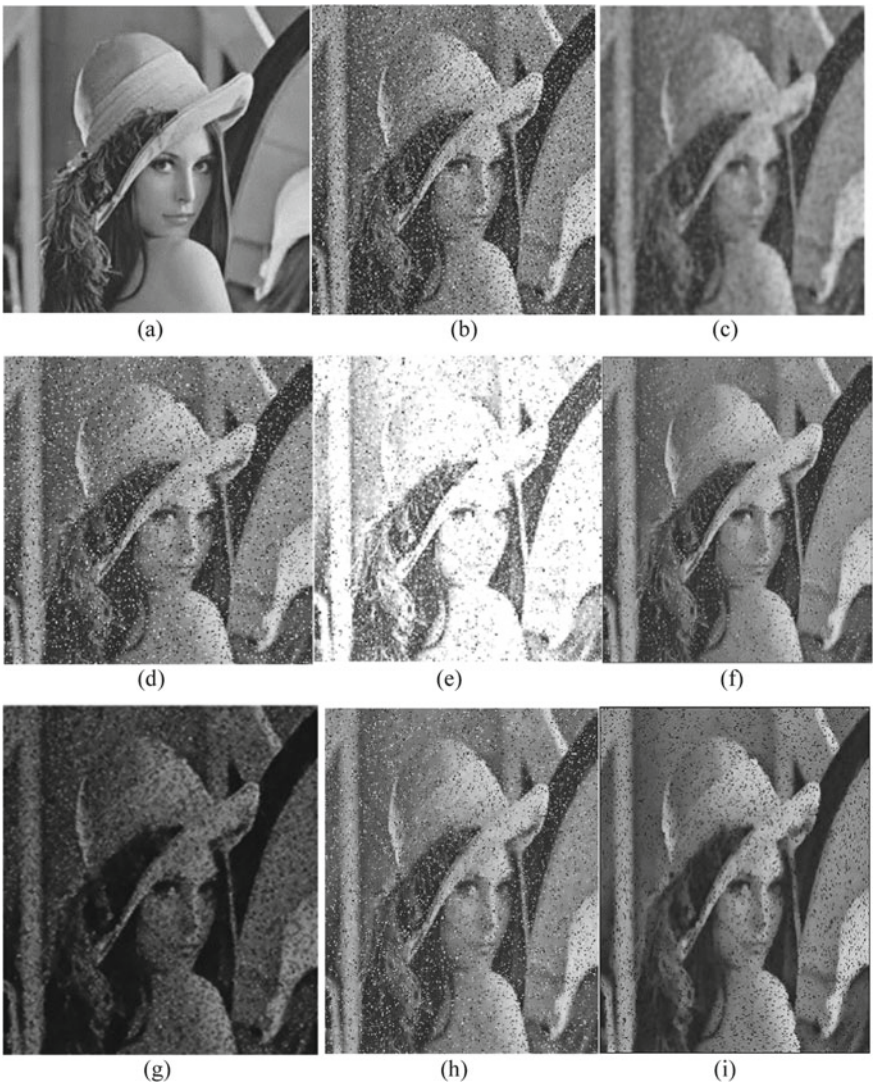

Fig. 4 **a** Original Lena image. **b** Noisy image (speckle noise = 20%). **c** Frost filtered image. **d** PM filtered image. **e** DPAD results. **f** OBNLM. **g** ADMSS. **h** Guided filter. **i** DMF

pixels. Whereas traditional intensity transformation, Histogram Processing, directional median filtering, Edge detection, and Edge filtering smooth important gradient information along with noise. Medical images require such anisotropic technique by proper formulation of the diffusion equation since the presence of even small artifacts leads to false diagnosis. However, the computational load of various AD methods needs to be reduced. Anisotropy can be combined with a guided filter which can be exploited for various contaminated images. Further to benchmark,

Table 2 Summary of various edge-preserving filtering techniques

Filtering technique	IQA technique	Image type
WAGIF [7]	FADE	Fog image
SKWGIF [8]	PSNR, SSIM	Barbara, Pirate, Baboon, Hazy image
SRAD [13]	FOM	US and SAR images
DPAD [25]	MSSIM	US image
OSRAD [26]	FOM	2D and 3D synthetic image
OBNLM [27]	Despeckling assessment index	2D and 3D synthetic image, real US image
Type-II fuzzy AD [14]	PSNR, ENL, CNR	OCT fingertip and retina images
POSRAD [15]	FOM	Cardiac US image
NSDD [16]	PSNR	Standard test images (Lena and Pepper)
IEED [17]	ENL index	SAR image
ADMSS [18]	Despeckling assessment index, PSNR, SSIM	US image
CDAD [19]	Contrast measure	US image
EPPR-SRAD [20]	SSIM, MSE, FOM	Synthetic and real US cardiac and liver images
IDDND [22]	PSNR, SSIM, MAE	Real ultrasound and RGB color images
GAD-LBM [23]	SSIM, PSNR, FOM	Synthetic and clinical images
SGS-SRAD [24]	SSIM, PSNR, MSE	Real and synthetic US images

Table 3 PSNR results for speckle contaminated Lena image

Filter method	PSNR (in dB)	
	Speckle noise (10%)	Speckle noise (20%)
FROST	26.30	24.16
PM	18.92	16.05
DPAD	8.52	8.33
OBNLM	23.86	19.88
ADMSS	28.68	28.51
Guided filter	31.58	29.74
Directional median filter (DMF)	28.46	27.67

various anisotropic diffusion technique, more advanced neural-based image quality metric can be explored depending upon the type and availability of image under processing. The filtering model must be power efficient, less time-consuming, robust, and uncomplicated in hardware and operational complexity. Fuzzy logic and neural network are emerging approximation tools which may be employed for optimizing

the edge threshold parameter needed in the diffusion filters. Some other decomposition and transform techniques may also be used in conjunction with diffusion filters and guided filters for image denoising.

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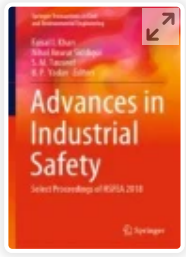

Advances in Industrial Safety pp 291–304

A Comparative Study of Fire Resistance of Concrete Incorporating Ultrafine Slag

Saurav, Anjani Kumar Shukla & Pratyush Malaviya

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Abstract

Exposure to fire symbolizes as one of the most severe environmental conditions to which a load bearing structure may be exposed in its service life; hence, fire safety prerequisites. While conceptualizing the design of concrete structures with regards to load bearing is imperative. The inherent nature of materials constituting concrete enacts an influential character upon the accomplishments of concrete throughout its

existence. Terrorist assaults, accidental fire-breakouts, and bizarre explosions fabricate an exponential transformation of temperature for a little episode of time and in such cases, the impending injury due to high ascent of temperature is found to be minimized by the properties of the materials that make up the concrete. Concrete among all other building materials has the upper hand of having intrinsic fire-resistive properties; but still, concrete structures must be intended to be impassive to any fire-induced effects. Engineered structures are anticipated to endure dead and live loads without caving-in inspite of the elevation in temperature due to fire exposure which has been evidently found to cause a decrease in the strength along with fall in modulus of elasticity for concrete and steel. Furthermore, the engineered concrete is expected to counter the stresses and strains resulting from the possible expansion of the constituents of structural components in the event of a fully full-fledged fire. While designing structures, the clauses in building code endowing fire resistance are at times overlooked and this may end up in expensive slip-ups (Bilow and Kamara in Fire and concrete structures, engineered structures, 2008). In recent days, due to the necessity of high performance concrete, the use of Alccofine-1203 is been widely put under study owing to its fine size and high strength achieved in partial replacement with cement. The paper aims at analysis of the consequences of high temperature in event of fire on the compressive strength of concrete made with

ordinary Portland cement containing ultrafine slag without using any admixtures. After heating at varying durations of diverse elevated temperatures, cubes are reinstated at room temperature and the results were evidently established in the laboratory. Compressive strength of concrete is of the foremost interest while designing fire-resistant concrete (Bose and Iffat in Int J Struct Const Eng 10(2), 2016). The analyzed results and the effects of augmented temperature upon the compressive strengths of concrete are presented as a percentage strength of the specimen, controlled at room temperature.

Keywords

Alccofine **Compressive strength** **Spalling**

Electric muffle furnace **Thermal performance**

Ultrafine slag

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1. Alliance for concrete codes and standards, balanced code provisions for residential structures.

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A Comparative Study of Fire Resistance of Concrete Incorporating Ultrafine Slag



Saurav, Anjani Kumar Shukla, and Pratyush Malaviya

1 Introduction

The inherent fire resistant personality of concrete is advantageous over many other constructional materials; but safety against fire must also be incorporated in the very design of concrete structures. In addition, ensuing stresses owing to the expansion of the structural components because of exposure to fully grown fires and resulting strains should also be resisted. For a safe and sound structure, fire contemplations must be elemental in the conceptualization along with the design-related junctures. This ascent of temperature forces the free water of concrete to convert itself from liquid stage into gaseous stage. Such alterations change the transmission rate of heat from the core concrete section (interior) heading for the periphery (exterior) and vice versa. This amplification in temperature creates a potency drop in context to the elasticity modulus of both concrete and steel. However, the cadence of descent in strength depends upon the stroke of temperature amplification of fire along with the natural insulation traits of concrete. The modification in concrete characteristics because of the elevation in temperature depends upon the sort of aggregates incorporated. Hence, we can say that study of the residual properties of concrete are imperative while assessing the load carrying competence of concrete along with inspecting the supplementary use of the damaged structures in an event of a fire. Prior investigations stand witness to the fact that the type of concrete, its ingredients, the duration and temperature of maximum exposure, mineral admixtures usage, their nature and magnitude of their involvement in concrete chemistry develop the fire endurance

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properties of concrete, exposed to high temperatures. As elevated temperatures are administered within concrete, the incongruities of thermal deformations within the rudiments of concrete instigate cracking. The microstructure change, owing to dehydration and steam pressure, builds-up and accumulates inside the pores. This shift in volume will conclude itself in building up of great internal stresses which shall ultimately lead toward release of accumulated energy via micro-cracks. Elevated temperature additionally spawns numerous chemical and micro-structural changes like the moisture exodus, thermal inaptness of interface between cement paste and aggregate. All such processes will pose a demeanor outcome on the strength and stiffness of concrete.

2 Literature Review

Concrete has been known to be the best fire resistant and economical building material as evaluated with other available building material (Kodur and Raut (2010)). The admirable fire resistance of concrete is owing to its constituents, which upon chemical combination, give birth to a material which is essentially of inert nature and possesses low thermal conductivity with an admirable heat proficiency and slower strength deterioration with rising of temperature. Slow rate of transfer of heat accompanied by delayed loss in strength enables concrete to perform as an efficient fire-shield not only between neighboring spaces but also in providing resistance to fire damage. The behavioral response of a fire-exposed structural member made up of concrete is reliant, upon thermo-mechanical and deformation characteristics of the composition of materials, participating as concrete. With respect to temperature variation, such properties are divergent in nature along with the accountability falling on the composition and characteristics of the individual constituents. A structural member subjected to a pre-determined and definite time interval of fire exposure, shall result in a predictable distribution of temperature within the member. Change in behavioral characteristics along with deformations has always been noticed in the constitutive materials of the structural members when subjected to fires. The modulus of elasticity of concrete is also an important parameter influencing the fire resistance of concrete which falls with elevation in temperature. At elevated temperatures, disintegration of products of cement hydration and bond rupture at the microstructure realm of cement paste diminishes the elastic modulus. The loss of moisture, temperature and the sort of aggregate used, can be held responsible for such a diminution.

2.1 Transient Strain

The strain occurring at high temperatures within concrete, when concrete structural members exposed to fire has been found to add to deformations; moreover, strains being generated in the initial phases of heating of concrete is known as transient

strain and are not time wise-reliant. Such strains are caused by thermal incompatibilities among aggregate and the cement paste. Transient strain of concrete, is a complex phenomenon analogous to high temperature creep, and is inclined toward the parameters such as loading under elevated temperatures, potency under the mix proportions, hydrations, etc. (Kodur 2014). Transient strains and creep fall under the category of time-oriented deformations of concrete and have been identified to be highly enhanced at elevated temperatures under compressive stresses (Bazant and Kaplan 1996). Increased creep in concrete registered under elevated temperatures has been articulated to be due to the exodus of moisture from the concrete matrix. Such phenomenon was additionally amplified by thinning out of moisture and bond rupture within the cement gel (C–S–H). We can infer that the liability of creep origin and its progressiveness is significantly due to two processes—"Dispersion of moisture and concrete dehydration due to high temperatures"; and; "Accelerated process of bond breakage." To summarize, we can establish that aspects like the modification of the concrete's chemical composition along with the misalignment of thermal expansion, originate internal stresses along with micro-cracking in the concrete components (aggregate and cement paste); this was found to be due to complex transformation of moisture along with chemical disparity in the composition of the cement paste and the thermal spreading out among the cement paste in addition to the non compliance of aggregates with each other resulting in transient strain in the concrete (Schneider 1988). Transient strain occurs during the first time heating of concrete, but it does not occur upon repeated heating (Khoury et al. 1985).

2.2 Fire-Induced Cracks

Fire efficiency of structural members is evaluated in terms of the duration of exhibiting stability with respect to structural integrity; the changes in state of concrete due to fire result in chemical variations in the concrete structure which end up adversely influencing its mechanical strength. Under administered fire, temperature generally exceeds 1000 °C (Buchanan 2002; Purkiss 2007). But several authors agree that concrete reaching up to a temperature of 500–600 °C should be treated as damaged (Kowalski 2010). Concrete, at elevated temperatures, undergoes significant physico-chemical changes. These cause thermal, mechanical, and deformation characteristics of concrete properties to behave abnormally at high temperatures and has been believed to be responsible for more complexities, such as crack genesis and maturing into spalling. Studied have shown that in normal concrete, under-fire spalling was observed to be initiated by cracks origination at an temperature of 250 °C. At about 300 °C, concrete began to loose strength and at 400 °C, significant spalling was visibly evident. Within 550–600 °C, the load bearing capacity was lost and finally, at 600 °C and above, concrete was seen to loose its ability to function as a structural member. The surface with close proximity to fire suffered

maximum damage[1] (Baley 2002). A case study emphasizing upon the penetration of fire-induced cracks in concrete inferred that depth of ingress of cracks was in accordance to the fire temperature and generally, penetration depth was evidently very profound, reaching to a depth of 300 mm and more inside the concrete. The heat-cool cycle due to dousing out of fire and resulting effect on the expansion-contraction of the concrete's constituents was held responsible by the authors for such a deep crack penetration (Georali and Tsakirdis 2005).

2.3 Fire-Induced Spalling

A trace of the prior cases presented a variance in opinion upon the spalling caused by fire and it questions the exact mechanism of spalling in concrete. Some investigators inferred spalling in a concrete structural member's subjected fire was explosive in nature while other studies presented little or insignificant spalling. A possible explanation for such contradicting phenomenon is all the factors involving spalling and their interdependencies; major causes were chalked out were concrete not being watertight and migration of moisture in concrete reported at elevated temperatures. Following are two theories of significance via which the explanation of phenomenon of spalling can be explained (Kodur 2000).

1. *Accumulation of pressure*: The hypothesis of spalling is supposed to originate by of pore pressure accumulation under-fire exposure (Diederichs et al. 1995; Hertz 2003). The enormously soaring water vapor pressure generated in event of a fire is incapable to exit the matrix owing to the highly densified and compact (low permeability) nature of concrete. When the tensile resistance of concrete gives-into the effective pore pressure (which is measured as porosity times pore pressure), chunks of concrete wear away from the structural member. This pore pressure is supposed to cause progressive failure which has lead to the belief that lower is the permeability of concrete, greater shall be fire-induced spalling. This degeneration of concrete may or may not be likely to explode on the surface depending on fire and concrete characteristics. (Harmathy 1993; Anderberg 1997).
2. *Thermally induced dilatation of restrained nature*: This philosophy considers that spalling is a result of restrained thermal dilatation in proximity of the heated surface, resulting in the occurrence of compressive stresses parallel to the heated surface. The compressive stresses generated fracture in the concrete which was brittle in nature (spalling). Pore pressure enacts a significant role on the inception of instability of the concrete matrix which is visible as the thermal spalling of explosive proportions (Bažant 1997). This massive vapor pressure, originated from a rapid augmentation of temperature, cannot escape owing to high density (low permeability) of concrete matrix, and this pressure accumulation often reaches the levels of saturation vapor pressure. Authors have reported that the pore pressure can reach up to 8 MPa at around 300 °C; such internal pressures are

[1] Alliance for concrete codes and standards, balanced code provisions for residential structures.

often too high to be resisted by the tensile strength of concrete. The drained conditions in the vicinity of the burnt concrete surface along with the low permeability of concrete leads to enormous pressure gradients close to the surface and are known as moisture clogging (ASTM 2011; ISO/DIS 2008). When the pressure generated by the vapor overcame the tensile resistance of concrete, pieces were seen to fall-off from the structure under evaluation; in such a study, the significant parameters which gained attention were strength, porosity, density, load, fire intensity, aggregate type, relative humidity, amount, and type of admixtures used (Kodur and Phan 2007; Kodur et al. 2003; Phan 2007). All above enumerated parameters were found to be very much dependable upon each other and this made forecasting of spalling became quite a complex task. Spalling was found to be associated with the cumulative epoch of concrete and its ambiguity is amplified during the entire serviceable life of concrete. In order to provide the necessary remedies, engineers recommended that the capability of aged (existing) concrete structures in resisting duress induced by fire and the structural loads needs to be assessed with regards to the risk of spalling resulting from fire (Wang et al. 2013). Most authors have concurred to the fact that aggregate expands and cement paste shrinks when subjected to heating (Khoury et al. 1985, 2002). The thermal incompatibility among the aggregate and cement paste, during initial phases of heating, had been considered damageable to concrete, and the expansion due to heat was considered as the superficial and a significant cause of spalling but owing to the dawn of new age modern methods of testing, certain authors contradicted such a reasoning. During the virgin heating, concrete's components move reciprocally, i.e., attenuation in cement paste accommodates the expanding aggregate and consequently, concrete under compression and subjected to high temperature, adjusts to the combined duress of fire and external load; this ends up eventually into unstable spalling when a certain limit is reached where-in the mutual adjustment cannot sustain itself anymore. Hence, shortening was also seen to appear against elongation in loaded structural elements (Chudzik et al. 2017).

An extensive review about the genesis and control of spalling can be summarized as follows. Concrete witnesses thermal distresses in terms of stresses and strains, upon fire exposure. The earlier approach to a fire proof design was targeted at the maximum temperature of the duress which was quite unsafe and an immature approach to the engineering aspect. It was later summarized that the rate of elevation of the temperature is also a very contributing factor, along with the maximum fire temperature. The maximum temperature determines the resulting temperature within the concrete and the rate of its ascent decides the episode of spalling. Serious structural damage has been visibly evident due to rapid heating inducing explosive spalling in structures. Concrete is advantageous as fire proof due to its non-combustibility and little thermal diffusivity but it experiences explosive spalling and deterioration of properties under heating which need to be addressed at the materials realm to produce a cost-effective concrete. The declines of properties such as compressive strength depend upon the constituents, their compatibilities, and molecular changes under fire.

Investigations of the loss of properties of concrete under fire keeping in mind the occurrence of explosive spalling should be the prime intentions of experiments carried out at the materials level. In such cases, the prologue of a thermal barricade at the correct locations needs to be considered along with a secure structural design to guarantee that the structure does not collapse in event of a fire and that the safety is made certain. Properties worth inspecting are the compressive strength and the strain behavior at the materials level. Rapid heating during fire induces explosive spalling with serious consequences to structure and people (Khoury 2008).

3 Experimental Investigations

Fresh Portland cement incorporating 12% alccofine-1203 by weight was assorted with fine and coarse aggregate. The relative amount of cement and aggregates was 1:1.35:2.19 and 12% cement (by weight) was replaced by the inclusion of alccofine. Optimum water cement ratio obtained which was 0.43 and used for the preparation of the specimen. Optimum dosage of alccofine has been established as 12% from previous investigations for maximum strength gain.

3.1 Alccofine

Alccofine 1203 exhibits superior approach than all other mineral admixtures used in concrete within our country. Because of its fundamental CaO content, ALCCOFINE 1203 triggers dual reactions during hydration phenomenon.

1. Primary reaction of cement hydration.
2. Pozzolanic reaction.

ALCCOFINE like pozzolans forms additional C–S–H gel by consuming the calcium hydroxide which happens to be a by-product obtained as a result of the hydration of cement. This has a domino effect in formation of a denser pore structure and evidently higher strength gain. ALCCOFINE 1203 is a particularly processed product based on slag of soaring glass content with high reactivity obtained via controlled granulation process. Its unprocessed materials are made up primarily of low calcium silicates. Processing along with other chosen ingredients results in desired particle size distribution (PSD). The computed blain value as per PSD is around 12000 cm^2/g and is beyond doubt ultrafine. Owed to its exceptional chemistry and ultrafine particle size, ALCCOFINE 1203 provides reduced water demand for a given workability, even up to 70% replacement level as per requirement. Authors have reported enhanced hardened characteristics of concrete with incorporation of Alccofine 1203 and the compressive strength of concrete using alccofine, in general upon investigation was found to be improved (Saurav AG 2014).

The outcome of analytical evaluation shows that the chemical components in ALCCOFINE 1203 are important features in controlling the theology of the concrete. The mechanism by which ALCCOFINE 1203 disperse cement particles is of proactive in nature with a dual nature of generating a negative charge on cement particles and causing dispersion via "electrostatic repulsion" and in the advance stages of the chemical reaction among the Alccofine 1203 and cement particles, dispersion is found to be steric-hindrance administered mechanism. The cement particles have a penchant for flocc formation when in contact with water. During such a process, they entrap water between them, resulting in lesser water available for hydration of cement which ultimately influences adversely upon the cement paste consistency. The consistency can be improved by higher water content but it brings a fall in the strength. ALCCOFINE 1203 remedies this issue owing to its surface-active agents which have charged periphery. When mixed with the cement particles, there occurs modification among the surface charges causing dispersion and releasing of any entrapped water. Hence, the consistency and flowability are improved and that too at low water cement ratio. These chemical enhanced assets are active only for limited period of time, and as soon as the desired intent is achieved, the cement paste starts stiffening. ALCCOFINE 1203 commences its enchantment in the green state instantly after mixing.

3.2 Casting and Curing of Specimens

Concrete under investigation was compacted via the compaction table and de-molded after a passing of 24 h from the initiation of casting and water-submerged for 7, 14, and 28 days awaiting the time of testing (Fig. 1).

3.3 Fire Resistance Test

The 100 mm × 100 mm × 100 mm size cubes were casted and mold was reserved in a wet place for 24 h, submerged under water for 28 days at room temperature after demoulding. Cubes were heated in the electric muffle furnace afterwards which is provided with a thermostat to preserve constant temperatures of different ranges. At a time, 24 cubes, i.e., eight sets of three cubes each, were prepared among which half were submerged for 14 days and other half for 28 days. These sets were heated for 1, 2, and 3 h at four different temperatures (27, 500, 650, 800 °C). After that, these sets were left at room temperature for 24 h for cooling. Compressive strength has been calculated as per BIS 516-1959. Each of the samples selected for testing should be exposed to the desired duration of constant temperature once it has reached the desired temperature. After fire resistance test, compressive strength of the samples was determined to detect effect of fire on strength properties of concrete cubes (Figs. 2 and 3).



Fig. 1 Cubes being casted and on vibrating table



Fig. 2 Cubes incorporating alccofine at varying temperatures placed in muffle furnace

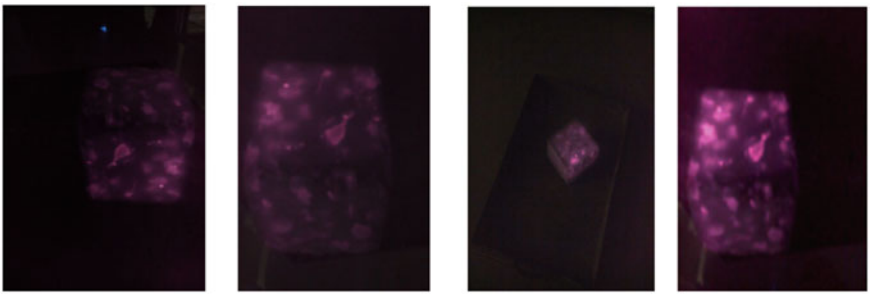

Fig. 3 Cubes taken out from furnace after desired exposure duration



Fig. 4 Superficial cracks on cubes due to varying thermal gradient

3.4 Development of Cracks at Elevated Exposure Temperature

Concrete on heating expands and contracts on cooling. Restraint to contraction causes the development of tensile stresses. The temperature-related contraction stress can cause cracking. Cracks may also be caused by differential temperatures in thick members. When the surface layer cools and contracts, movement is restrained by the core of the member which is still at a higher temperature, and hence cracks may form in the surface (Fig. 4).

3.5 Testing of the Specimens

Subsequent to heating in the oven, the concrete specimens were tested using a compression testing machine having a capacity of 400 tons and the evaluation of compressive strengths at 07, 14 days, and 28 days are as shown in Tables 1, 2 and 3 (Figs. 5, 6, 7 and 8).

Table 1 Compressive and % residual compressive strengths of cubes after exposing to elevated temperature cured for 7 days

Temperature (°C)	Compressive strength (N/mm^2)			% residual compressive strength (N/mm^2)		
	1 h	2 h	3 h	1 h	2 h	3 h
27	42	42	42	100	100	100
500	48	40	29.09	114.28	95.238	69.26
650	45	38	20.65	107.142	90.476	49.166
800	19.7	21.11	17.75	46.904	50.261	42.0261

Table 2 Compressive and % residual compressive strengths of cubes after exposing to elevated temperature cured for 14 days

Temperature	Compressive strength (N/mm^2)			% residual compressive strength (N/mm^2)		
	1 h	2 h	3 h	1 h	2 h	3 h
27	48	48	48	100	100	100
500	54	46	35.09	112.50	95.833	83.54
650	45	40	26.65	93.75	83.33	55.520
800	25.5	27.11	23.75	53.125	56.479	49.479

Table 3 Compressive and % residual compressive strengths of cubes after exposing to elevated temperature cured for 28 days

Temperature	Compressive strength (N/mm^2)			% residual compressive strength		
	1 h	2 h	3 h	1 h	2 h	3 h
27	58.2	58.2	58.2	100	100	100
500	67.51	57.42	41.31	116.006	98.65	70.97
650	63.17	55.65	30.61	108.53	95.61	52.59
800	26.29	27.252	28.60	45.17	46.82	49.14



Fig. 5 Random specimens before and after testing

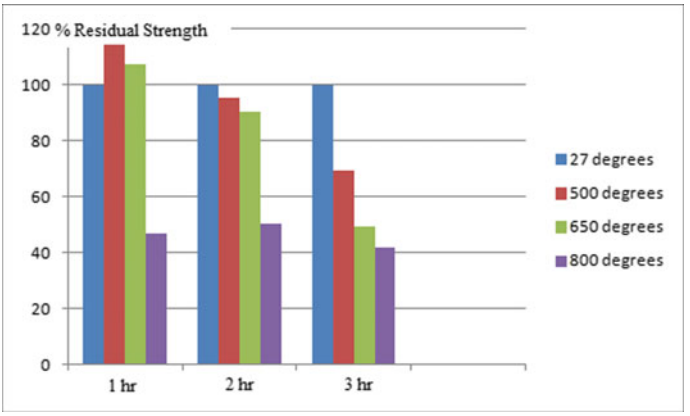

Fig. 6 Variation of % residual compressive strength with varying temperature at 7 days of curing

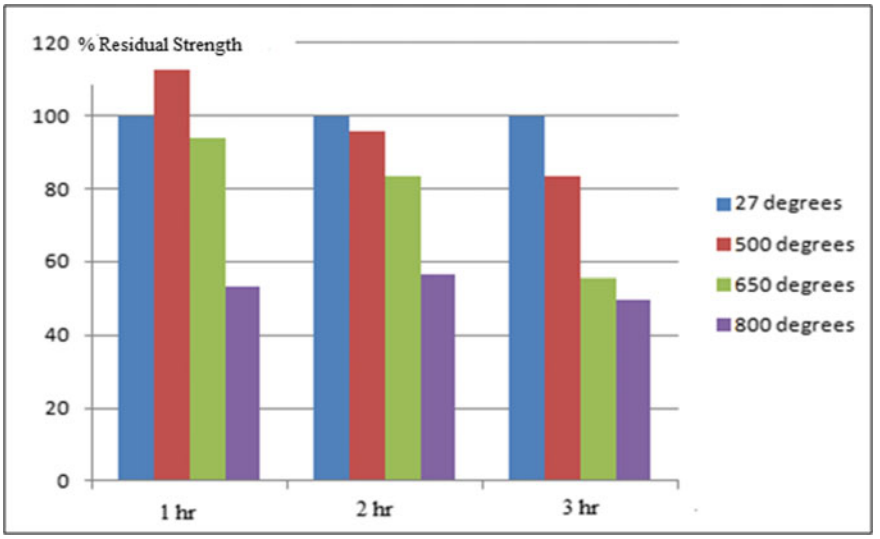

Fig. 7 Variation of % residual compressive strength with temperature at 14 days of curing

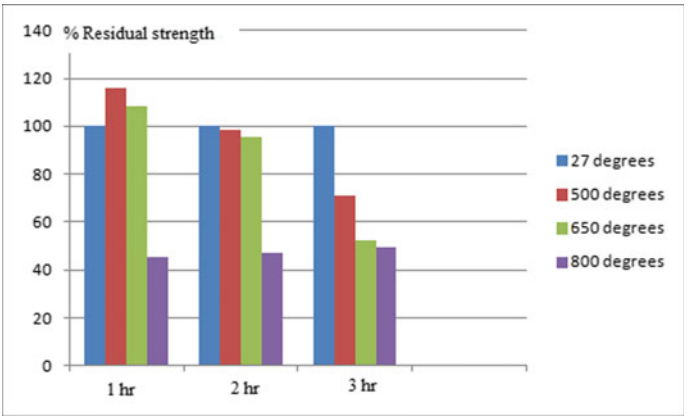

Fig. 8 Variation of % residual compressive strength with temperature at 28 days of curing

4 Results and Discussions

4.1 Inferences Based upon Appearance

At 500 °C, concrete experienced minor cracks along with dehydration of the cementitious paste with absolute loss of liberated moisture and a diminution in paste volume.

At 650 °C, prominent cracking of both the cementitious paste and aggregates due to expansion. Color of concrete turned some-what pinkish.

At 800 °C, cComplete dehydration of the cementitious paste accompanied with substantial shrinkage cracking was observed. Concrete became crispy and easily broken down upon contact. Color of concrete tainted to gray.

5 Conclusion

The disparity of compressive strength with the augmentation in temperature is studied in terms of the percentage residual compressive strength for different durations of 1, 2, and 3 h. Initially, the strength improved with temperature 27–500 °C for different durations and ahead of that, it was reduced. Utmost compressive strength was perceived when the cube was heated at 500 °C for 1 h duration. The compressive strengths are increased up to 27–500 °C and beyond that, it was rapidly reduced with increasing temperature. The compressive strength was lost to a large extent when they are heated to temperatures greater than 500 °C. Addition of Alccofine 1203 provided a revolutionary advent to the fire resistance of concrete and evidently restricted spalling up to a stage, owing to its presence in the concrete matrix.

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Chapter 1
A Framework for Assessment of Existing Solid Waste Management Practices and Characterization of Municipal Solid Waste in Muzzafarnagar City, India

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ABSTRACT

This chapter reports the details of the existing system of MSW management and characterization of Muzaffarnagar City located in Western Uttar Pradesh (UP) state in India. The overall waste generated in the city is about 120-125 tons per day (TPD) with a per capita generation rate of 0.415 kg/person/day with a collection efficiency of 70-80%. Physico-chemical and geotechnical properties of the MSW were carried out to determine its overall characteristics. The characterization results showed about 46% of the waste generated in the city is organic nature (from HIG and MIG) and 52% for (LIG) with chemical characterization showing that the elemental carbon was in the highest proportion. Further, the chapter also recommends suitable remedial measures for proper management of the existing MSW management system and suitable treatment alternatives.

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INTRODUCTION

Rapid rise in India's economy due to increased urbanisation and globalization and thereby changing lifestyle coupled with increasing population (births, migration etc.) has led to production of eight fold increase in MSW generation in comparison to 1947 (Sharholy et al, 2008; Talyan et al, 2008) leading to severe degradation of existing environmental conditions (Hazra et al, 2009). With the passage of time it is expected that Indian population will increase further with the annual rate of growth of urban population in India being predicted at 5% ("Census of India", 2011). Further, rapid influx of population from rural areas in urban cities lead to unwanted population growth leading to development of unplanned rural areas in the outskirts of the Indian cities leading to additional generation of MSW which are often unaccounted. In general, waste is defined as a material of unuseful nature and of no economic value to its owner, the owner being the generator of the waste (Mor et al, 2006b). Effective management of MSW is a global problem with developing countries facing the biggest obstacles (Ramachandra et al, 2003; Tchobaanpoglous et al, 1993). It has been inferred that increasing population is directly related to rapid increase in MSW generation in developing countries with India being no exception and might be reaching critical levels particularly due to unavailability of barren land for disposal (Indris et al, 2004; Talyan et al, 2008).The per capita waste generation of India rate varies between 0.15 kg in rural areas to 0.45 kg in urban areas (Akhtar, 2014; Katiyar et al, 2013) and it has been observed that increased economic success leads to increased per capita consumption and generation of MSW (Taylan et al, 2007; Tricys, 2002). The average per capita waste generation in India is 370 g/day as compared to 2200 g/day in Denmark, 2000 g/day in US and 700 g/day in China (Liu et al, 2011).

In an Indian context, the MSW can be classified primarily as the solid waste generated from domestic, commercial, institutional sources and to a lesser extent biomedical and industrial (toxic waste). The most prevalent method for disposal of such wastes in India are open dumping (90%) which over the period of time leads to choking of sewer pipes, breeding grounds for vectors and other serious heath hazardous and environmental problems. Such status of MSW disposal is regularly observed for Tier-II and Tier-III cities. In Tier-I and metropolitan cities some of which have implemented management strategies for tackling such huge voluminous quantities the procedures implemented have been outdated and inefficient due to lack of characterization studies which would have enabled these municipalities in implementing an effective treatment and disposal system. For example, it is estimated that about 1.3 million cubic metre of biogas per day or 72 MW of electricity from biogas can be produced for agricultural purposes along with about 5.4 million metric tonnes of compost annually ("Central Pollution Control Board", 2015). However, due

to improper MSW management practices including no segregation of wastes being followed the end products of several waste to energy (WTE) systems implemented are poor in nature with no economic value (Rana et al, 2015).

In the above context, it is an essential duty of concerned urban local body (ULB) for effective management of the MSW generated within their city limits ("The Gazette of India" 2000). However, implementation of an effective MSW management system requires suitable data including quantity, quality and characterization results which are further dependent on geographical locations, food habits and other socio-economic conditions and also adequate budgetary provisions (Goswami et al, 2007). A detailed characterization study can help in determining the drawbacks in the existing treatment processes; identify the most appropriate treatment technology for effective management of the MSW

The main objectives of the study were to assess the existing MSW management and determine the characteristics of the waste generated in Muzaffarnagar city to determine deficiencies in the existing management system and propose remedial methods for improving the existing system.

MUZAFFARNAGAR CITY AND EXISTING MSW MANAGEMENT

Muzaffarnagar Municipality has a population of 392,451 and the urban agglomeration has a population of 4, 95,543 as per census 2011 with a growth rate of about 17% in a decade (2001-2010) covering an area of 150 Km^2 ("Census of India" 2011). The population of the city is increasing at a rate of 1.5% per annum. Presently, the city is divided into 41wards. The overall municipal solid waste generation in the city is about 120-125 Tonnes/day (TPD) [Personal communication with an employee of A2Z Infrastructure Limited, 2017] with an average generation rate of 0.32 kg/(capita-day). The per capita generation can be further subdivided for different socio-economic groups with average per capita generation of 0.14, 0.17 and 0.65 kg/day respectively for Low Income Group (LIG), Middle Income Group (MIG) and High Income Group (HIG) respectively.

The city has ample number of institutes, hospitals, shops, hotels and restaurants and approximately 64000 households [Personal communication with an employee of A2Z Infrastructure Limited, 2017]. Further, biomedical waste generated from hospitals and clinics (particularly syringes) do not undergo separate processing. These biomedical wastes are mixed with the MSW and are dumped at the non-engineered landfill site. Moreover, manufacturing wastes generated from different industries including sugar mills, paper mills and Steel Rolling mills don't under go to any special treatment and are disposed with the MSW making the overall nature of the waste highly hazardous.

Collection efficiency of domestic MSW generated is about 70-80% of the city is covered by door-to-door collection method using handcarts of volume 2-5 m^3. As mentioned earlier, the city is divided into 41 wards and if certain wards are not covered by door-to-door collection these wards have a designated collection point for waste. Insufficient bin capacity, use of open bins and location of these bins in inaccessible stations in some wards lead to overflowing of such bins almost through the entire year. Further, some wards have no designated bins leading to open dumping of generated MSW in these wards. No source segregation is followed and hence no separate bins exist for organic and inorganic wastes. Further, it has been observed that waste is open dumped in middle of road particularly in the vegetable market areas and even though collection is done on a daily basis if there is a lapse in collection of one day could lead to epidemic like conditions.

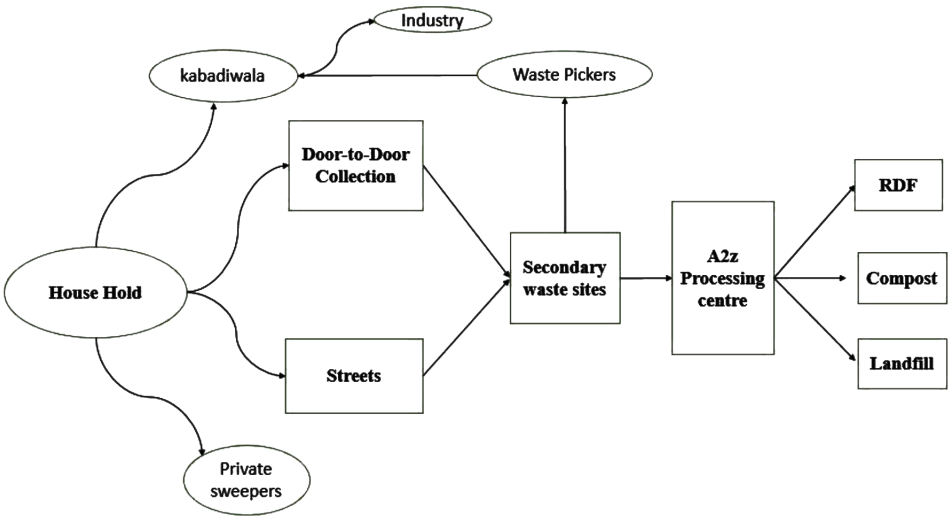
Loading of MSW is done manually and there exists only one garage in the city from where the transportation vehicles are operated and maintained with the help of private contractors. Transportation of the collected MSW is done using a total of 13 collection vehicles (6 dumpers, 3 J.C. Bamford Excavators limited, popularly designated as JCB, 3 tractors and 1 Tata Ace). Assuming the density of waste to be around 300 kg/m^3, the collection capacity per capita was determined to be only 0.001 m^3 which is extremely low and almost negligible highlighting the need for procurement of additional transportation vehicles. Further, lack and too much dependency of labourers, unplanned routing, non-covering of waste on top during transportation process highly reduces the efficiency of the transportation system. There are no intermediate transfer stations and no equipment or machinery is present at the open landfill site for segregation of wastes due to which mountains of waste exist in and around the landfill site and since last few years the load on the dumpsite has increased significantly. This leads to production of highly obnoxious odours, breeding ground of infectious vectors and propagate unhygienic environment in the vicinity of the dumpsite. Since, it is a non-engineered landfill contamination of groundwater and soil due to leachate percolation could lead to severe environmental hazard.

Though Ministry of Environment and Forests (MoEF) has specified detailed guidelines for management of MSW but majority of the cities in India generally follow only comprises only four activities (waste generation, collection, transportation and disposal) for management of MSW which is inadequate (Sharholy et al, 2008). The same was observed for our study location. Figure 1 shows the study location and Figure 2 summarizes the existing MSW management practice at the study location. Though there is an integrated SWM facility in the city, very poor condition of plant including machinery, equipment, scarcity of technical manpower, lack of interest of local bodies, lack of detailed characterization results, limited funds and inadequate management procedures not being thereby reducing the efficiency of the process. In

Figure 1. Location map of Muzaffarnagar, Uttar Pradesh



Figure 2. Schematic diagram of Solid Waste Management Practice in Muzaffarnagar city



practice, since waste generation rate is very high and capacity of machines installed to processes the waste is very low, the waste stream coming to the plant is being underutilized leading to waste being accumulated.

MATERIAL AND METHODS

Sample Collection

Sampling was done as per the guidelines laid out in ASTM D5231-92 (ASTM, 2004a, ASTM, 2004b; ASTM 2004c; ASTM 2006a; ASTM, 2008. To summarize, sampling was carried out consecutively for a week at the dump site, with each day 150 kg sample collected while trucks used to unload. From the total waste collected over the week, about (n =7 (denoting sampling days); collection =1050 kg) about 100 kg of the final homogenised mixed waste was processed. Further, the physical characterization was carried out for LIG, MIG and HIG, to determine the characteristics of the MSW generated from the three different socio-economic groups.

Physical Characterization of MSW

Physical characterization is one of the most important components for designing an effective MSW management system. The samples (collected using the procedure described above) was segregated manually into food waste, garden trimming, paper, plastic, rubber, glass, metals, drain silt and construction debris and weighted to express as percentage of total weight. The fundamental aim of following this process was to identify the organic and the inorganic components. One of the major sub-classification of inorganic waste type is inert waste the major characteristics of which are non-reactive and non-biodegradable. For our present study, the inert fraction was primarily due to stones, sand and gravel. Such high quantities of inert wastes are generally accumulated due to road sweeping of construction dust which is collected and dumped at the open landfill site. Moisture content of the waste was determined immediately after collection of the samples and then the samples were processed for chemical characterization.

Chemical Characterization of MSW

Chemical characterization was carried out using both proximate and ultimate analysis to determine the elemental composition of the MSW and also its ash content. Collected samples were processed as per the procedure laid out in BIS-IS: 9234 and ASTM-D5231-92 (ASTM, 2004a; ASTM, 2004c; ASTM, 2006a; ASTM,

2008). While the proximate analysis method was adopted to determine ash content, fixed carbon and volatile matter the ultimate analysis was used to determine the proportions of carbon, hydrogen, nitrogen, sulphur and oxygen content in dry sample. The calorific value of the MSW waste sample was determined by bomb calorimeter (Model 6200 Spectronics).

Geotechnical Characterization of MSW

Different sieves with diameter 200, 150, 100, 50 and 20 mm was used to perform the gradation of MSW. Generally, geotechnical properties (moisture content, specific gravity, unit weight, field capacity, coefficient of permeability, and degree of saturation) helps in design and maintenance of the landfill. Constant head method has been used to evaluate the coefficient of permeability at 25^0C in the laboratory.

RESULTS AND DISCUSSION

The characteristics of a MSW generated at a location are significantly influenced by geographical demographics, lifestyles, cultural traditions, economic prosperity, literacy rates, dietary habits and climatic conditions (Jin et al, 2006). Accurate characterization of MSW generated is the foremost step in designing an effective management system (Lin et al, 2011; Rana et al, 2014).

Physical Characterization

Physical characterization is helpful in determining the organic and inorganic fraction present in the waste stream and forms the basis for determining the treatment alternative. The results of physical characterization of MSW from Muzaffarnagar have been summarized in Table 1.

Density of MSW helps in deciding the appropriate handling processes including collection and transportation of the MSW generated. A higher inert fraction as observed from Table 1 significantly increases the bulk density and was found to 475 kg/m^3. Further, it is observed that the organic fraction accounts for the highest proportion from the entire socio-economic group (about 46% from HIG and MIG) and about 52% from LIG followed by inert constituents (27%, 34% and 32% for HIG, LIG and MIG respectively).

As observed from Table 1, the organic fraction comprises mainly of food wastes and garden trimmings for the different socio-economical conditions. Further, the maximum organic fraction is generated from the LIG community and is similar to other reported studies. This is primarily because with decrease in economic status

Table 1. Physical Characterization of Municipal Solid Waste in Muzaffarnagar city

Waste Type	HIG (%)	MIG (%)	LIG (%)	Mean± SD (%)
Food Waste	14.82	17.26	24.72	18.93±5.16
Garden Trimming	31.45	29.12	27.56	29.38±1.96
Paper	7.88	5.12	5.23	6.08±1.56
Plastic and Rubber	17.23	13.76	9.09	13.36±4.08
Glass	0.7	0.45	0.32	0.49±0.19
Metals	0.45	0.35	0.28	0.36±0.09
Drain Silt	21.24	25.34	26.43	24.34±2.74
Construction Debris	6.23	8.6	6.37	7.07±1.33

of the location there is an increase in the organic content of the waste generated (Goel, 2008; Sharholy, 2008). Further, it has been reported that MSW generated in developing countries have high proportion of organic waste (40-70%) making them unsuitable for disposal by incineration (Khajuria et al, 2010).

It has been further reported that proportion of paper increases with increase in population and generally varies between 1 to 6 (Garg et al, 2012). For our study location, the fraction of paper constituent was determined to be 5.3%, and lies within the range as reported by literature. In addition, the combustible fractions of the waste including paper, pouches, cardboards, polyester fibres, rubber, leather, egg tray, jute bags etc. was determined to be about 19%. Such other studies carried out in Indian context, reported similar values for Varanasi with combustible fraction being 14% (Dasgupta et al, 2013). High proportion of plastic and rubber was also observed as plastics are used on daily basis by the local residents. In particular, plastic, rubber and paper waste were significantly higher in HIG in comparison to LIG and MIG areas, similar to other reported literature. Glass and metal fraction was higher in HIG as compared to the other socio-economic groups.

Inert fraction was determined to be approximately 35%, which mainly include sand, silt, ash, and was on the higher side. This is primarily due to the street sweeping of construction wastes which end up being finally disposed off at the landfill site. The inert fraction determine for Muzaffarnagar was similar to other reported studies in Indian cities, for example Pune reported about 26% of inert wastes (Mane et al, 2012); Jalandhar reported about 21-33% of inert (Sethi et al, 2013) and the tricity regions of Chandigarh, Mohali and Panchkula as about 25-30% (Rana et al, 2017). Further, increased inert fraction decreases the calorific value and increases the density of the waste (Sethi et al, 2013). Drain silt fraction was found to be maximum

in LIG areas because unpaved roads are more in the LIG locations in comparison to HIG areas which conditions are roads which have more paved roads reducing the percentage of drain silt.

Recyclable components include glass, metal, plastic, cartons packs, synthetic fibres (nylon ropes), were determined to be approximately 1%, which is very less, primarily due to rag pickers and waste collectors who cover all of residential areas, markets institutes, industrial areas collecting all recyclables and then selling it to the *kabaddis*. They directly sell these to the industries to be recycled.

Chemical Characterization

Physical Characterization of the MSW provides information of the components of the waste stream but is not sufficient enough for deciding the overall processing technique of the waste, hence chemical characterization is performed in order to determine crustal element present in the MSW. Ultimate and Proximate analysis were carried out to determine the chemical characterization and the results have been summarized in Table 2.

Moisture content in Asian countries vary from 17-65% (Kolekar et al, 2016; Kumar et al, 2009) and the moisture content of our study location was determined to be about 22.6% lying within the prescribed limits. High value of moisture content indicates higher fraction of biodegradables.

Table 2. Chemical Characterization of Municipal Solid Waste in Muzaffarnagar city

Parameter	Mean± SD
Moisture Content	22.60±1.16
Volatile Matter	22.30± 2.63
Ash Content	44.90± 2.30
Fixed Carbon	10.10 ±1.57
Calorific Value	4236.15 ±119.78
Carbon	31.21±2.35
Hydrogen	3.87±0.52
Nitrogen	1.34±0.29
Oxygen	20.91±0.63
Mineral Content	42.68±2.29
C/N	23.75 ±4.78

*All values in percentage except calorific value (kcal/kg) and C/N

Ash Content was determined to be 44.9% primarily due to the high fraction of inert present in the waste stream. Such high percentage of ash content has also been reported for earlier studies in Jalandhar (42%) (Rawat et al, 2013) was reported.

The C/N ratio for Muzaffarnagar was determined to be 23.75 which were well within the C/N ratio reported for Asian countries which vary from 17-50 (Kolekar et al, 2016; Rawat et al, 2013; Sharholy et al, 2008). Elemental composition shows a high fraction of C (31.21%) followed by O (20.9%), H (3.87%), N (1.34%). Analysis of elemental components are particularly useful in determination of stoichiometric reactions and thereby estimation of gaseous by products of the waste (Khajuria et al, 2010).

Determination of Calorific Value provides information regarding energy recovery from the waste. Due to a high proportion of combustibles (19%), the calorific value of the waste generated from Muzaffarnagar area has been determined to be 4236 kcal/kg. In practice, calorific value generally varies between 800 to 1000 kcal/kg (Saha et al, 2010). However, studies conducted at Indian cities show higher reported calorific values.

Geotechnical Characterization

Particle size distribution of the different components has been summarized in Table 3.

It is observed from Table 3 that paper and cardboard has the maximum size range whereas ash and dust have particle size less than 20 mm and the food component varies between 20-100 mm. Particle size distribution of different waste stream characteristics are important as decomposition rate is directly proportional to the size distribution. Further, lesser the size of the particle lesser will be the pore size between two adjacent particles which limits the passage of oxygen, thereby facilitating the process of anaerobic degradation. The optimum particle size should vary between 12 to 50 mm for design of a successful composting system (Thakur et al, 2015).

Table 3. Particle Size distribution of Municipal Solid Waste in Muzaffarnagar city

Component	Size Range (mm)
Food	20-100
Paper and Cardboard	above 200
Plastic	50-150
Glass	50-200
Rubber	below 20
Ash and Dust	below 20
Rags	100-20

Geotechnical properties of the waste affect waste degradation, leachate distribution, and the overall stability of landfills (Yu et al, 2011). The geotechnical characterization of the MSW has been summarized in Table 4.

The moisture content was determined to be 0.19, which is very less in comparison to other reported literature (Sethi et al, 2013; Rana et al, 2017). This was primarily due to the climatic conditions existing at the study location which is exceedingly hot and had experienced very less rainfall. The unit weight was determined to be 11.34 kN/m^3. This parameter is primarily significant in determining the strength of the landfill as it depends upon the effective over burden pressure and effective overburden pressure is directly related to the unit weight. Further, it has been reported that unit weight also effects the capacity of the landfill (Yu et al, 2011). The degree of saturation of the waste was determined to be 76% and the coefficient of permeability was determined to be 3.0 x 10^{-3} cm/s.

RECOMMENDATIONS FOR IMPROVEMENT OF EXISTING MUNICIPAL SOLID WASTE MANAGEMENT PRACTICES BASED ON CHARACTERIZATION ANALYSIS

The characterization study carried out for Muzaffarnagar reveals that an integrated MSW management system is of immediate need. Though there exists waste processing system, it is severely lacking and needs a severe upgradation or a complete overhaul. The following remedial measures are suggested for better management of the MSW generated in Muzaffarnagar.

Table 4. Geotechnical Properties of Municipal Solid Waste in Muzaffarnagar city

Parameter	Mean± SD (%)
Moisture Content (v/v)	0.19±0.03
Degree of Saturation (%)	76.1±9.6
Specific gravity	2.15±0.11
Wet Unit Weight (kN/ m^3)	11.34±1.82
Coefficient of Permeability(cm/s)	3 x 10^{-3}

Source Segregation

Physical characterization of the MSW carried out has revealed that about 48% of waste stream are biodegradables and about 32% of inert materials. In this context, source segregation of the waste should be carried out to effectively reduce the burden on the landfill site and for implementation of adequate treatment procedures. Further, unsegregated wastes significantly reduce the calorific value of the waste thereby diminishing the potential energy content. The process of source segregation can be easily implemented with provisions of two bins (or colour coded containers) one for collection food waste and other organic materials and the second bin for other waste types. Further, education and importance of source segregation should be imparted to the local residents to apprise them of the potential benefits of the process. It had also been observed from our study that the combustible fraction is about 19% and it would be highly beneficial if source segregation of combustible methods were performed to yield better quality of Refuse Derived Fuel (RDF). In particular, it should be ensured that inert waste should not be mixed with domestic generated solid waste. The density of the MSW was determined to be 475 kg/m^3 and an effective strategy would be implement adequate size and number of bins depending upon the population, waste generation rates and density of wastes at the different wards of the city. The number of transportation vehicles should be increased and proper maintenance along with planned route layouts should be followed to improve the efficiency of the disposal system.

Recycling and Recovery

Our study show that about less than 1% of recyclables enter the waste stream with informal recycling process being most predominant carried out by rag pickers and waste collectors which are passed onto the industries. Though to a certain extent, such informal recycling practices reduce the burden on the landfills, the absence of formal recycling units significantly lower the economic potential of the recyclables with no benefits being passed onto the government. In this context a formal recycling unit should be set up with proper management to derive all potential benefits of the recycling process.

Installation of Biomethanation Plant

Since, the municipal solid waste consists of a high fraction of biodegradables in the waste stream it will be highly appropriate to install a biomethanation plant. Further, organic wastes from other sources should also be utilized (like kitchen and restaurant wastes) for proper functioning of the biomethanation plant.

Composting

The climatic conditions of the study location are highly suitable for composting process. Composting process is one of the finest methods for disposal of organic waste as it stabilizes the waste and the end product of the composting process can be used as a natural fertilizer. It is an environmental friendly aerobic process carried out through microbial action. The efficiency of the composting process depends upon the efficiency of segregation of organic wastes from other types. Further, composting process can be carried out at household levels and as such proper training and education should be provided to the residents to start their own household composting systems. At the governmental levels, community composting pits should be set up to utilize the voluminous quantity of organic waste generated.

Installation of RDF Plant

It is observed from our characterization study that a RDF could be utilized effectively as a part of an integrated MSW management system. In practice, a working RDF plant already exists in Chandigarh city and can be similarly implemented for Muzaffarnagar. For the existing plant in Chandigarh it has the capacity to treat about 500 tonnes per day (TPD) with the RDF produced having a calorific value of 3100 kcal/kg and moisture content less than 15%. Implementation of RDF unit will significantly reduce the volume of waste thereby increasing the lifespan of the landfill.

Engineered Landfill and Other Recommendations

Municipal Solid waste is openly dumped at the landfill site leading to possible contamination of soil and groundwater. In this context, it is proposed a proper engineered landfill site with leachate collection and extraction system should be installed to avoid such contamination. Skilled manpower should be employed and periodical trainings should be provided to such personals for operation of such systems. Further, the personals should be educated on occupational health hazard and medical checkup of ragpickers and waste collectors to be done.

CONCLUSION

The book chapter reports the existing solid waste management practices in Muzaffarnagar city along with characterization analysis studies which are then utilized in recommendations as important strategies for the municipal solid waste management. With an increased population and excessive consumption rates the city

is nearing a critical point with no implementation of an integrated MSW management facility. Existing status for management of MSW is deficient in almost all aspects with less collection efficiency due to inappropriate bin size, inaccessible locations of bins, inadequate number of transportation vehicles per and non-functioning of the integrated MSW management system. Physical Characterization of the waste stream generated from the Muzaffarnagar denotes high fraction of organics followed by inert. Waste streams from LIG were determined to have the highest organic fraction. Chemical characterization showed a high proportion of ash content primarily due to presence of inert. In this context, source segregation should be carried out to obtain maximum benefits of using WTE technology with biomethanation and composting for organic fraction and RDF for the inorganic fraction of the waste. Further, a formal recycling unit should be setup to to derive the economical benefits of the recycling system. In particular, local administration will need full support of the local public to implement any potential schemes for integrated MSW management system. This can be done by educating the general public on the drawbacks of the existing waste management practices. There is a great scope for improvement in the existing practices of MSW management in the city, however significant efforts are required by the Urban Local body of Muzaffarnagar and support of the public. Waste reduction, waste segregation at source, reuse, recycling, and WTE schemes like composting, biomethanation and RDF could provide long-term solutions to reduce the burden of waste disposal on the landfill site. Finally, the open dumpsite should be converted to an engineering landfill site with immediate effect.

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A Taxonomy on Machine Learning Based Techniques to Identify the Heart Disease

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Abstract

Every year average death of human being is 17.7 million caused by Heart Disease or Cardiovascular diseases (CVDs), which is 31% of all global deaths reflected in Survey of World Heart Day 2017 [33]. In September 2016, many countries have taken the various Global Hearts Initiative in prediction and diagnosis of heart Diseases at earlier stages so that

it can be cure perfectly [5]. Many authors have studied in this filed to optimize the performance of various ML techniques using various approaches. In latest studies, many groups have uncovered that many optimization algorithm like Differential Evolution, Genetic Variants, and Particle Swarm optimization are associated with prediction algorithm like K-Nearest neighbor, Decision Tree, Neural Network, Support Vector machine, Logistic Regression etc. to make efficient medical system for CVDs. The Objective of our current study is to analyze the comparatively study of the ML techniques in terms of performance measure of different ML techniques that have been used by various authors in their research work in earlier studies of heart disease prediction and diagnosis process.

Keywords

Heart disease **Data mining**

Machine learning **Heart failure**

Logistic regression (LR) **K- means (KM)**

Decision Tree (DT)

Support vector machine (SVM)

Multivariate adaptive regression splines (MARS)

Rough sets (RS) **K-Nearest neighbor (KNN)**

Genetic algorithm (GA) **Neural network (NN)**

Differential Evolution (DE)

Dictionary-based keyword spotting (DBS)

Natural language Process (NLP)

Random forest (RF)

Classification and regression tree (CART)

Naïve Bayes (NB)

Classification by clustering (CC)

Multilayer perceptron (MLP)

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Bagged Tree (BT) **AdaBoost (AB)**

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A Taxonomy on Machine Learning Based Techniques to Identify the Heart Disease

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Abstract. Every year average death of human being is 17.7 million caused by Heart Disease or Cardiovascular diseases (CVDs), which is 31% of all global deaths reflected in Survey of World Heart Day 2017 [33]. In September 2016, many countries have taken the various Global Hearts Initiative in prediction and diagnosis of heart Diseases at earlier stages so that it can be cure perfectly [5]. Many authors have studied in this filed to optimize the performance of various ML techniques using various approaches. In latest studies, many groups have uncovered that many optimization algorithm like Differential Evolution, Genetic Variants, and Particle Swarm optimization are associated with prediction algorithm like K-Nearest neighbor, Decision Tree, Neural Network, Support Vector machine, Logistic Regression etc. to make efficient medical system for CVDs. The Objective of our current study is to analyze the comparatively study of the ML techniques in terms of performance measure of different ML techniques that have been used by various authors in their research work in earlier studies of heart disease prediction and diagnosis process.

Keywords: Heart disease · Data mining · Machine learning · Heart failure · Logistic regression (LR) · K- means (KM) · Decision Tree (DT) · Support vector machine (SVM) · Multivariate adaptive regression splines (MARS) · Rough sets (RS) · K-Nearest neighbor (KNN) · Genetic algorithm (GA) · Neural network (NN) · Differential Evolution (DE) · Dictionary-based keyword spotting (DBS) · Natural language Process (NLP) · Random forest (RF) · Classification and regression tree (CART) · Naïve Bayes (NB) · Classification by clustering (CC) · Multilayer perceptron (MLP) · Radial basis function (RBF) · Single conjunctive rule learner (SCRL) · Bagged Tree (BT) · AdaBoost (AB) · Particle swarm optimization (PSO)

1 Introduction

In human body heart is very crucial part, through blood vessels it pumps the blood to complete body parts, so other body parts get the oxygen and essential nutrients from bloods as well as heart assists in the removal of metabolic wastes.

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So it's very important that heart works properly. According to WHO on the basis of one survey as data available in 2015 [32], maximum human deaths (appox 17.7 million) are caused by the heart diseases and there are some factors that put people at increase risk for heart disease like Smoking, high cholesterol, high blood pressure, genetic effect, diabetes, obesity, etc. and few symptom that indicate the heart disease Chest pain (angina), Shortness of breath, Sweating, Irregular heartbeat, Nausea, heart burn, heart attacks.

Machine learning techniques can be used in heart disease prediction at earlier stages so that it can be cure within a desirable time period. In last 15 years many studied carried out in this field. Objective of each studied is to optimize the implemented algorithm with some suitable proposal.

1.1 Data Mining Techniques

Data Mining techniques are the process to convert raw data into useful information or we can say that it is the process to find some useful hidden patterns of data to predict some outcomes. These are the important DM techniques:

- Decision Tree
- Clustering
- Association
- Classification
- Prediction

In data mining techniques Association method works on the rule if-else procedure. It helps to discover the patterns between two items or data. Association rules are useful for analyzing and predicting the different diseases.

Classification data mining technique is the example of supervised learning technique. Classification algorithm predicts categorical class level. Prediction algorithm is also example of supervised learning technique but it predicts continuous valued function. For example we can suggest a classification model that predicts that heart is working correctly or not, that means answer will be yes or not on the basis of symptoms of patients. And in same case prediction algorithm predict the probability of chances of heart failure.

Clustering is the example of unsupervised learning techniques. It is the process of creating the group or classes of similar behavioral objects or data.

In clustering process on the basis of similar characteristics of objects or data and using any automatic techniques we makes meaningful cluster or classes.

J. Ross Quinlan in 1980 developed decision tree technique also known as ID3 later he presented C4.5. Decision tree algorithm concept is based on greedy approach and follows the tree structure.

1.2 Machine Leaning Algorithm

ML uses the DM techniques and other learning techniques to build model, so that we can predict the future outcomes. If we compare the DM and ML, Dm is the process to extract the hidden information or patterns from a particular dataset whereas ML deals

the algorithm improves automatically through experience based on data. Basically ML uses the learning techniques, on the basis of leaning algorithm ML can be categorize into 3 category Supervised Learning, unsupervised learning and reinforcement learning.

1.2.1 Supervised Learning

It can be explained that it uses training or labeled data to learn the mapping function F() from the (Z) input variable with (Y) output variable.

$$Y = F(Z)$$

Again supervised leaning problem can be divided into 2 category classification and regression.

Examples of Supervised learning are Logistic Regression, KNN, CART, blog–Linear Regression, Naïve Bayes. Ensembling is one type of supervised learning, In which we use the multiple combinations of weal ML models to predict future outcomes on new sample. Some examples are Bagging with random forest, Boosting with XGBoost. In [4], Author used the different ensembling methods in prediction of of heart disease and computed the accuracy of each techniques.

1.2.2 Unsupervised Learning

It only processes the input variable (Z) with no corresponding output variables and uses the unlabeled data to build mode for future prediction. Unsupervised learning problems can be divided into 3 types Association, clustering and Dimensionality Reduction. Dimensionality Reduction can be done using Feature selection methods and Extraction methods. In the process of Feature Extraction actually data transform from multi dimensional space to small or low dimensional space. K- means, Apriori, and PCA are examples of unsupervised learning.

2 Related Work

Since the last decade, many studies have been implemented and evaluated the performance measures in process of heart disease prediction and diagnosis. Different Authors used different algorithm with different feature set in prediction and diagnosis of heart diseases especially in heart failure.

Vivekandan et *al.* implemented a scheme to used the modified Differential Evolution algorithm for optimize feature selection [1]. Author has identified 13 features for the heart disease prediction, diagnosis and dataset taken from UCI repositories [2], further reduced these attributes to nine attributes for improving the accuracy. In this study author adapt the Fuzzy AHP algorithm to obtain the relative weight of each feature. Further author implemented feed forward NN algorithm for prediction and diagnosis of heart disease.

In [3], the author adapt the SVM classifier along with forward feature selection, back elimination feature and forward feature inclusion and implemented SPECTF dataset from UCI. Author concluded that, current approach obtained smaller subsets

and increases the performance accuracy of diagnosis compared to back elimination techniques and forward inclusion.

Shao et *al.* [4] proposed as feature selection algorithm rough set, multivariate adaptive regression splines and logistic regression to reduce the set of critical features for heart disease prediction and diagnosis with higher accuracy. In this study author analyzed hybrid multivariate adaptive regression splines artificial neural network algorithm is the best alternative because this method contained the less number of explanatory variables (features) and provided the efficient classification accuracy on prediction. On the other hand Oluwarotimi et *al.* [6] suggested hybrid algorithm based on Fuzzy-AHP and ANN mythology for Heart Failure and risk prediction using medical dataset [23]. This prediction process consists of two sequential stages. At first stage author implemented Fuzzy-AHP to choose rank and obtained the local weights of Heart Failure features and for set of given attributes author computed global weight, Author's implanted algorithm and declared that an average accuracy is 91.10%, which is more better than conventional Artificial neural network method. (4.40% higher in comparison)

Jabbar et *al.* implemented a classification algorithm which is the combination of genetic and KNN algorithm to predict and diagnose the heart disease of a patient for Andhra Pradesh population [7]. Author used 7 data sets computed the accuracy with and without GA along with KNN and concluded.

In [19], Performance Analysis of Ensemble classifier Random Forest, AdaBoost, Bagged Tree with PSO on parameter like accuracy, sensitivity, specificity, PPV, NPV are performed. Author used the Heart Disease Dataset which contains 270 instances and 14 attributes and concluded that Particle Swarm Optimization (PSO) is computationally efficient (inexpensive) in context to speed and memory.

Pouriyeh et *al.* [16] compared MLP, Decision Tree, NB, K-NN, SVM, SCRL and RBF classifiers in two experiments. In first experiment author evaluated the accuracy with the help of 10 fold cross validation method and further to estimate the efficiency performance of each algorithm. Author used K = 1, 3, 9 and 15 In case of KNN classifier and obtained the performance of KNN is best at K = 9 using whole data set [17]. In second experiments author use the bagging, boosting and stacking concept for evaluation of algorithm efficiency.

In this study Author found that, no improvement in support vector machine performance but, maintained its performance (accuracy) level in case of Bagging. SCRL improved 10.56%, it increased from 69.96% to 80.52% and Decision tree improved 0.99% (from 77.55%–78.54%). In case of Boosting SCRL improved 11.22% and Decision Tree improved 4.62% (from 77.55% to 82.17%). The others algorithm performance remained same as earlier. Where the combination of SVM and MLP has the best accuracy 84.15% in case of stacking.

In [15], Soni et *al.* analyzed the performance efficiency of Naïve Bayes, Decision Tree, ANN, classification via clustering Algorithm in heart disease prediction and diagnosis. In this study, research is divided into two phases, the first part author used the 25 set of Attributes and implemented the algorithm, in second phase author used the Genetic Algorithm for optimizing the feature set 25 to 15 while applying the classifying algorithm and found that efficiency is optimized as compare with first case.

In optimization of feature set from data set, Yan et *al.* used the genetic algorithm in selection of 24 critical features among 40 features available from data set [14]. With these features implemented system provides better diagnostic performance.

Anbarasi et *al.* compared the performance measure in the context of accuracy in percentage of Decision Tree, classification via clustering, Naïve bayes, in prediction of heart disease [12]. Author used the Genetic Algorithm to select the critical attributes which participate more closely in the heart risk, HF prediction and diagnosis. This result reduces the required no of tests taken by patient indirectly. 13 attributes (features) are compressed to six attributes using genetic search with dataset Cleveland Heart Disease database [31]. Further apply the classifiers and investigated the performance.

Guidi et *al.* implemented Heart Failure clinical decision support system along with a portable kit to acquire the set of clinical attributes [11]. This system provided various functioning with the using of different ML techniques. Author selected 12 attributes from database, data taken in period of 2001 to 2008 from Hospital of Maria Nuova, Florence, Italy.

Author compared different types of ML techniques and declared that the CART method provide the best result among all ML. Also give the humanly understandable decision making process, Classification and regression tree provides the accuracy of 87.6% in type prediction and 81.8% in severity assessment

Olaniyi et *al.* compared the efficiency performance efficiency of SVM and Back propagation Neural Network in heart disease prediction and diagnosis [9]. In this research implementation works are divided into two phases, the first part author used back propagation training and testing of the network while in second part prediction applied using support vector machine.

In [26], Author implemented a automatic system that automate the feature design for numerical sequence classification using Genetic programming, system is called Autofeed which is fully data driven.

Fen et al. designed comprehensive risk model using a modified method of random survival forest technique for predicting and diagnose the heart failure mortality with a high level of performance accuracy [20]. Author worked on MIMIC II database With 32 variables and achieved 82.1% performance.

In 2017 [21], Jin et *al.* designed robus and effective paradigm for heart failure prediction at earlier stage using short-term memory network (LSTM) model and author compared with methods such as Adaboost, Rnadom Forest and LR. Author showed that these methods performs best in the prediction and diagnose of heart failure.

Pu et *al.* proposed the method, with this we predict and prevent all kinds of diseases including cardiovascular diseases on the basis of Genes detection [22]. Because in human body Genes generally stable for long time after birth. Author finds that gene detection plays an important role in prediction of heart diseases.

Hui et *al.* [8] worked with data set [25] and proposed a system which extract the information and identify the risk factor for heart disease from clinical text using NLP techniques. Author analyzed the characteristics of clinical evidence and categorized into 3 main types, sentence level clinical measurements, token level clinical entities and sentence level clinical fact.

Nahar et *al*. Analyzed the promising techniques for feature selection for prediction for heart disease author proved that motivated feature selection process (MFS) and

MFS along with computerized feature selection process (CFS) are the best suited feature selection techniques [28]. Author used the SVM and Naïve Base classifier prediction and found that SVM predict more efficient then Naïve Base.

3 Research Methodology

This section discusses the different approaches or techniques used by various author in their studies. Broadly on the basis of literature work we conclude that in heart disease prediction and diagnosis process every author used the feature extraction phase using any feature selection algorithm, prediction and diagnosis phase using any machine learning algorithm. Each author worked on any particular medical dataset [2, 10, 18, 24, 27], which contain various instances and attributes.

3.1 Feature Extraction Phase

Prediction of any diseases is completely based on the features selections. Feature selection is the process to define few important and critical features from available feature dataset. We also know the 80–20 rule means 80% effects comes from the 20% effect [29]. So it's very important to selection of critical variables or features in the process of prediction and diagnosis. In the progress of diseases prediction expert system many authors used different optimization algorithm in feature selection process in last decades.

Optimization algorithm provides the optimal feature set because minimal feature set provide efficient result and this set consist of no irrelevant attributes. In today's scenario there are many optimization techniques available, all techniques work using heuristic based and gradient based search techniques in stochastic and deterministic contexts correspondingly. To make large acceptability of the optimization approach, medical expert systems are desired to develop using robust and efficient optimization algorithms. There are few example of optimization algorithm used in heart diseases prediction and diagnosis mainly are particle swarm optimization (PSO), Evolutionary algorithms simulated annealing and ant colony optimization.

3.1.1 Differential Evolution Optimization

Differential Evolution (DE) algorithm is one type of heuristic approach; it has mainly 3 advantages [30]. First, whatever initial parameter values is it can find true global minimum value. Second, is its speed, robustness and third, is less no of control parameters. DE developed in 1997 by Price and Storm. It is the branch of evolutionary programming.

The Coverage speed is the main issues in Evolutionary Algorithm, there are many studies have carried out to increase the speed with DE. It is mutation scheme that make self adaptive and self selection process. It is the stochastic optimization method that minimizes an objective function.

DE Algorithm is population based same as genetic algorithm using same operators like crossover, mutation and selection. But DE mainly relies on mutation in search operation.

3.1.2 Genetic Optimization

Genetic Algorithm (GA) is also population based same as the DE algorithm. It deals with constrained and unconstrained optimization problem that is completely based on natural selection [30]. GA iteratively modify the population of individual solutions. While creating the next generation from current population GA use the following three Rules

(a) Selection Rules
(b) Crossover Rules
(c) Mutation Rules

The best point in the population approaches an optimal solution and GA follows the population approaches.

The fundamental difference between GA and De is GA based on crossover whereas DE or Evolutionary Algorithm based on mutation for search mechanism.

Generally Genetic Algorithm needs the fitness function for evaluation of solution domain and genetic representation for solution domain.

3.1.3 Particle Swarm Optimization

PSO is also population based optimization technique. PSO developed in 1995 by Dr. Kennedy and Dr. Eberhart. Both Scientist were inspired with fish schooling or bird flocking. PSO has multiple advantages over GA like PSO is easy to implement and needs few parameter to adjust.

Algorithm start with set of random particle i.e. solution and then searches for best particle by updating generations.

PSO and GA both algorithm have many similarities like PSO and GA start with group of random generated population and search for best by using random technique and both have memory. Only difference is that PSO does not have operators like crossover and mutation. Particle updates them with internal velocity.

PSO have been applied in many research and application area in past several years. The best part with PSO is it does require few parameters to adjust, which makes PSO is more attractive for researchers. If we compare with other optimization algorithm following 2 points make stronger to PSO

(a) Fast (speed)
(b) Less costly (cheaper)

3.2 Prediction and Diagnosis Phase

Various ML Techniques involved in prediction and diagnosis of CVDs in different studies with different dataset. Each ML techniques have own strength and limitations.

Concept of **Neural network** is inspired from human brain concept. NN is based on a collection of connected nodes called artificial neurons. Nodes are called processing element. NN learn from itself from examples. There can be 3 layer input layer, hidden layer (not in all cases), output layer. In some simple cases only input and output layer can provide the result.

K- Means clustering is one type of unsupervised learning technique [34]. It used for unlabeled data. It finds the different group on basis of similarities of objects or data. K shows the no of groups. Algorithm iteratively works and rearranges the attributes in matched groups at each time.

Logistic Regression is used when the dependent variable (target) is categorical.

Example, Suppose we want to predict email is spam or not means yes (1) or No (0), Whether the HF is malignant (1) or not (0).

Multivariate Adaptive Regression Splines Jerome H. Friedman introduced MARS in 1991 in a form of regression analysis. It is also called non parametric regression technique. It helps to solve regression type problems because with the help of MARS we can predict the values of continuous dependent from a set of independent variable.

Rough set theory Zdzislaw Pawlak proposed RS theory, with this theory we can approximate the lower and upper boundary of the original set. **K-Nearest neighbor** is also non parametric technique used in both regression and classification. KNN classify the input data into defined groups on the basis of prior data that is called training data.

Support Vector Machine is works with labeled data means it is the example of supervised learning technique. SVM can perform efficiently with linear classification as well as non linear classification. Vapnik and Chervonenkis invented SVM in 1963. SVM performance is not good with large data set, when data set contain more noise.

Classification and regression tree is one type of Decision tree algorithm, in which we use classification tree and regression tree technique.

Decision Tree is the powerful tool used in ML. it is the graph based model classification tree and regression tree technique. It is the graph based model that represents possible consequences including all event outcomes. Tree consist of nodes always start with root node; mainly three types of node can be possible end node, chance node and decision nodes. Sometime in decision tree predictor values are continuous or infinite possible outcomes is called regression tree. Many authors used several of ensemble methods with DT to increase the performance of DT mainly are Boosted tree, Bagging and Random forest classifier.

Bagging used in regression and statistical classification, It avoid the over fitting means reduces variance.

Boosting helps in, to builds a series of trees is a sequential form in regression problem.

Random Forest is just like Bagging only difference is that bagging takes 1 parameter that is no of tree with all possible features whereas RF takes 2 parameter one is no of tree and second is how many features participate to search to find optimal or best feature.

Naïve Bayes is a one type of probabilistic classifier based on Bayes theorem. It is conditional probability model. In many situations in supervised learning with some type of probability model, NB classifier can train very optimally and efficiently.

Classification by Clustering is the technique by which we can find homogeneous subgroup and it is the type unsupervised learning technique. When we identify clusters or group inside the classified group is called classification by clustering. CC model gives best result at compare with individual classification or clustering technique.

4 Analysis

In order to further explore the relation between the heart disease prediction and techniques applied for prediction, efforts have been and same is mapped with the help of Table 1. It is clearly shown from Table 1 that Neural Network is the technique which is explored in maximum number of studies.

Table 1. Machine learning techniques used in different studies for heart disease identification

Features / References	DE	LR	MARS	GA	RS	SVM	DT	KNN	NN	KM	Fuzzy	DBS + NLP	CART	RF	NB	CC	MLP	SCRL	RBF	BT	AB	PSO
[1]	√								√		√											
[3]						√																
[4]		√	√		√				√													
[6]									√		√											
[7]				√				√														
[8]												√										
[9]						√			√													
[11]				√		√			√		√		√	√								
[13]							√								√	√						
[14]				√																		
[15]							√	√	√						√	√						
[16]							√	√							√	√	√	√	√			
[19]														√						√	√	√
[20]														√								

Table 2. Performance of algorithm along with set of attributes used for heart disease prediction and diagnosis in different studies

Reference No	Data set name	No of features used in experiment	Algorithm name	Algorithm accuracy (%)
[1]	UCI Repository	13	NN	83.0
		09		85.0
[3]	SPECTF	44	SVM	75.0
		19		78.0
	heart disease dataset	10		81.0
		4		85.0
[4]	UCI datasets	13	MARS + NN	82.14
[6]	Cleveland Heart Disease Dataset	13	Fuzzy + NN	91.10

(*continued*)

Table 2. (*continued*)

Reference No	Data set name	No of features used in experiment	Algorithm name	Algorithm accuracy (%)
[7]	Heart disease A.P	12	KNN + GA	100.00
[8]	i2b2 corpus	06	DBS + NLP	91.5
[9]	UCI ML datasets	13	NN + SVM	87.5
[11]	Maria Nuova Hospital, Florence, Italy, (2001–2008)	12	NN	77.8
			SVM	80.3
			Fuzzy + GA	69.9
			CART	81.8
			RF	83.3
[13]	Cleveland Heart Disease database	6	NB	96.5
			DT	99.2
			CC	88.3
[14]	352 diagnosed heart disease dataset	24	GA	92.3
[15]	CAD data set	15	NB + GA	96.5
			DT + GA	99.2
			CC + GA	88.3
[16]	Cleveland Data Set	76	SVM + MLP	84.15
[19]	Heart Disease Dataset	14	BT + PSO	100%
			RF + PSO	90.37
			AB + PSO	88.89
[20]	MIMIC II database	32	RF	82.1

In the current study we compared the accuracy measurement of different classifier KM, DT, LR, MARS, RS, KNN, GA, SVM, NN, DE, DBS, NLP, CART, RF, NB, CC, MLP, SCRL, RBF, BT, AB, PSO and combination of these. Table 1 show the various ML techniques used in various studies. Table 2 shows the accuracy of ML techniques in percentage along with associated no of features.

On the basis of Table 2 we found, accuracy of algorithm is depends upon the number of features selected for heart disease analysis.

When studies used the GA or PSO optimization techniques for feature selection, classifier worked efficiently.

Figure 1 Represents the various algorithms along with the number of attributes used in several studies.

Table 3. Performance comparison of ML algorithm used in different studies

Sr. no	Algorithm name	No of attributes	Accuracy
01	NN	9	85.0
		12	77.8
		13	83.0
02	MARS + NN	13	82.14
03	Fuzzy + NN	13	91.10
04	SVM + NN	13	87.5
05	SVM	4	85.0
		10	81.0
		12	80.3
		19	78.0
		44	75.0
06	SVM + MLP	76	84.15
07	GA	24	92.3
08	NB	06	96.5
09	DT	06	99.2
10	CC	06	88.3
11	NB + GA	15	96.5
12	DT + GA	15	99.2
13	CC + GA	15	88.3
14	KNN + GA	12	100.0
15	RF	12	83.3
		32	82.1
16	BT + PSO	14	100%
17	RF + PSO	14	90.37
18	AB + PSO	14	88.89
19	CART	12	81.8
20	DBS + NLP	06	91.5

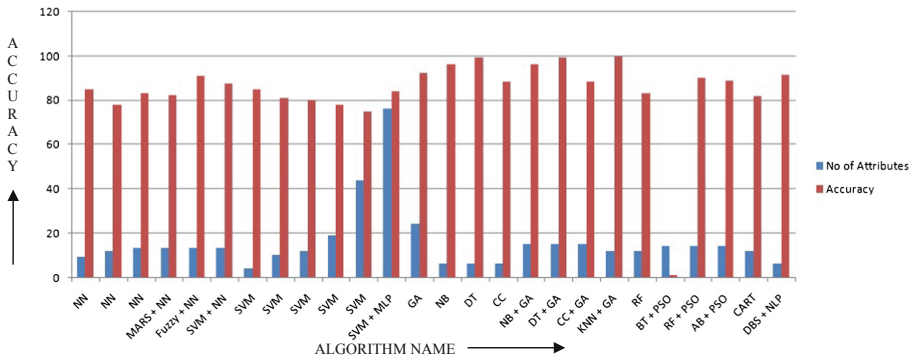

Fig. 1. Algorithm performance graph

5 Conclusions

Everyone knows if Heart is not functioning properly then how it can affects our whole body and. so Detection of heart diseases at early state is essential to prevent from other diseases affected from heart and save lives. In this study we are showing the comparatively analysis of various ML algorithm performances in the prediction and diagnosis of heart disease. Table 3 shows the comparatively study of all ML Techniques and on the basis of this table we analyze following conclusion.

First Conclusion, NB, DT, CC along with GA has shown better performance as NB, DT and CC performed without GA.

Second conclusion, BT, RF and AB along with PSO performed better as compared with performance of BT, RF, and AB without PSO.

Third Conclusion, Accuracy of NN along with Fuzzy or SVM is optimal as compared to accuracy of NN algorithm alone.

Summary of this study (Fig. 1) that classifier algorithm gives optimal result along with any feature optimization algorithm like GA or PSO.

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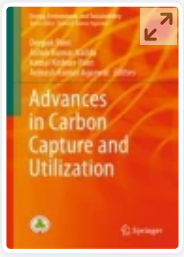

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Advances in Carbon Capture and Utilization

Editors: Deepak Pant, Ashok Kumar Nadda, Kamal Kishore Pant, Avinash Kumar Agarwal

Highlights the advances in carbon Capture techniques

Discusses utilization of Carbon dioxide

Presents Carbon Management and utilization

Part of the book series: Energy, Environment, and Sustainability (ENENSU)

14k Accesses | **16** Citations

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About this book

This book focuses on the recent trends in carbon management and up-to-date information on different carbon management strategies that lead to manage increasing concentration of atmospheric carbon dioxide. The growing evidence of climate change resulting from the continued increase of atmospheric carbon dioxide concentration has made it a high profile political–social and trade issue. The mean global average earth temperature rose by 0.6± 2°C during the second half of the century with the rate of 0.17°C/decade. As per GISS data in the year of 2017, it rose 0.9°C (1.62 °F) above the 1951-1980 mean global temperature. Recently World Meteorological Organization analyzes the past record temperature and found the past 10 years were the warmest years about 1.1°C above preindustrial level. Over the past decade, carbon management by various techniques has to come to fore as a way to manage carbon dioxide emissions contributing to climate change. The proposed book addresses the need for an understanding of sustainable carbon

dioxide management technologies mainly focused on (a) minimizing carbon dioxide emission from sources; (b) maximizing environmentally sound recuse, reduce and recycling; (c)emerging technology toward carbon dioxide mitigation and d) converting carbon dioxide into valuable products form sustainable use. Other books related to carbon management attempt to cover the carbon capture and sequestration, carbon mineralization, utilization and storage but the topic of CO2 management strategies is not discussed in detail for sustainable development. Furthermore, this book also covers all physical, chemical and biological process for long-term capture, removal and sequestration of carbon dioxide from the atmosphere for sustainable management which is not described in other carbon management books. In order to meet CO2 emissions reduction target, a range of technological approaches, including development of clean fuels and clean coal technologies, adopting cleaner and more energy efficiency and conservation, developing renewable energy and implementing CCS technologies, will also be considered for sustainable future.

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Keywords

Carbon Dioxide **Carbon Capture**

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Carbon Credit **Carbon Utilization**

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Reviews

"This is an interesting book that focuses on carbon capture and to a large extent sequestration. ... the book will be particularly useful for readers with specific interest in rural applications and the unique ecosystem of South Asia. It is a useful addition to the library of greenhouse gas mitigation technologies, bringing a different approach." (Peter Styring, Johnson Matthey Technology Review, Vol. 66 (4), 2022)

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Chapter 1
Advances in Carbon Capture and Utilization



Deepak Pant, Ashok Kumar Nadda, Kamal Kant Pant, and Avinash Kumar Agarwal

1.1 Introduction

A combination of enzyme and material which jointly capture and convert the CO_2 into methanol plausibly energizes the CO_2 utilization (Sharma et al. 2020a). The CO_2 to methanol conversion utilizes carbon better than the conventional syngas and the reaction yields fewer by-products, and the methanol produced can further be used as a clean-burning fuel, in pharmaceuticals, as a general solvent, etc. The various aspects of circular economy with present scenario of environment crisis will also be considered for large-scale sustainable biorefinery of CO_2. In this book, thirteen chapters have been included which represent the natural, conventional, and artificial systems for carbon management. The contents of the book have been divided into four sections.

The natural systems of carbon sequestration have been discussed in detail in the first section of this book. Since ancient times, fossil fuels are used in huge amount to meet the energy demands across the world. In India, the emanations from fossils fuels have developed a lot, but alternative sources are not enough to fulfil the demand.

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The emissions from fossil fuels are considered as one of the major factors leading to climate change (Kumar et al. 2019). To limit the pace of emissions of these harmful gases, various methods and approaches like reduction of energy consumption, switching to alternative fuels, have been reported. This section emphasized on the carbon capture and storage (CCS) using geological and soil-based methods. The recent advancement in CCS technology is progressively concerned with ideal design and functioning of the CCS infrastructure collectively maintaining every strategy of CCS system throughout a certain range. The attainable quality of CCS technology would reduce the reliance on sustainable power sources. CCS system also implies transfer of atmospheric CO_2 into other long-lived global pools including pedologic, oceanic, geological and biotic strata to reduce the net rate of atmospheric CO_2 increase. Since industrialization in the nineteenth century, the CO_2 concentration in the atmosphere has increased and an accord is there where a visible impact on world's climate due to mankind is forming. The CO_2 emissions from man-made sources have also been increasing in the same time frames which are known to produce greenhouse effect. CO_2 holds 82% of all the greenhouse gases present in the atmosphere. There are various techniques where CO_2 is injected into geological strata, oil wells, deep ocean, old coal mines, and saline aquifers. Furthermore, the soil is the biggest terrestrial sink of carbon (C) and store nearly three times of the atmospheric carbon pool and 4.5 times of the biotic carbon pool, and thus, maintains the global carbon cycle. Therefore, any change in the atmospheric carbon could be the result in modification of soil carbon. However, the carbon stabilization as well as subsequent sequestration in soil is greatly affected by different climatic and soil factors, such as soil type, nature of organics presents in soil, management practices, diversity of soil microorganism, rainfall, and temperature, etc. The sequestration of carbon in soil is very crucial to mitigate the effect of climate change by reducing the greenhouse gases emission and also to improve the soil quality for better crop productivity in sustainable manner (Roudi et al. 2020).

Among different developed methods, biomineralization and bioinspired storage systems are not only cost-effective but also efficient in controlling global warming and CO_2 emission. A microbial-enzymatic CCSU system can act as a green source of energy in form of electricity along with the utilization of wastewater by bacterial and algal biomass (Sharma and Kumar 2021). Instead of the whole-cell capturing systems, enzyme-based CO_2 capturing systems have also been proved efficient for various industrial applications.

Researchers are been joining their hands for the improvisation of several carbon capture materials. In the second section, superior performance of organic blended physical–chemical solvents is drawing much attention in recent times. Even some blends attained the optimal performances, advancements in the materials have not come to an end. Various types of nano-materials, nano-textured surface, and microwave regeneration techniques are being introduced to bring down the energy consumption of the setup. Amine technology for the capture of carbon dioxide has certain drawbacks including cost, energy consumption and by-products formation. Other methods such as membrane, cryogenic, biologicals are also of interest but not technically or economically feasible at large or industrial scales. In view of this,

ionic liquids (ILs) are the one of the alternatives for the conventional and other technologies.

Some other methods of simultaneous wastewater treatment and carbon capture have also been explored in the third section of this book. Conventional wastewater treatment systems are not environmentally friendly as they significantly contribute to the CO_2 emission, directly as well as indirectly. It has been realized that there is an urgent need to not only reduce the emission of CO_2 but also capture it to counter the negative impacts of climate change. Microbial fuel cell (MFC) has the potential of carbon capture while treating the wastewater with an additional advantage of direct electricity production (Verma et al. 2020). On the other hand, algal technology has the potential to capture and utilize CO_2 for the production of algal oil, which can be utilized for bioenergy production (Kamyab et al. 2019a).

Furthermore, the climate smart agriculture is one of the key tools for carbon capture which ensures the efficiency in income generation, productivity and food security; adaptation to climate change and resilience. Although sequestration of carbon and depletion in emissions of greenhouse gases can happen with various smart agricultural practices, perhaps there are numerous challenges while making these pillars of climate smart agriculture into reality. The change in soil carbon pool can directly influence the climatic conditions of any area due to its capability to store carbon twice as much of the atmosphere. The soil is one of the principle components for capturing terrestrial carbon, so the spatial distribution map developed along with the major nutrients from the study will provide an input for agricultural land evaluation for selecting appropriate land use plans for healthy carbon budgeting in the area (Kamyab et al. 2019b).

The biological carbon cycles are not sufficient enough to switch the billions of metric tons of CO_2 emission while the biochar (a recalcitrant organic charcoal material produced from pyrolysis of biomass under limited oxygen conditions) emerging as a considerable tool for long-term sink of carbon. Biochar has many other advantages of increasing the water absorption and water holding capacity of the soil which aids to increase the fertility. The charcoal produced by incomplete burning due to the limitation of oxygen in this system captures much more natural carbon from the biomaterial. Along with the ability to lock up additional carbon, biochar can also store CO_2 in sink for thousands of years, displaces the fossil fuel use and also reduces the release of nitrous oxide (N_2O) and methane, thereby reduces the greenhouse gas emission from the atmosphere and helps in mitigating the impacts of climate change. The Western Himalayan regions are characterized by marked climatic conditions, variations in topography, soil-texture, and land-use practices. In the present scenario, the fragile landscapes of the Himalayan region are facing an ongoing concern about current and potential climate change impacts. Carbon stocks in vegetation types of western Himalayas have immense ecological significance, vital for the regional and global carbon reserves. Among the vegetation types, forests, pasture, agricultural fields, and orchards dominate in this region. The increasing human interventions, land management practices and natural ecosystem processes are the potential sources of GHGs emission in the atmosphere. Deforestation and other changes in land use cause significant exchanges of CO_2 between the land and the atmosphere. The carbon

stock storage and climate change mitigation cannot be easily achieved in the high-altitude Himalayan regions, because of the type of land use available, cold climate, and the land holding capacity of the people (Sharma et al. 2020b). The sustainable management regimes for these land uses can increase their potential to act as a sink for long-term carbon storage along with providing livelihood opportunities and vulnerability of natural resources to climate change can be reduced through adoption of these management practices. Anthropogenic CO_2 discharges are viewed as the significant patron of ozone-depleting substance outflows around the world. Conversion of CO_2 into fuels or energy-rich compounds is very beneficial as it is cheaper to produce, less inflammable, can be produced from biomass and is discussed in the last section. Also, it is advantageous to many automobiles, power plants, and other industries like pharmaceuticals, fine chemical, and food production units. Methanol is gaining popularity as an alternative to petroleum-based fuels and is beneficial for a safer and cleaner environment. The enzymatic method for CO_2 conversion has attracted much attention due to its improved selectivity and yields under mild reaction conditions. CO_2 can be reduced through different methods like physical, chemical, electrochemical, photochemical and biological or enzymatic methods. Among these potential approaches, biological or enzymatic methods offer viable, effective, green and potent alternative of CO_2 conversion into value-added products because of high stereo specificity and region/chemo-selectivity of enzyme.

The development in global carbon management strategies becomes the mandate of all educational and research bodies. In fact, the public awareness and inclusion of climate change topics at elementary education is also equally important. We should focus on the techniques and methods to minimize the emission of excessive greenhouse gases. Alternatively, more green and sustainable methods should be developed to generate the energy for transport and industrial applications. The protection and conservation of natural ecosystem forest, lakes, rivers, wild fauna and flora should be increased to elevate the biotic carbon level and minimize the atmospheric release. Thus, in this monograph various developmental strategies for carbon management in our ecosystem have been highlighted in respective chapters. Specific topics covered in the monograph include:

- Carbon capture: Innovation for a green environment
- Geological carbon capture and storage as a climate-change mitigation technology
- Soil carbon sequestration for soil quality improvement and climate change mitigation
- Post-combustion of carbon capture technologies: Advancements in absorbents and nano-particles
- Carbon biocapturing system for environment conservation
- Simultaneous wastewater treatment and carbon capture for energy production
- Carbon dioxide capture by ionic liquids
- The climate smart agriculture for carbon capture and carbon sequestration: The challenges, risks and opportunities
- Quantification of the soil organic carbon and major nutrients using geostatistical approach for Lahaul valley, cold arid region of Trans-Himalaya

- Biochar: A carbon negative technology for combating climate change
- Carbon sequestration potential of different land use sectors of Western Himalaya
- Progresses in bioenergy generation from CO_2: Mitigating the climate change
- Recent advances in enzymatic conversion of carbon dioxide into value-added product.

The topics are organized in four different sections: (i) carbon capture as natural phenomenon; (ii) advance carbon management techniques; (iii) miscellaneous techniques, and; (iv) value addition techniques.

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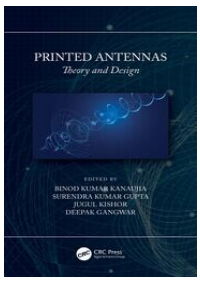

Advances in Patch Antenna Design Using EBG Structures

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ABSTRACT

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11 Advances in Patch Antenna Design Using EBG Structures

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11.1 INTRODUCTION

High-performance applications in wireless communication systems require an advanced form of electromagnetic materials. The development of "metamaterials" with unique features has recently gained great attention from the researchers [1]. Metamaterials are used in many fields such as optics, nanoscience, material science,

and antenna engineering. These materials have special characteristics that do not exist in naturally occurring materials. Hence, designing metamaterials with unique characteristics and using them in several antenna applications is an interesting concept for researchers. The concept of photonic crystals was introduced by Yablonovitch in solid-state physics [2]. The photonic crystals with a forbidden band gap are used in optics and solid-state physics. Therefore, the term photonic band gap (PBG) of the optics is used as electromagnetic band gap in the microwave domain. EBG structures are classified as a special type of metamaterial and can be defined as periodic or non-periodic structures that prevent or help the transmission of electromagnetic waves in a specific band of frequency [3,4]. EBG structures have many names in the literature, including left-handed materials, soft and hard surfaces, double-negative materials, negative refractive index materials, high-impedance surfaces (HIS), magnetomaterials, and artificial magnetic conductors (AMC) [5]. They are categorized into three groups: (i) three-dimensional volumetric structures, for example woodpile structure, (ii) two-dimensional planar structures, for example mushroom-like EBG structure, and (iii) one-dimensional transmission lines, such as holes in the ground plane. The EBG unit cell has a single band gap; however, a periodic arrangement of EBG structures can have multiple band gaps. In addition to the band gap feature, EBG structures also have some other important characteristics such as AMC and HIS [6]. For example, for both TE and TM polarizations, the two-dimensional EBG structures show a high-impedance surface. And when a wave strikes the EBG surface, 0° reflection phase is obtained and the EBG surface behaves as an AMC. These special features of EBG structures lead to a broad range of applications in microwave and antenna engineering [7,8].

In this chapter, we discuss the recent advancements in patch antenna design using EBG structures. These structures help improve the gain and bandwidth of the patch antennas. They are also used to reduce mutual coupling and to obtain band-rejection characteristics in ultra-wideband (UWB) antennas. A number of techniques to improve the gain and bandwidth, to achieve multi-band characteristics, to reduce mutual coupling, and to obtain multiple band-notch characteristics using compact EBG structures are also discussed later in this chapter. Finally, some real-life applications of EBG structure-integrated patch antennas, such as RFID and wearable electronics, are summarized.

11.2 EBG STRUCTURES AND THEIR PROPERTIES

An EBG structure is made up of metallic patches, ground plane, dielectric materials, and vias that connect patches to the ground plane [6]. From inductance and capacitance, the notch resonance frequency of an EBG cell can be determined using eq. (11.1):

$$f_s = \frac{1}{2\pi\sqrt{LC}} \tag{11.1}$$

where f_s represents the operating frequency of the EBG structure. This operating frequency can be varied by varying the inductance and capacitance. The values of inductor L and capacitor C are evaluated using the given formula [6–8]

$$L = \mu_0 h \tag{11.2}$$

$$C = \frac{W\varepsilon_0(1+\varepsilon_0)}{\pi}\cosh\frac{(2W+g)}{g} \tag{11.3}$$

where W, g, h, μ_0, and ε_0 are the width of the patch, the gap between two EBG structures, the substrate height, the permeability and permittivity of free space, respectively. The EBG structures' band gap can be evaluated by three methods, i.e., reflection phase, dispersion diagram, and the transmission characteristics calculated by suspended line method. Reflection phase characteristics of an EBG unit cell are used to predict the electromagnetic nature of the surface. For perfect electric conductor (PEC) and perfect magnetic conductor (PMC) ground planes, the reflection phase is 180° and 0°, respectively [9]. However, the PMC does not occur in the environment. For an EBG ground plane, the reflection phase varies from +180° to −180° with increasing frequency. The frequency range between +90° and −90° generally overlaps the band gap of an EBG structure [10]. Figure 11.1a indicates the reflection phase. The dispersion diagram, which is calculated using Eigenmode solver, is used to obtain the band gap of periodic EBG structures. The plot of phase constant and resonant frequency is referred to as the dispersion diagram [11]. Figure 11.1b illustrates the dispersion diagram. In the transmission characteristics method, the band gap is calculated by replacing the PEC ground plane with the EBG array. Figure 11.1c indicates the transmission loss. Transmission losses less than −15 dB are generally considered as the band gap of the EBG structure [12]. The transmission characteristics and reflection phase are enough for calculating the band gap of an EBG structure. From the transmission characteristics and reflection phase, the AMC at 0° and the surface wave band gap of the EBG structure can be easily recognized [13]. The dispersion diagram consumes more memory and time, but gives more information on band gap.

11.3 EBG STRUCTURES IN PATCH ANTENNA DESIGN

For wireless communication application, patch antenna are mostly preferred due to its low profile and low cost with high performance. The patch antennas have major benefits such as ease of installation, low cost, low profile, and integration with printed circuits. Some of the drawbacks of patch antennas are low efficiency, low power, high Q, surface wave excitation, and narrow bandwidth [15]. The unique features of the EBG structure are found useful to overcome the drawbacks of a patch antenna. The EBG structure helps in gain and bandwidth improvement [16–19]. In general, an EBG patch antenna produces a plane radiation profile, fewer side lobes, and a good antenna efficiency compared to a normal patch antenna. The EBG structure also ensures low interference to the adjacent elements and acts as a shielding material between the antenna and the communication system user. Further, the EBG structure has also been used in MIMO [20–22] systems and array antennas to alleviate the mutual coupling [23] effect. The application of EBG structures in patch antennas is a smart research area; however, some problems arise as two different structures are combined together to achieve enhanced performance. Some

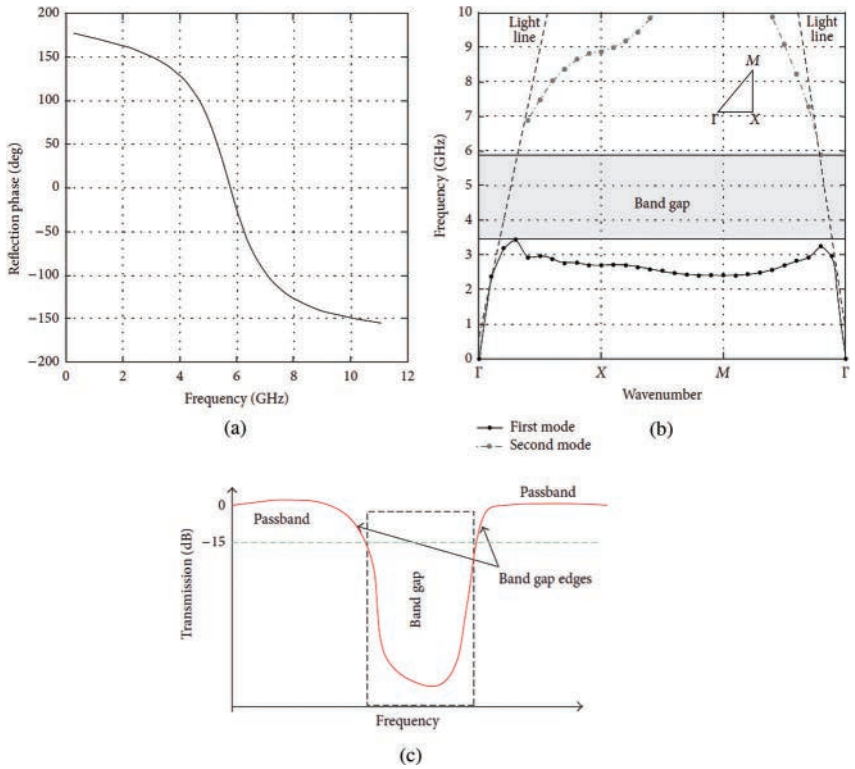

FIGURE 11.1 Different methods for calculating the band gap: (a) reflection phase methods (b), dispersion diagram methods, and (c) transmission characteristics methods [14].

new designs and their applications to enhance the performance of patch antennas are discussed in this chapter.

11.3.1 Bandwidth Improvement in Patch Antennas Using EBG Structures

For wireless communication systems, the mostly preferred antenna is the patch antenna. Generally, the conventional patch antenna has narrow bandwidth because of the PEC material in the ground plane. To achieve a wide bandwidth, the researchers have done intensive research and suggested a number of EBG structures. A wide band of 3–35 GHz is achieved by placing a periodic structure of circular and square EBG patch around the half-circular monopole antenna [24]. By inserting the conventional mushroom-type EBG structures on either side of the feed line, the impedance bandwidth is increased by 0.1 GHz as compared to the monopole UWB antenna. A good improvement in bandwidth is obtained by etching dummy EBG patterns on the feed line [25] as shown in Figure 11.2.

The EBG array is inserted on a substrate with a height of 0.4 mm and a dielectric constant of 2.33. The patch size is 8 mm × 6.3 mm, resulting in an operating frequency

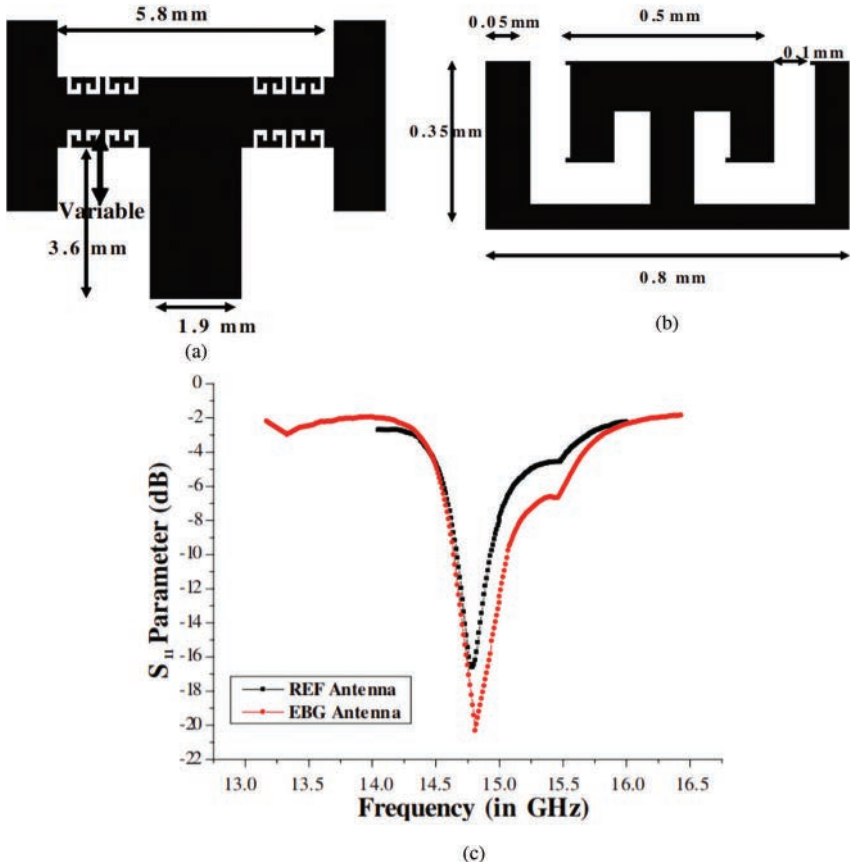

FIGURE 11.2 (a) Magnified view of feed line and (b) magnified view of EBG pattern [25] (c) S11 parameters Vs frequency.

of 14.8 GHz. Eight rows of dummy EBG structures are etched on the patch feed line with a gap of 5.8 mm in between two patches. The test data show the improvement in the bandwidth of over 0.381 GHz. In [26], Fabry–Perot (FP) antennas were integrated with EBG metamaterials for getting 4.92% impedance bandwidth and 10.7 dB gain simultaneously [27]. From Figure 11.3, it can be seen that using a trapezoidal ground plane in combination with a uniplanar EBG structure [28] increases the bandwidth and also improves the radiation characteristics of a monopole antenna. By changing the width of an EBG structure, one can vary its operating frequency. The total volume of the antenna is $100 \times 75 \times 0.762$ mm^3 including eight EBG cells. A conventional mushroom-type EBG structure was modified by inserting multiple vias to increase the band gap for noise suppression [29,30]. As shown in Figure 11.4, four vias are optimized to achieve a wider band gap and it is termed as ground surface perturbation lattice (GSPL) [31]. Figure 11.5 illustrates a lotus flower patch attached to a wide transmission line with an EBG ground plane to increase the bandwidth of the antenna. A slanted ground plane with an EBG structure was used to enhance the

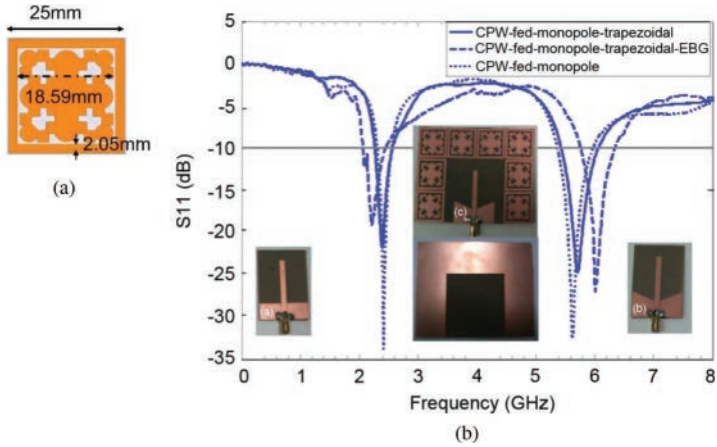

FIGURE 11.3 (a) Dual-band EBG structure; (b) return loss measurements [27].

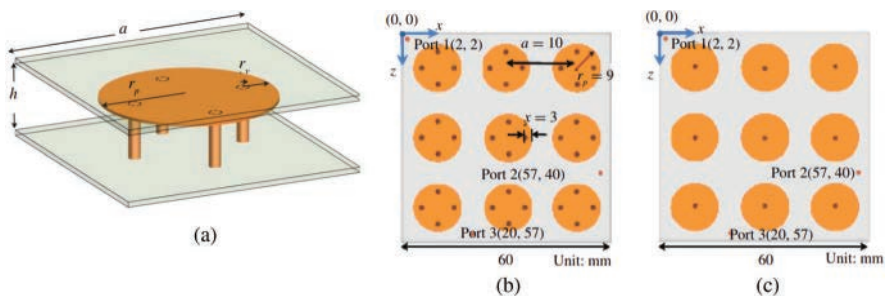

FIGURE 11.4 (a) Side view of GSPL structure; (b) GSPL structure. (c) Two-dimensional EBG structure [31].

bandwidth of the elliptical and rectangular monopole antennas [32]. In the literature, to enhance the bandwidth, a multilayer EBG structure [33] was also used. Monopole antennas of different shapes such as elliptical [34] and semi-circular [35] were suggested for enhancing the bandwidth. Further, the bandwidth of an UWB antenna can be improved by using EBG structures with a monopole antenna. Thus, in Table 11.1, some of the EBG structure approaches are described for bandwidth improvement.

11.3.2 Gain Improvement Using EBG Structures

With the arrival of new wireless communication services, the demand for ultra-wideband with low cost and compact size is increasing tremendously. The main drawbacks of printed antennas are low gain and low radiation efficiency because of the propagation of the surface wave. If an antenna is placed over a PEC ground plane such as copper or gold, it starts radiating into space. Additionally, it also produces currents that move along the sheet. These currents are also called surface waves and propagate to an edge of the antenna surface and cause multi-path interference.

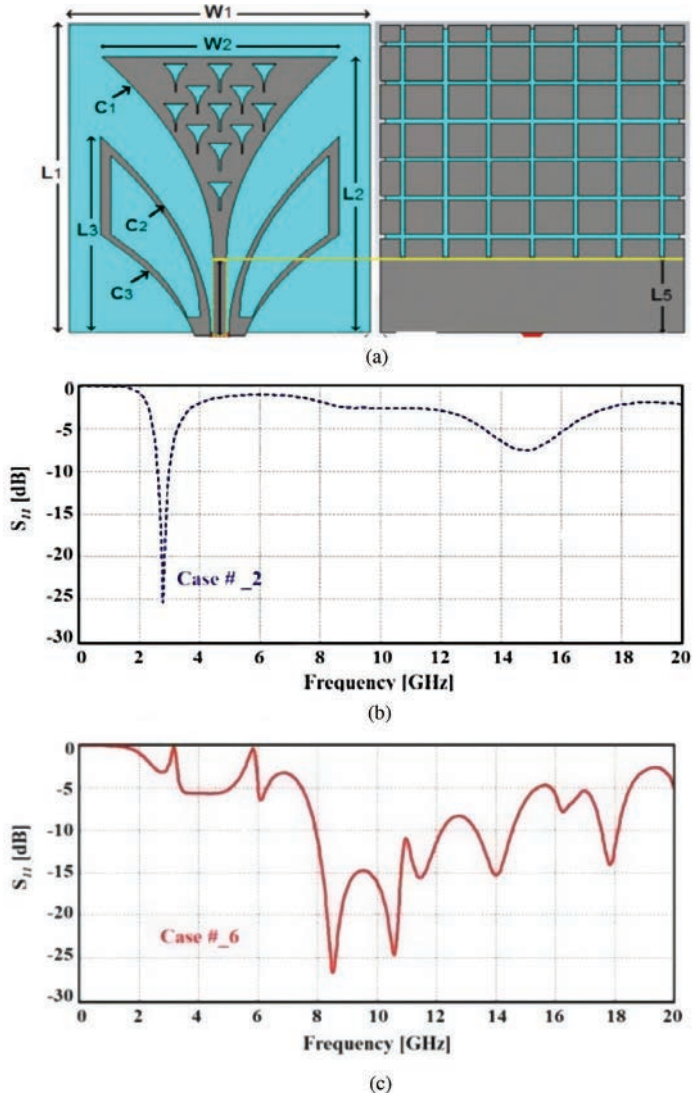

FIGURE 11.5 (a) Lotus-shaped antenna with an EBG ground plane, (b) $|S_{11}|$ of lotus-shaped antenna with partial ground plane, (c) $|S_{11}|$ of lotus-shaped antenna with EBG ground plane [32].

A number of approaches to increase the gain of patch antennas using EBG structures have been proposed. In these approaches, the EBG structure is designed in a way that its band gap and antenna resonant frequency band overlap. As a result, the surface waves cannot propagate along the substrate and the amount of radiating power increases. In order to improve gain, the EBG structure can be placed in two ways – the first is by placing the EBG structure around the patch antenna, which is [36] termed simply as the EBG structure, and the second is by replacing the ground plane with the EBG structure which is called AMC [37]. A double-rhomboid bow

TABLE 11.1
Bandwidth Enhancement Using Different EBG Approaches

S. No.	EBG Approach	Reason	Reference
1.	EBG pattern on the feed line	Bandwidth is improved due to impedance matching	[25]
2.	Multilayer EBG structure	Merging multiple bands into one wide band gap	[30,36]
3.	Symmetric placement of EBG structure around the patch	Bandwidth enhancement due to the different resonant frequencies	[28]
4.	Multiple-via EBG structure	By increasing inductance, reflection phase behavior gives much wider bandwidth	[32]
5.	EBG ground plane	To couple between the patch and EBG-AMC resonance frequencies	[24,27,33,34]

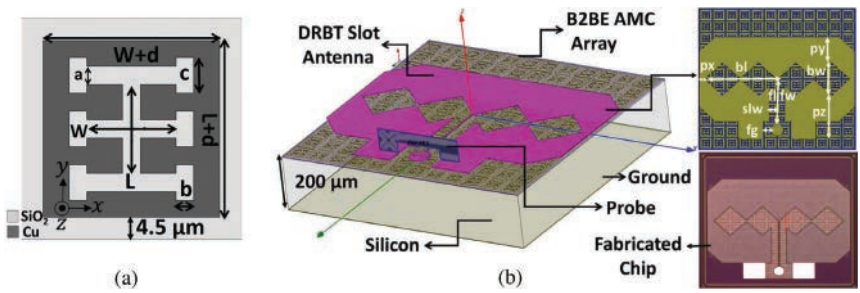

FIGURE 11.6 (a) EBG structure; (b) antenna with AMC array [38].

tie-slot antenna [38] was presented with an end-to-end E-shaped EBG surface for gain improvement at the W-band, as shown in Figure 11.6. This EBG surface behaves as a reflective surface that helps to improve the gain of the on-chip antenna. To prevent the losses due to waves entering into the lossy silicon substrate, an AMC array surface is placed beneath the patch. In another interesting study, a low-temperature co-fired ceramic (LTCC) patch antenna's gain was improved using a Sievenpiper EBG structure [39]. This LTCC was designed to resonate at 60 GHz on a DuPont™ Greentape™ 9K7 ($\varepsilon_r \sim 7.0$) of 5 mm thickness.

The two-element LTCC patch array was combined together with the Sievenpiper EBG structure to eliminate surface waves. As a result, around 4 dBi of gain enhancement and 8 dB of reduction in side lobe level were obtained, as shown in Figure 11.7. The design of eight-element MIMO antennas for 5G applications such as smartwatch and dongle [35] is presented in Figure 11.8. To improve gain and efficiency, an EBG surface was used as a ground plane. The upper layer of the substrate has eight MIMO antennas [36–40], whereas the bottom layer is composed of an EBG ground plane. The gain and antenna efficiency obtained were 8.732 dB and 92.7% at the resonant frequency, respectively.

Another study was performed [40] by changing the vias' positions in different patterns in the EBG ground surface, as presented in Figure 11.9a–d, and it was found

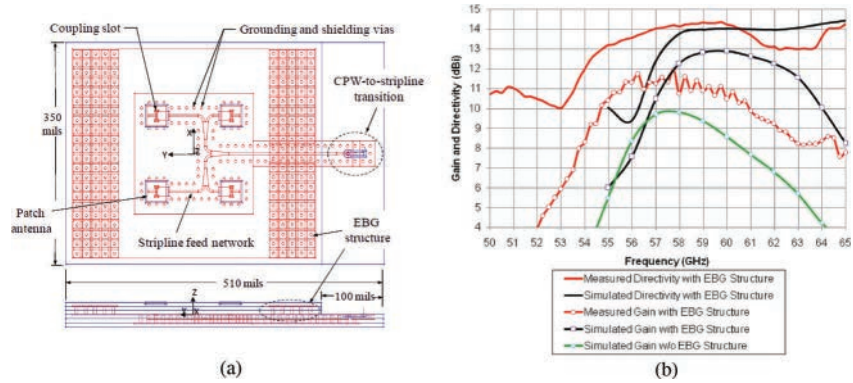

FIGURE 11.7 (a) 2×2 patch array; (b) gain and directivity versus frequency of the 2×2 patch array [39].

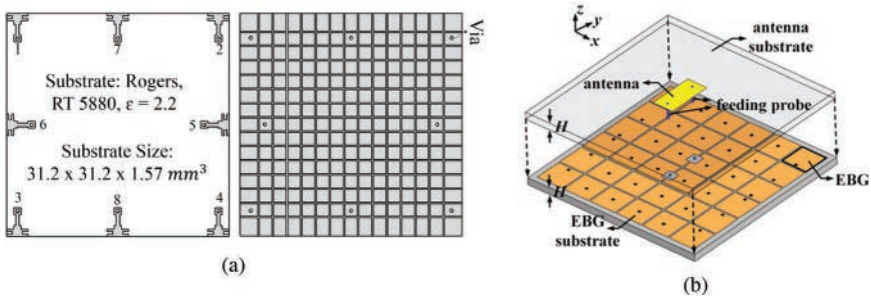

FIGURE 11.8 (a) Top and bottom views of an eight-element MIMO antenna with EBG ground plane [35]; (b) 3D view of cylindrically projected EBG planes [40].

that the antenna gain and efficiency were improved by 14.1 dB and 107.2%, respectively. Besides improving gain and directivity, the EBG superstrate also obtains dual-band dual-polarization [41–43] and suppresses the grating lobes in array antennas. Different EBG structures [42–48] were discussed based on the position of the EBG structure, such as below the patch and around the patch, to improve the overall performance of the antenna. In [49], a slotted EBG structure was used to improve the gain and to reduce the radar cross section (RCS) of a patch antenna. This slotted EBG structure was made of arrays of mushroom-type structure with rectangular slots on the patch. From the tested results, it was observed that the gain improved by 2.5 dB and RCS reduced to 4.3 dB as compared to the conventional patch antenna. Thus, few EBG structure approaches are discussed in Table 11.2 to improve patch antenna gain.

11.3.3 Mutual Coupling Reduction Using EBG Structures

Mutual coupling between antenna elements is due to the propagation of surface waves, and it affects the overall performance of the antenna. In case of a patch antenna, the E-plane coupling is stronger than the H-plane coupling. Several

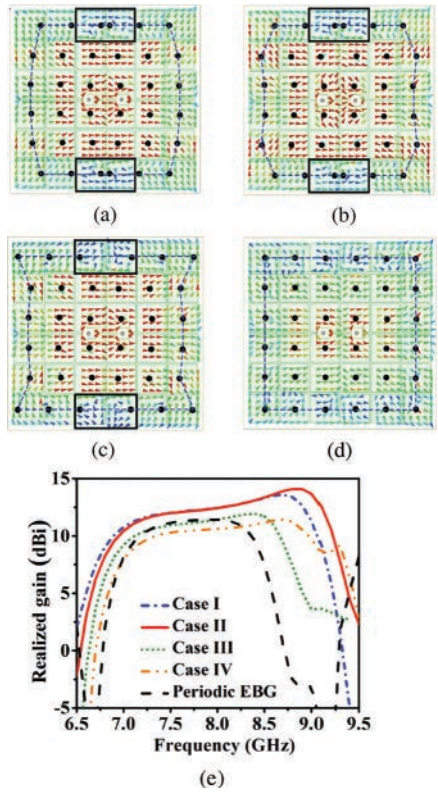

FIGURE 11.9 (a–d) Different patterns of vias in EBG ground plane; (e) realized gain of different EBG planes [40].

TABLE 11.2
Gain Enhancement Using Different EBG Structure Approaches

S. No.	EBG Structure Approach	Reason	Reference
1.	EBG structure placed around the patch	Surface wave suppression results in improved gain	[38,42,44,47,48]
2.	EBG structure ground plane	AMC property is utilized as a reflector	[35,40,49]
3.	Superstrate EBG structure layer above the patch antenna	Multiple reflections in cavity result in performance enhancement	[50,51]

methods were discussed and applied to reduce the mutual coupling between the MIMO system and antenna array, which include defected ground plane, decoupling strips, and neutralization line. For the MIMO system, it is desirable to have a mutual coupling of less than 15 dB, the envelope correlation coefficient (ECC) should be less than 0.5, and the total active reflection coefficient (TARC) should be less than 0 dB. The ECC is used to measure the correlation between radiation patterns of

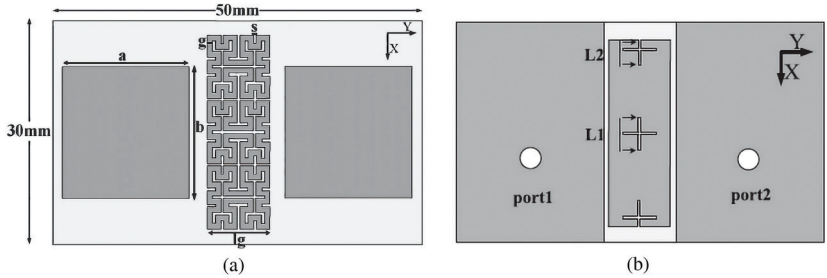

FIGURE 11.10 (a) Top view and (b) back view of patch antenna array [52].

MIMO antennas. The TARC is similar to return loss, but also considers the effect of mutual coupling. In [52], the mutual coupling was reduced by using two fractal uniplanar compact EBG structures and three cross-slots in between the patch arrays, as shown in Figure 11.10. By placing the two rows of fractal uniplanar compact EBG structure on the top layer, the mutual coupling was reduced 13 dB. Moreover, etching three cross-slots on the ground plane further improves the reduction in the mutual coupling. In [53], the conventional uniplanar compact EBG structure was modified by inserting rectangular slots. The modified EBG is shown in Figure 11.11a. Two-element MIMO antennas [53] were designed in a way that one element is positioned in front of the other. The introduction of the modified EBG array amid the two patches eliminated the propagation of surface waves. A parallel connection of L and C with series L and C connections formed a narrow band-stop filter. Because of the parallel inductance connections, the overall inductance decreased, and due to the parallel capacitance connections, the overall capacitance increased. These parallel connections aided in reducing the isolation by increasing the quality factor. The relation, given in eq. (11.4),

$$Q = \eta\sqrt{\frac{C}{L}} \tag{11.4}$$

Another investigation accomplished in [54] considered the planar compact EBG structure. To achieve better mutual coupling reduction, the planar EBG structure is placed in three different arrangements as shown in Figure.11.12. The planar compact EBG structure was fabricated using an FR4 substrate with a height of 1.6 mm and an overall dimension of 5.05×6.52 mm^2. The operating frequency of the antenna was nearly 5.6 GHz, which is at the WLAN band. In [56], a split EBG structure was placed amid the patch elements and the mutual coupling was decreased by 28 and 45 dB at 3.49 and 4.788 GHz, respectively. The split EBG structure is illustrated in Figure 11.13. In [55], miniaturized two-layer EBG structures were studied for decreasing the mutual coupling between UWB monopoles. These EBG structures contained slits in the ground plane, and as the number of slits increased, the electromagnetic coupling reduced. Figure 11.14 shows the variation in the mutual coupling with the number of slits in the ground plane. Table 11.3 shows the different EBG structures discussed in the literature to reduce the mutual coupling..

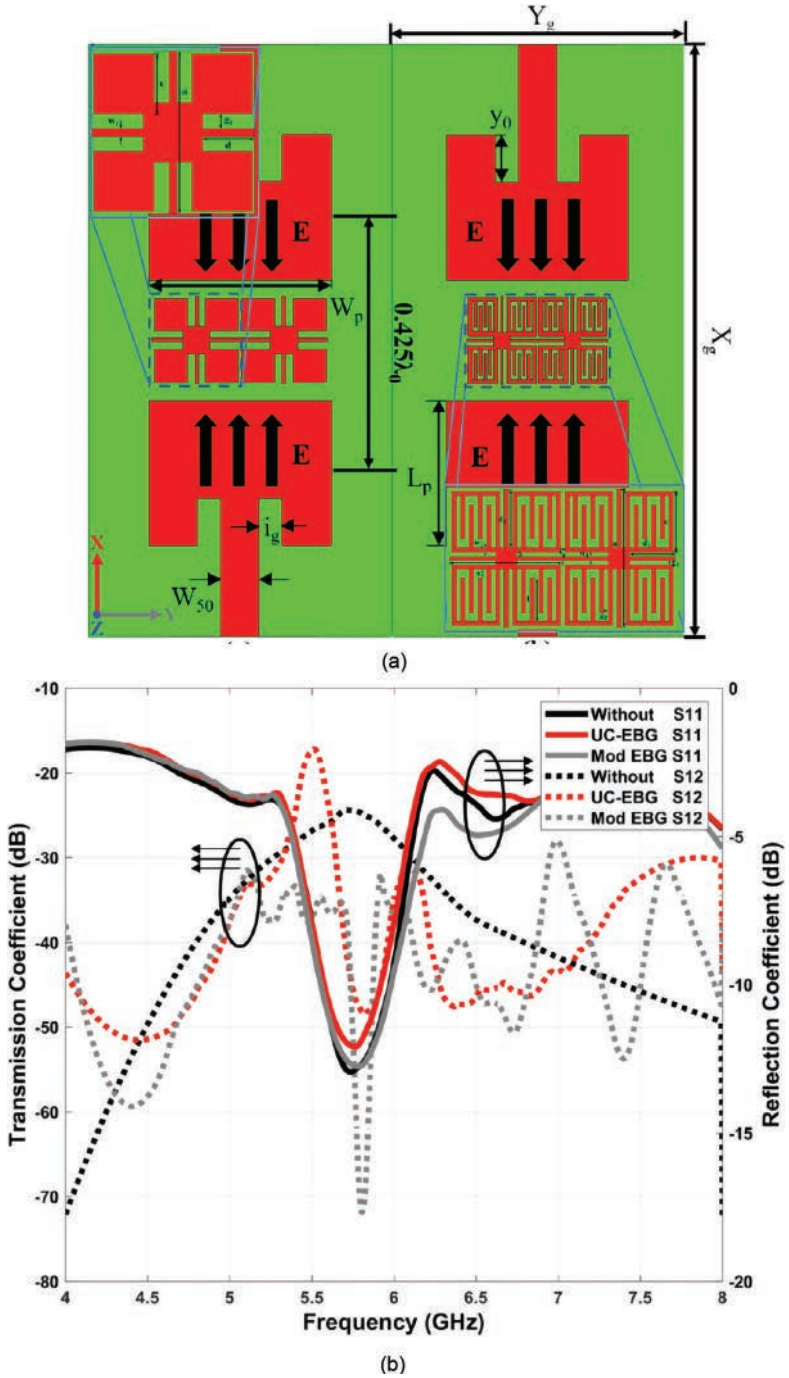

FIGURE 11.11 Two-element UWB MIMO antenna with inset feed: (a) UC-EBG structure and the proposed modified EBG structure; (b) *S*-parameters of three different cases [53].

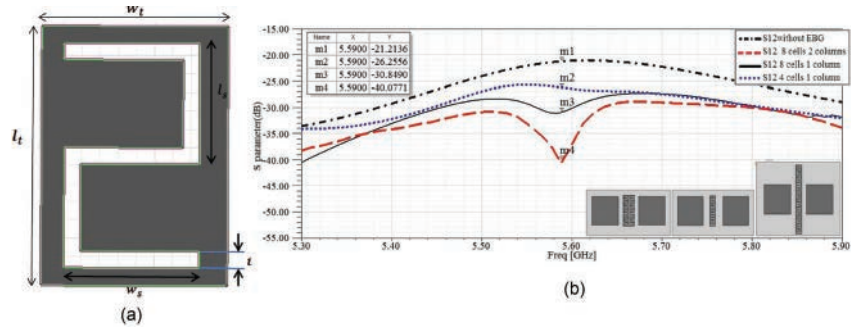

FIGURE 11.12 (a) Planar compact EBG structure; (b) mutual coupling of EBG structure array in three different arrangements [54].

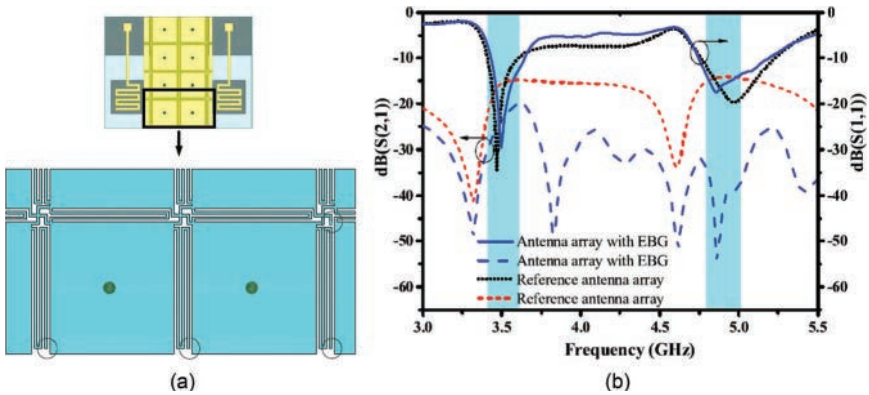

FIGURE 11.13 (a) Two-element meander line antenna; (b) reflection coefficient and mutual coupling with and without split EBG structure [56].

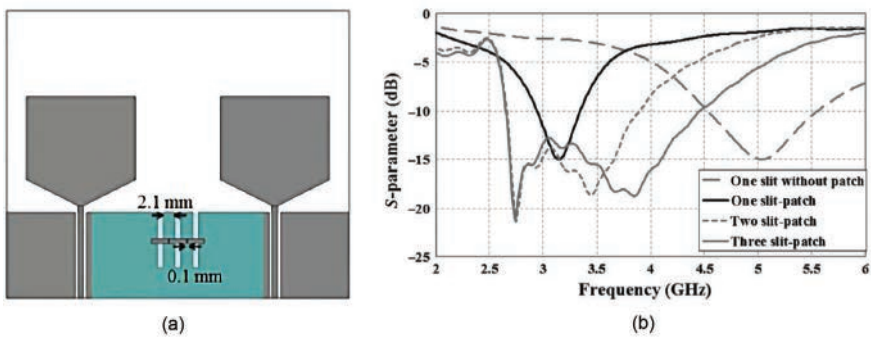

FIGURE 11.14 (a) Planar monopole MIMO antenna; (b) variation of mutual coupling [55].

TABLE 11.3
Mutual Coupling Reduction by Using Different EBG Structures

S No.	Type of EBG Structure	Mutual Coupling	Dielectric Constant (ε_r)	Height (mm)	Reference
1.	Fractal uniplanar compact EBG structure	−37 dB	2.65	1	[52]
2.	Modified EBG structure	−70 dB	4.4	1.6	[53]
3.	Planar compact EBG structure	−28 dB	4.8	1.6	[54]
4.	Double-layer EBG structure	−22 dB	4.5	1.55	[55]
5.	Split EBG structure	−44 dB	4.4	1.2	[56]
6.	Uniplanar compact EBG structure	−28 dB	10.2	1.27	[59]
7.	EM band gap metamaterial	−37 dB	4.3	1.6	[60]
8.	Uniconductor EBG structure	−46 dB	4.4	1.6	[61]
9.	Tunable double-layer EBG structure	−45 dB	4.5	1.55	[62]

11.3.4 Band-Notch Operation in Patch Antennas Using EBG Structures

In April 2002, FCC unbound the frequency range that lies from 3.1 to 10.6 GHz and this band is termed as UWB. Some narrowband communication systems (WiMAX, WLAN, and X-band) also work within this range, which produces interference. Many different design methods have been presented in the literature to avoid interference. The methods such as etching slots and using stubs and resonators, such as capacitively loaded loop and electric ring, disturb the radiation pattern because of discontinuities in the radiating elements. This problem can be solved by using the band-rejection characteristics of EBG structures. By inserting the EBG structure near the feed line of the UWB antenna, the interference of narrowband communication can be discarded [57]. In the literature [58], various designs of EBG structures have been presented to obtain band-notch characteristics. A swastika-type EBG structure [63] was used to achieve single-band-notch characteristics with a band gap of 7.5–11.1 GHz. In [64], by placing the EBG structures near feed line, three notches at WiMAX (3.5 GHz) and WLAN (5.2/5.8 GHz) bands are achieved. Mushroom-type EBG structures with vias at center [65] and edge-located mushroom-type EBG structures [65–68] are some structures presented by the researchers. A uniplanar EBG structure and two mushroom-type EBG structures [70] were placed near the feed line of the monopole antenna to have triple-band-rejection characteristics. A hexagonal-shaped c-slot mushroom-type EBG structure [66] was used to achieve band-notch function for X-band satellite communication systems (6.7–7.7 GHz). In [71], four EBG structures were placed close to the feed line to attain dual-band-notch characteristics [72], as shown in Figure 11.15a. The patch antenna and EBG structure were fabricated on a cheap FR4 substrate of dimensions $58 \times 45 \times 1.6$ mm^3. Figure 11.15b indicates the VSWR of an UWB MIMO antenna. In another interesting study [74], a circular monopole antenna [75–77] with two mushroom-type EBG structures was used to obtain band-notch characteristics for WLAN and WiMAX. Moreover, 34% of compactness was also achieved by etching an L-shaped slot on the EBG surface.

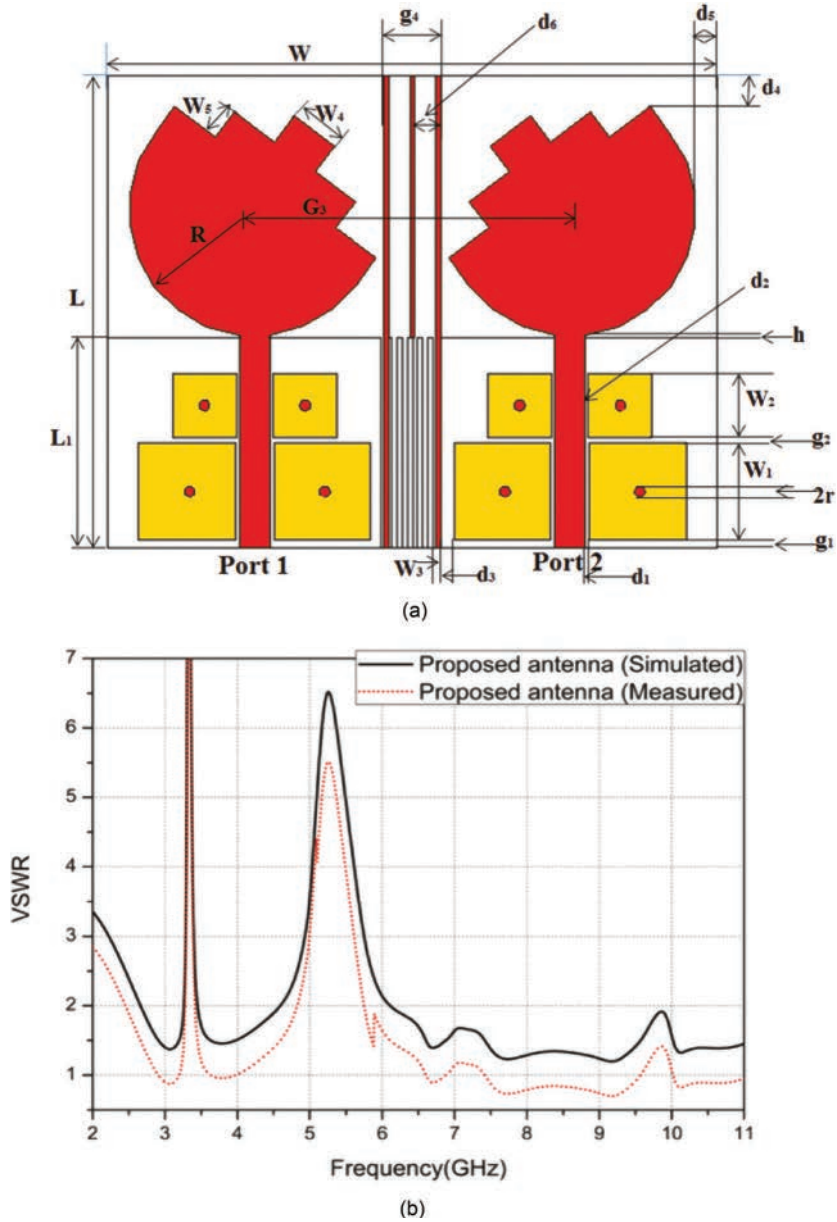

FIGURE 11.15 (a) Band-notched UWB MIMO antenna; (b) VSWR plot [71].

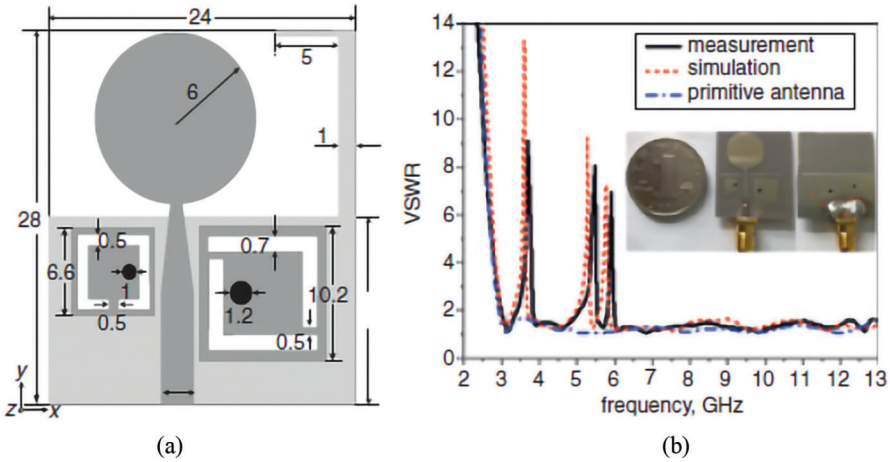

FIGURE 11.16 (a) Triple-band-notched monopole UWB antenna; (b) VSWR plot [74].

Figure 11.16a shows a circular monopole antenna with two modified EBG structures. This modified EBG structure contains two L-shaped slots with an edge-located via (ELV) that achieve two notched bands. So, in this, a single EBG structure is used to obtain dual-band-notch characteristics. A dual-band-notched MIMO antenna obtains notches in WiMAX band (3.3–3.6 GHz) and WLAN band (5–6 GHz), as presented in Figure 11.16b. A triple-band-notched UWB MIMO antenna [70] was realized by using three EBG structures. Figure 11.17 indicates the band-notched antenna. The designed antenna avoids the interference from WiMAX band ranging from 3.3 to 3.6 GHz, WLAN band ranging from 5 to 6 GHz, and the X-band for satellite communication systems ranging from 7.2 to 8.4 GHz. Another modified EBG structure connected with the feed line was used to reject the interference from narrowband communication systems [73]. This modified EBG structure also rejects are for WiMAX, WLAN, and X-band satellite communication system.

This single EBG structure rejects are for WiMAX, WLAN, and X-band satellite communication systems. Figure 11.18a displays the band-notched UWB antenna. The antenna and EBG structure are designed using a FR4 substrate with a height of 1 mm, a dielectric constant of 4.4, and an overall dimension of $30.5 \times 26 \times 1$ mm^3 and 8×5.95 mm^2, respectively. A pentagonal printed UWB monopole antenna having three notched bands is shown in Figure 11.19a. Two slots are inserted in the EBG structure to attain multiple band rejection. The dimension of the EBG structure is 9.4×4.5 mm^2. Figure 11.19b indicates the VSWR of the band-notched UWB antenna. Thus, Table 11.4 shows several cases of different EBG structures for achieving band-notch characteristics.

11.3.5 Dual-Band and Multi-Band Characteristics Using EBG Structures

In the previous section, numerous EBG structures were discussed to improve bandwidth and gain, to reduce mutual coupling, and to obtain band-notch characteristics.

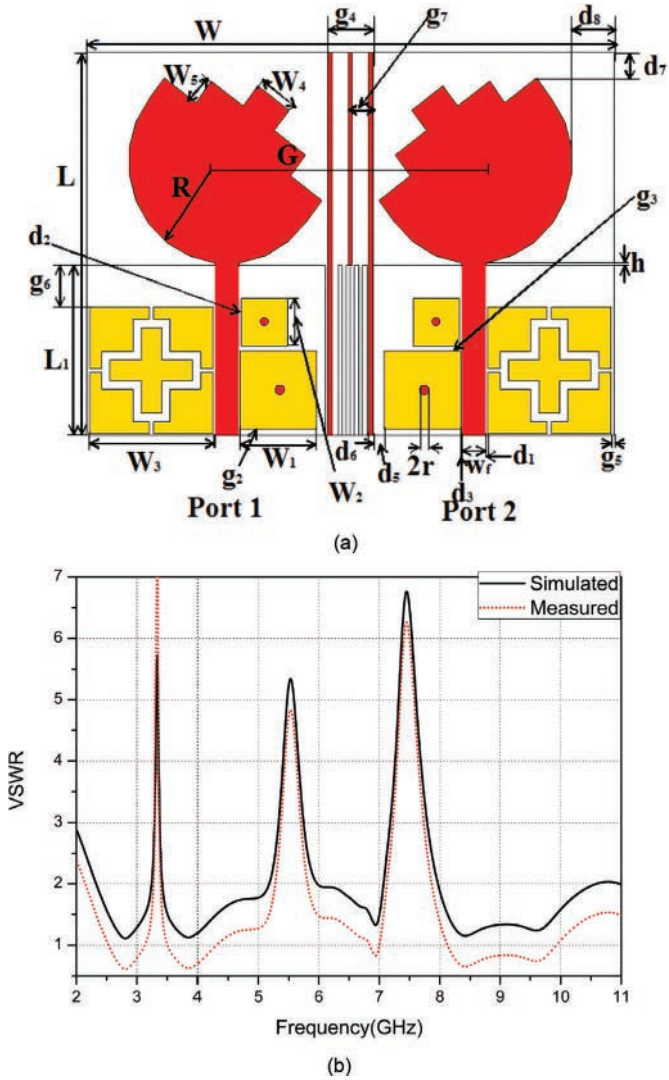

FIGURE 11.17 (a) Triple-band-notched UWB MIMO antenna; (b) VSWR plot [70].

The motivation of this section is to study the idea of multi-band operation in patch antennas using EBG structures. The resonant frequency of EBG structures can be calculated using a distributed lumped network. Using this distributed lumped network, the researchers have designed numerous EBG structures to obtain dual-band and multi-band characteristics in patch antennas.

In [79], dual-band characteristics were obtained by placing pinwheel-shaped slot EBG structure periodically around the antenna. The antenna combined with periodical EBG structures resonated at 4.9 and 5.4 GHz. The tested result also showed a bandwidth improvement of 41% and 25.4% at low frequency and high frequency,

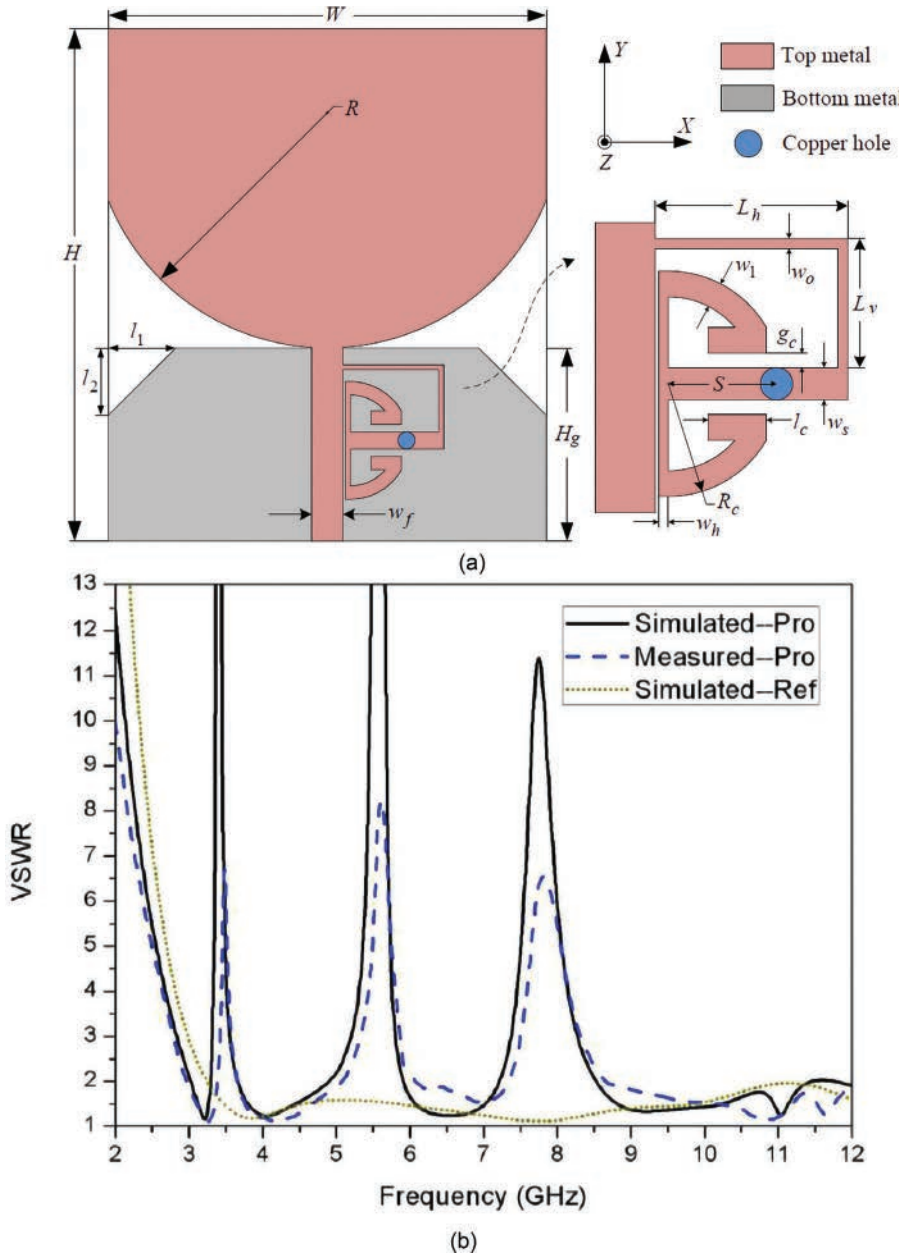

FIGURE 11.18 (a) Band-notched UWB antenna; (b) VSWR of triple-band-notched UWB MIMO antenna [73].

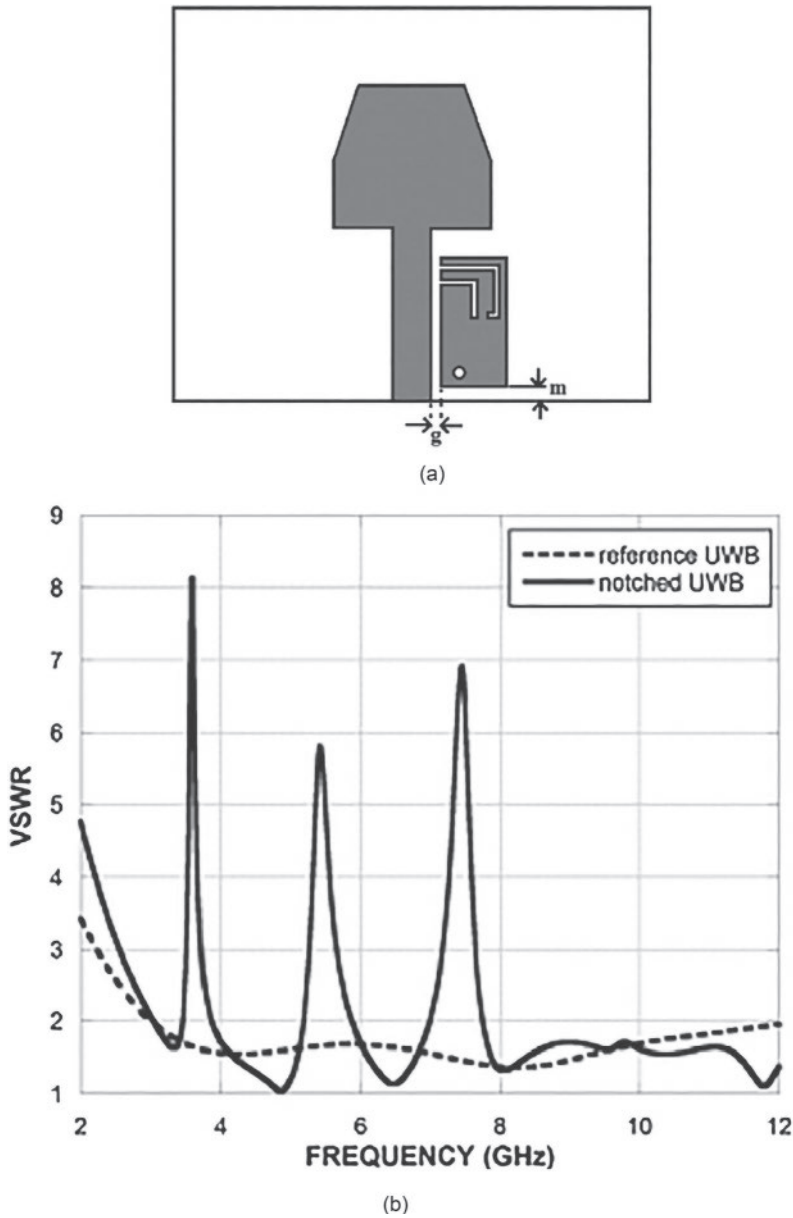

FIGURE 11.19 (a) Pentagonal UWB monopole antenna; (b) VSWR plot [75].

TABLE 11.4
Band-Notch Characteristics by Using Different EBG Structures

S. No.	No. of Notches	Type of EBG Structure	Notched Band (GHz)	Size (mm²)	Reference
1.	Single-notched band	Mushroom EBG structures	5.36–6.34	6.25×6.25	[22]
2.	Triple-notched band	Mushroom EBG structures and two split ring resonators	6.7–7.7	3.9×3.9	[66]
3.	Dual-notched band	Mushroom EBG structures	3.3–3.6 5–6	9.25×9.25 6.1×6.1	[76]
4.	Dual-notched band	DG-CEBG	3.3–3.6 5–6	5×5 3×3	[77]
5.	Dual-notched band	Uniplanar EBG structures with a π-shaped slot	3.45–3.9	5.2×5.2	[78]
6.	Triple-notched band	Uniplanar EBG structure Mushroom EBG structure	3.3–3.6 5–6 7.1–7.9	15×15 9.25×9.25 5.6×5.6	[79]

respectively. Figure 11.20 illustrates the H-shaped MPA with pinwheel-shaped slot EBG structures and the VSWR of three different cases. Another study performed in [80] presented a polarization-dependent EBG structure, as presented in Figure 11.21. This EBG structure behaves as a reflector of a dual-band dipole antenna. This reflector transforms the linearly polarized wave into a circularly polarized wave [80]. The tested antenna attained impedance bandwidths and axial ratio bandwidths of 13.4% and 3.2% and 2.4% and 3.5%, respectively. Another dual-polarized dual-band patch antenna was designed by loading a modified mushroom-type EBG unit cell [81], as presented in Figure 11.22. A square slot was etched from the radiating patch antenna, and the modified mushroom unit cell was placed at the slot to attain triple-band characteristics [82]. A new interesting study was performed in which the PEC ground plane was replaced by an EBG surface to obtain dual-band characteristics. The dual-polarized dual-band patch antenna and its simulated and tested results are presented in Figure 11.23. Thus, Table 11.5 lists several cases of EBG structures for obtaining multi-band/dual-band characteristics of patch antennas.

11.3.6 A Low-Profile MPA Using EBG Structures

In wireless communication systems, the dimension of the patch antenna depends on the resonating frequency. In this condition, it is a challenge to design the smallest possible antenna at low frequency. If the total thickness of the antenna is less than one-tenth of the operating wavelength, then the antenna is called a low-profile antenna.

The mutual coupling effect of the nearby ground plane degrades the overall performance. In [81], the performance of an MPA was examined by placing three different ground planes, namely PEC, PMC, and EBG, with the same height. When PEC

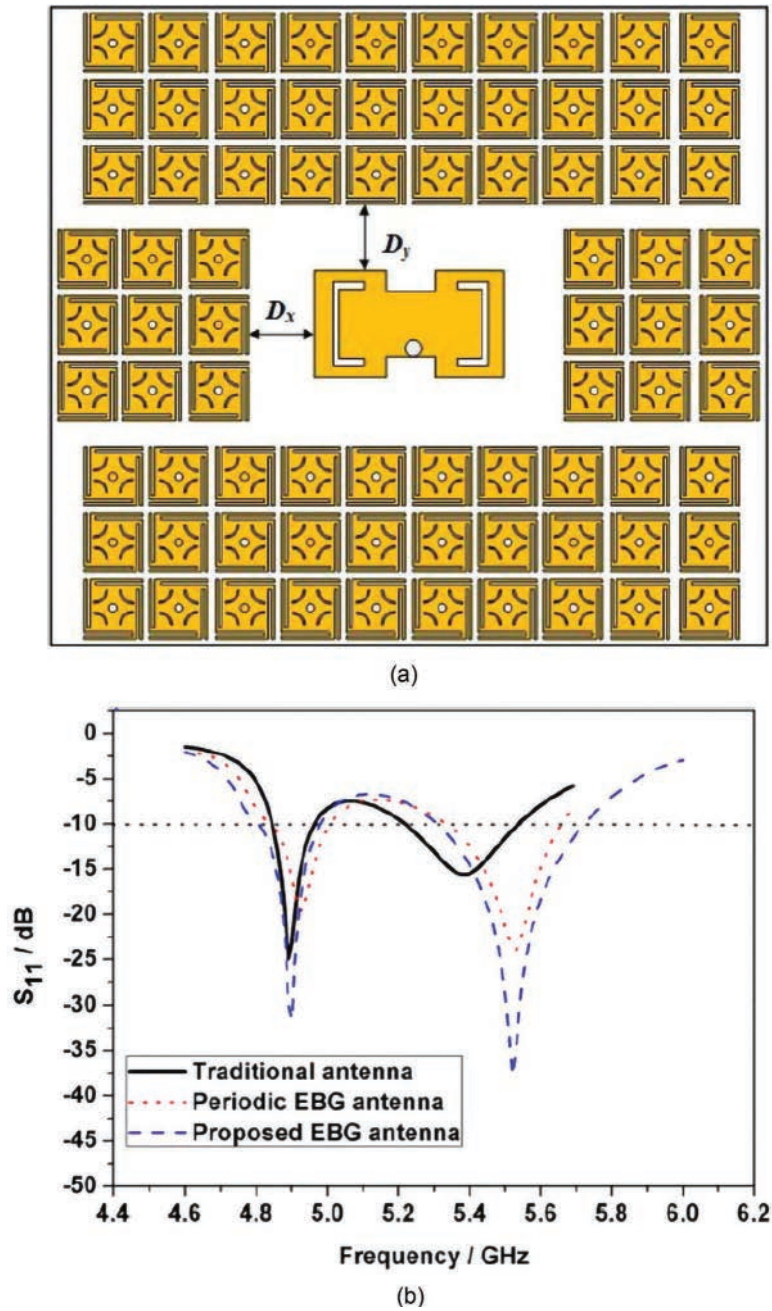

FIGURE 11.20 (a) Patch antenna with coaxial feed; (b) VSWR plot of microstrip antenna [79].

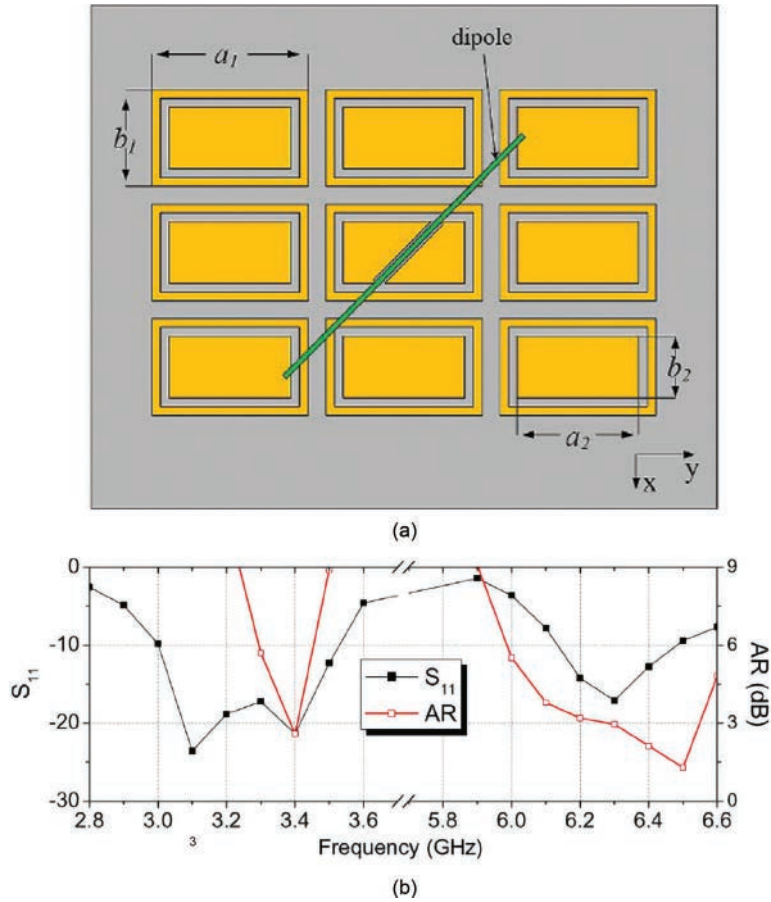

FIGURE 11.21 (a) Circularly polarized antenna; (b) S_{11} parameter and axial ratio plot [80].

TABLE 11.5
Multi-Band/Dual-Band Characteristics by Using Different EBG Structures

S. No.	Type of EBG Structure	Resonating Band without EBG Structure (GHz)	Resonating Band with EBG Structure (GHz)	Reference
1.	Dual-band EBG structure	2.265–2.563 and 5.434–6.061	2.062–2.453 and 5.765–6.343	[33]
2.	Pinwheel-shaped EBG structure	4.85–4.96 and 5.20–5.52	4.82–4.97 and 5.31–5.72	[79]
3.	Modified mushroom-like unit cell	2.21–2.29 and 2.45–2.5	2.21–2.29, 2.34–2.39 and 2.5–2.55	[81]
4.	Spiral conductor EBG structure	2.12–3.35 and 6.01–7.16	2.12–2.98, 5.24–5.80 and 6.05–7.77	[82]
5.	Uniplanar EBG structure	1.7–5.63 and 9.9–11.36	1.5–5.63 and 9.52–13.06	[83]

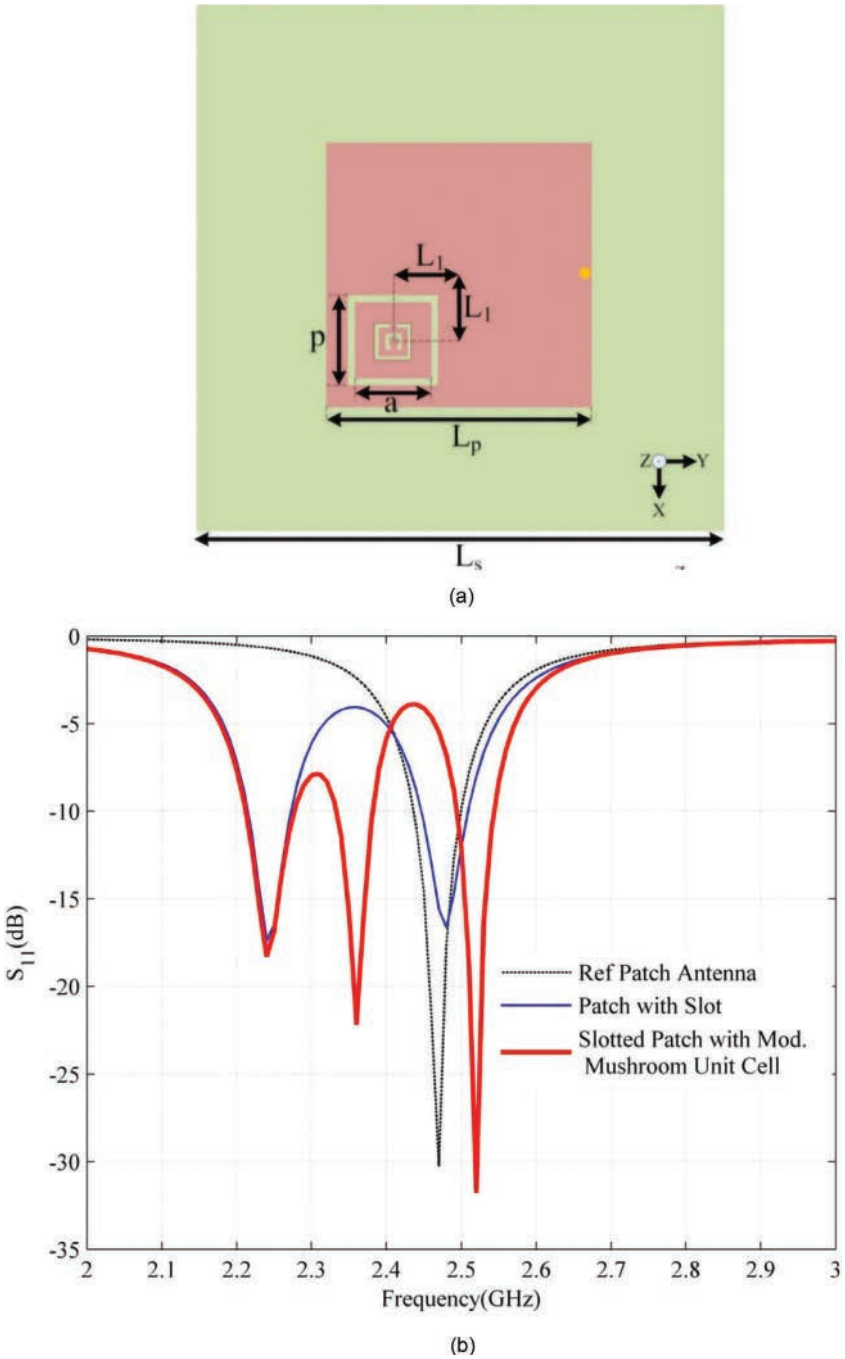

FIGURE 11.22 (a) Dual-polarized dual-band PA; (b) return loss of dual-polarized dual-band PA [81].

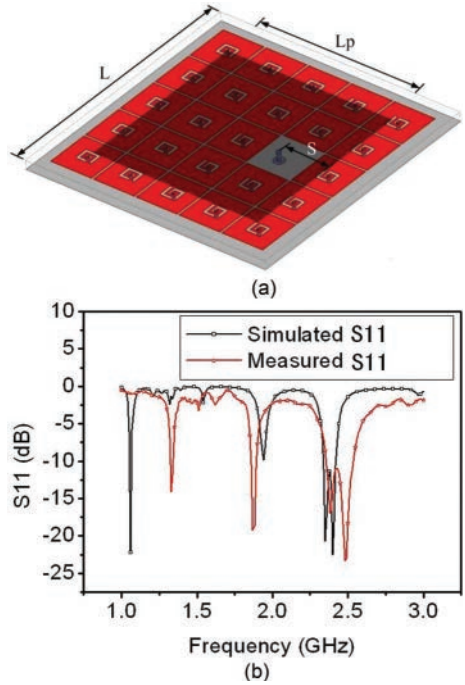

FIGURE 11.23 (a) Multi-band patch antenna; (b) return loss plot [82].

materials such as copper and gold are used as the ground plane, the return loss is −3.7 dB. The reason is that the PEC surface has a reflection phase of 180° and the image current has the opposite direction to that of the printed antenna. The reversal image current cancels the radiation from the printed antenna, resulting in poor return loss. When the ground plane is a PMC, the reflection phase is 0°. But the strong mutual coupling between the patch and image current results in a mismatch between the 50-Ω transmission lines [82]. Only if a proper impedance transformer is used, a good return loss can be obtained. Moreover, the PMC is an ideal surface and does not occur in the environment. However, when the ground plane is replaced by an EBG surface, the reflection phase varies from −180° to +180° and results in constructive interference of image current and radiation from the printed antenna [83–85]. The best return loss of −30 dB is obtained by the printed antenna over the EBG ground plane. From the above discussion, it is observed that the EBG ground plane has the desired features to design low-profile antennas. In [86], a dual-band, low-profile antenna with mushroom-like structures loaded with circular slots was described and is shown in Figure 11.24a. From Figure 24b, we can observe that the first resonating frequency shifts toward the right in case of EBG-CS that leads to compact size at low frequency. By using an EBG-CS superstrate, a low-profile antenna was achieved. In another study, a printed slot antenna placed above an AMC plane was used to obtain a low-profile, wideband antenna [87]. The radiating slots are shown in Figure 11.25a, with three unequal arms that are etched for widening the impedance bandwidth.

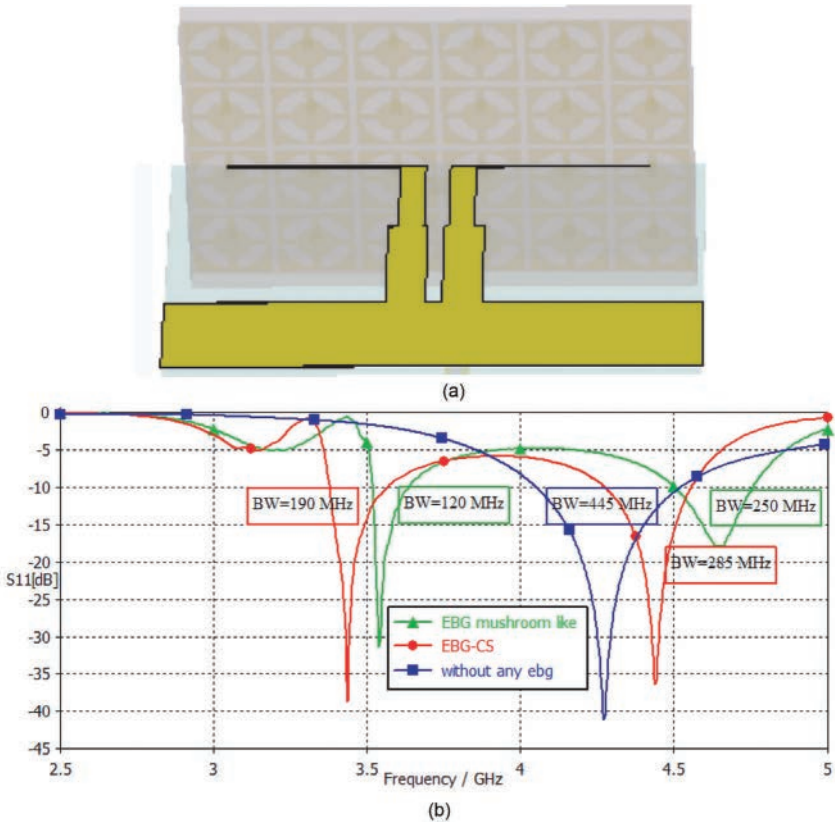

FIGURE 11.24 (a) Dual-band antenna with mushroom-like structures loaded with circular slots; (b) return loss of three different cases [86].

By placing an AMC [88,89] array as the ground plane, the radiation pattern was improved. Using an AMC with a printed antenna resulted in 62.82% compactness in size, a bandwidth improvement of 41%, and a perfect impedance matching. In [90–92] EBG structures that can generate adjustable bandgaps. The EBG structures can be placed as AMC in modern electronic products and potentially cover multiple frequency bands of wireless communications. Similarly, in [93], an AMC array was placed as a ground plane underneath a dual-wideband circularly polarized [80,94] antenna to achieve a low-profile antenna.

Two barbed-shape and bow tie dipoles printed on FR4 substrates are presented in Figure 11.26. To obtain an antenna with a higher broadside gain and a low profile, the ground plane was replaced by a square-shaped cavity plane. Finally, the cavity was modified to a pyramid-shaped cavity and it was found out that the inclination angle should be around 45° to further improve the gain, particularly in the high-frequency band. Figure 11.27a–c illustrates the high-gain reconfigurable antenna and a comparison of three different ground planes.

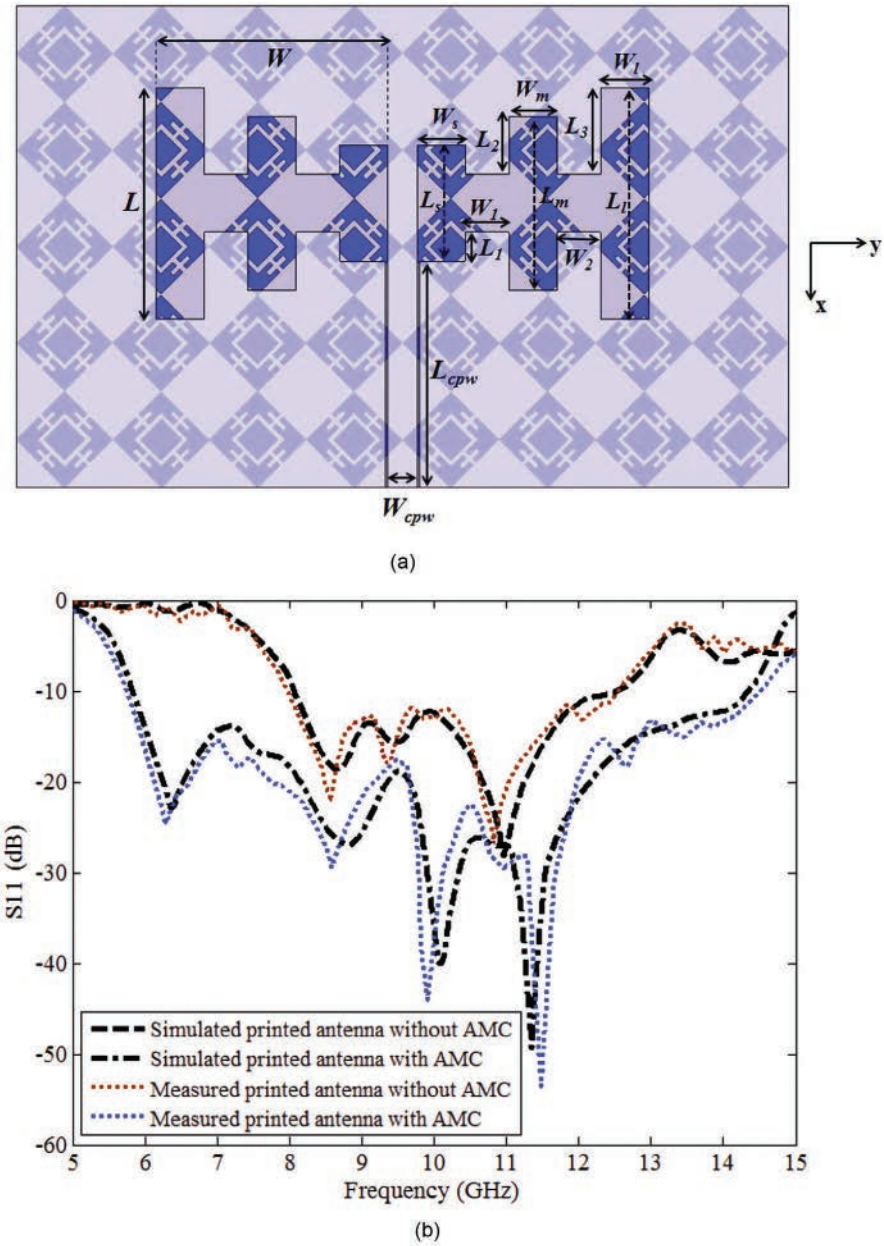

FIGURE 11.25 (a) Slot antenna with an AMC array; (b) return loss of slot antenna with an AMC array [110].

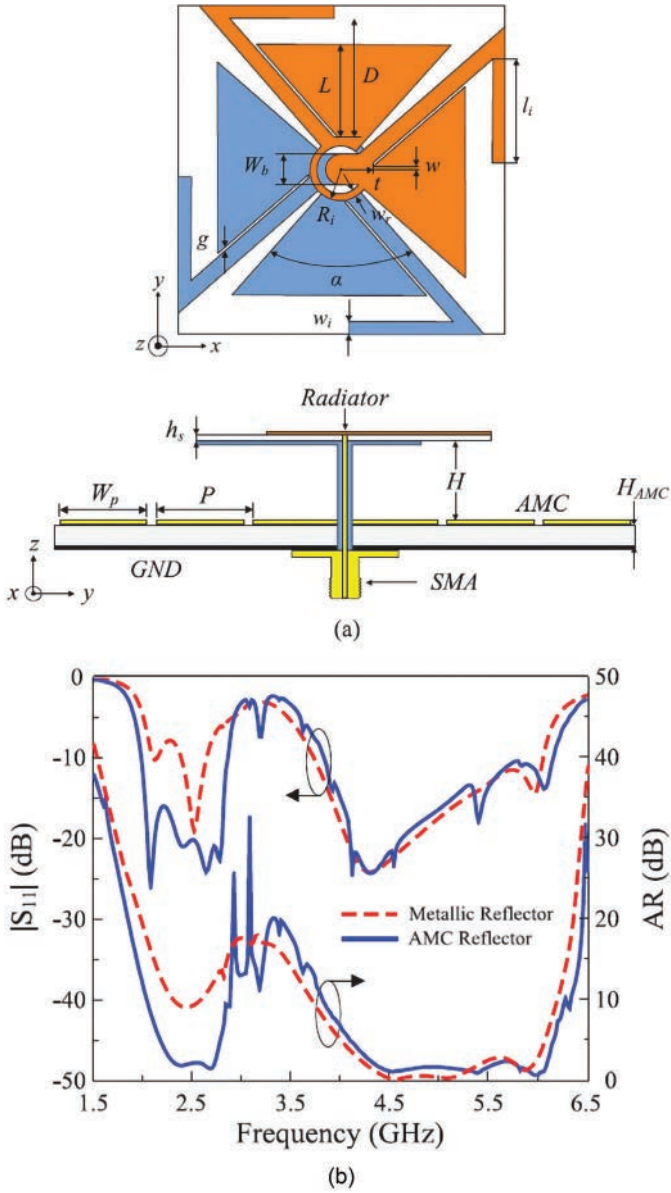

FIGURE 11.26 (a) Dual-wideband circularly polarized antenna; (b) return loss of dual-wideband circularly polarized antenna with an AMC and metallic reflector [93].

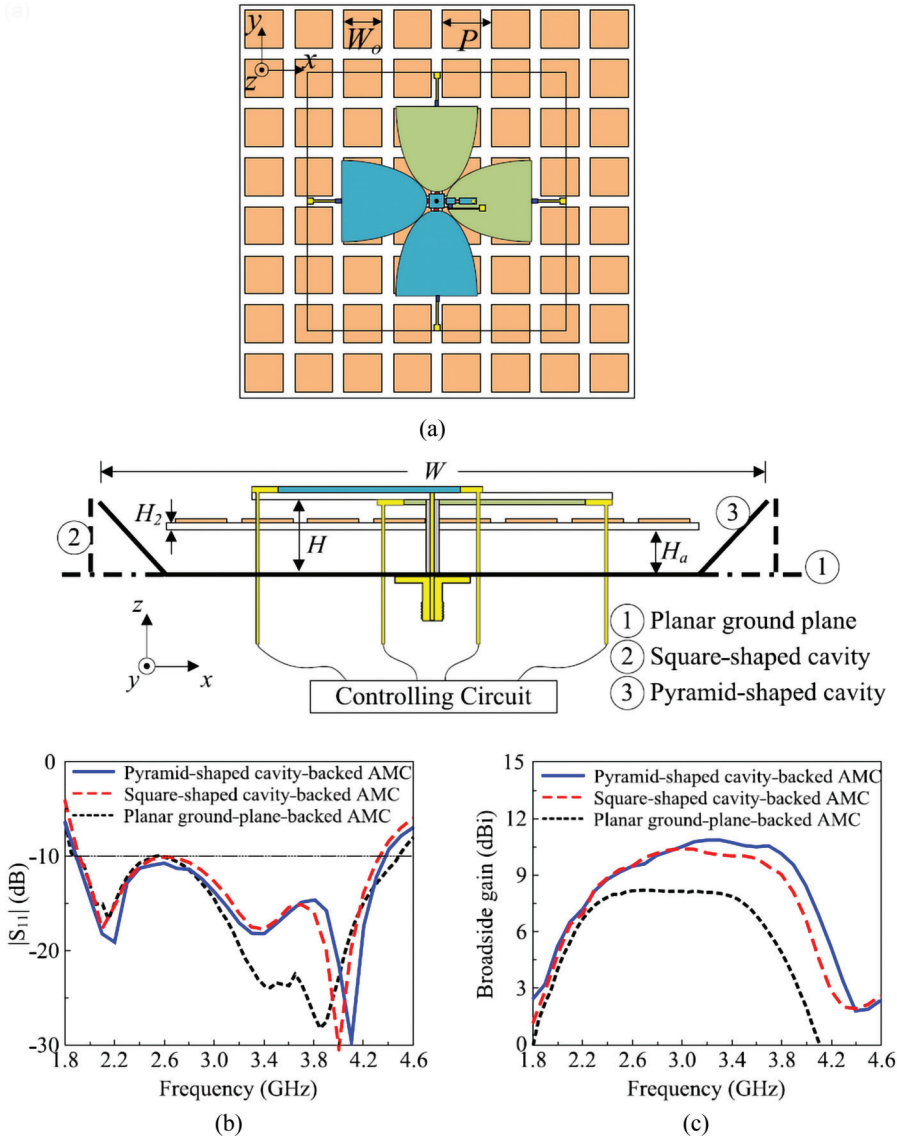

FIGURE 11.27 (a) High-gain reconfigurable antenna; (b) return loss; (c) broadside gain [96].

11.4 REAL-LIFE APPLICATIONS OF EBG PATCH ANTENNAS

11.4.1 High-Precision GPS

High-precision positioning can be achieved by combining global navigation satellite systems (GNSS) such as GPS and Galileo [97–99]. By using this system, surveyors can make measurements with sub-centimeter accuracy. In order to acquire such accurateness, some precautions are required to shield the antenna from false signals. The conventional approaches such as choke rings provide a good performance [100]. But, choke rings are generally very huge and expensive. Nowadays, EBG structures are used while maintaining good antenna performance.

A Galileo antenna on an EBG substrate is illustrated in Figure 11.28a. To achieve best gain for GPS applications, the dimension of the EBG structures is optimized. It is observed that with the combination of EBG substrate and patch antenna, an axial ratio of 2 dB is achieved. The axial ratio value for choke rings is 1 dB, which implies that the EBG patch has a better performance. Similarly, the patch and Koch fractal EBG structure [98] are shown Figure 11.28b. The tested results show the significant improvement in axial ratio bandwidth, which fits the requirement of GPS applications (Figure 11.29).

11.4.2 Wearable Electronics

Wearable electronic systems are technology that finds applications in many fields that include military, telemedicine, sports, and tracking. In [101], the jean fabric was used as a substrate having a dielectric constant of 1.7 with a thickness of 1 mm. As shown in Figure 11.29, the design consisted of a fractal monopole patch antenna with an EBG surface. This fractal antenna resonates at 1,800 MHz and 2.45 GHz for GSM and ISM applications, respectively. The antenna is placed over a 3×3 EBG array of size 150×150 mm^2. Figure 11.27 illustrates the fractal-based monopole patch antenna with an EBG surface. Another researcher used a Pellon fabric substrate [102] with a dielectric constant of 1. The designed antenna consisted of a coplanar waveguide (CPW)-fed monopole antenna with an AMC array of 4×6 units, with the overall size of 102×68 mm^2.

TABLE 11.6
Low-Profile Patch Antennas by Using Different EBG Structures

S. No.	Type of EBG Structure	Dimension (cm^3)	Height (mm)	Resonating Frequency Band	Reference
1.	EBG-CS	1.65	3	Two bands (3.5 and 4.5)	[86]
2.	Miniaturized EBG structure	4.2	0.7	One band (2.4)	[88]
3.	Square Sierpinski fractal EBG structure	10.24	1.6	Three narrow bands at 2.4, 3.5, and 4.6 GHz	[87]
4.	Uniplanar EBG structure	46.4	8	One band (1.25–29)	[95]
5.	Modified EBG structure	94.8	7.9	Two bands (2–3 and 3.8–6.3)	[93]

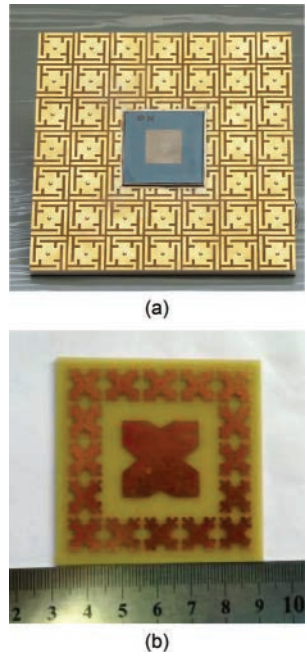

FIGURE 11.28 (a) Galileo antenna on an EBG ground plane [100]; (b) circularly polarized patch antenna with fractal HIS [102].

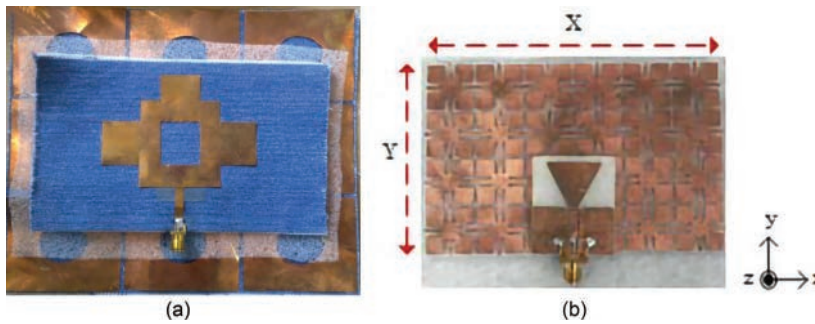

FIGURE 11.29 (a) Dual-band wearable fractal-based monopole patch antenna [101]; (b) the fabricated monopole antenna with an artificial magnetic conductor as a ground plane [102].

11.4.3 Radio Frequency Identification (RFID) Systems

RFID systems have been used since World War II, and the demand for RFID systems is rapidly growing in both business and daily life. Currently, the RFID system is used in many applications such as hospitals and healthcare, passports, stores, and people identification. One of the biggest challenges associated with RFID systems is the long-range operation capability [103–106]. In [107], a CPW-fed bow tie antenna was mounted over an AMC. The AMCs reduce the backward radiation that results in

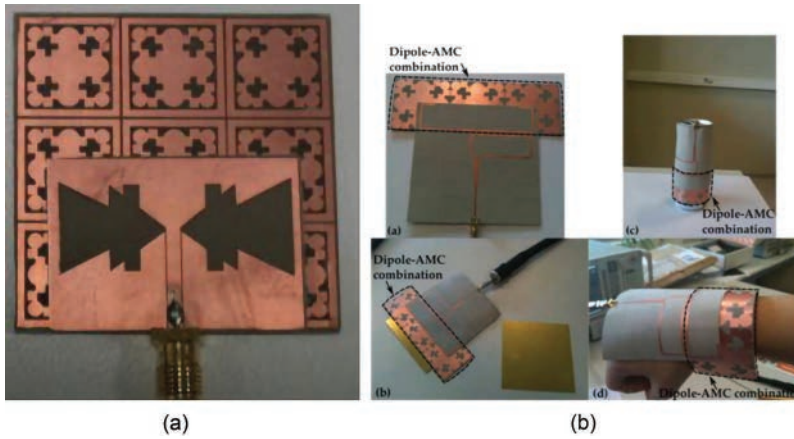

FIGURE 11.30 (a) CPW-fed bow tie antenna mounted over an AMC [107]; (b) dipole AMC [108].

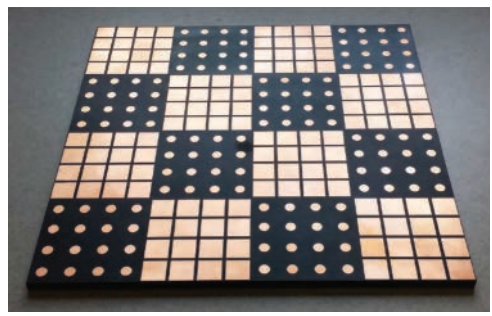

FIGURE 11.31 EBG checkerboard ground plane [109].

improved gain and directivity of the overall system. The antenna was fabricated using an ARLON 25 N substrate with a thickness of 0.7 mm and a relative permittivity of 3.3. Figure 11.30a illustrates the bow tie antenna over an AMC. This structure helps in the enhancement of gain by 2.53 and 1.86 dB at 5.8 and 6.4 GHz, respectively. In [108], a dipole antenna over an AMC was designed to improve the overall performance. From the tested results, it was observed that the dipole with a balun AMC achieved an improvement of 2.9 dBi as compared to the dipole without balun AMC.

11.4.4 Radar Systems

To reduce the radar cross section, the reflection phase property of the EBG structures is used to change the direction of the fields that are scattered by a radar target. This change in direction of the scattered fields is achieved by using checkerboard EBG structures and results in a wider frequency band RCS reduction. Figure 11.31 shows the checkerboard EBG surface which is a combination of two EBG structures.

11.5 CONCLUSION

The EBG structures have greatly attracted researchers because of their unique and desirable properties. This chapter stated how the integration of EBG structures and patch antennas improves the overall performance of the antenna systems. The recent advancements of patch antenna design using EBG structures were included. Different EBG approaches to improve gain and bandwidth were discussed. The band gap property of EBG structures has been found useful to eliminate the surface wave propagation to reduce the mutual coupling and to achieve band-notch characteristics. Real-life applications of EBG structures, such as RFID, wearable electronics, and radar systems, were also included. A number of recent publications proved that the EBG technology eliminates the drawbacks of patch antenna and is most preferable for the modern-day wireless communication systems.

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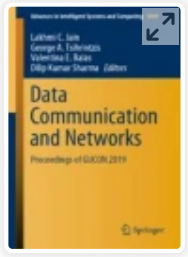

Data Communication and Networks pp 1–11

An ECC with Probable Secure and Efficient Approach on Noncommutative Cryptography

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Abstract

An Elliptic Curve Cryptography (ECC) is used on the Noncommutative Cryptographic (NCC) principles. The security and strengths of the manuscript are resilient on these two cryptographic assumptions. The claims on the Noncommutative cryptographic scheme on monomials generated elements is considered be based on hidden subgroup or subfield problems that strengthen this manuscript, where original assumptions are hidden and its

equivalents semiring takes part in the computation process. In relation to the same, the research gap is well designed on Dihedral orders of 6 and 8, but our contributions are in security- and length-based attacks enhancement over Dihedral order 12, reported in work done. We modeled the said strategies and represent the ideal security concerns for applications.

Keywords

ECC **Noncommutative cryptography**

Monomials generations **Length based attacks**

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An ECC with Probable Secure and Efficient Approach on Noncommutative Cryptography



Gautam Kumar and Hemraj Saini

Abstract An Elliptic Curve Cryptography (ECC) is used on the Noncommutative Cryptographic (NCC) principles. The security and strengths of the manuscript are resilient on these two cryptographic assumptions. The claims on the Noncommutative cryptographic scheme on monomials generated elements is considered be based on hidden subgroup or subfield problems that strengthen this manuscript, where original assumptions are hidden and its equivalents semiring takes part in the computation process. In relation to the same, the research gap is well designed on Dihedral orders of 6 and 8, but our contributions are in security- and length-based attacks enhancement over Dihedral order 12, reported in work done. We modeled the said strategies and represent the ideal security concerns for applications.

Keywords ECC · Noncommutative cryptography · Monomials generations · Length based attacks

1 Introduction

In cryptography, the security algorithm and its measures are playing important role responsiveness, which has been considered as an integral part of computer science. Cryptography is a combined discipline of mathematics, computer science, electrical engineering, and physics. It is one of the foundations that give guaranteed secure communication in the presence of adversaries. Where, the strength and powerful computing techniques are most useful to avoid the threats and supports challenges. A lot of applications are available in the realistic sense for showing the essential requirements that contain to avoid adversaries to occur, the assurance of legitimacy,

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protection of information from confession, protected message communication systems involved in transmission(s), and storage of information(s). The cryptographic algorithms are shown appropriateness in the full-fledged measurements with the proposed and/or available resources. But instead of the same, from a research point of view, the motivational issues on the algorithms with more impulsiveness and arbitrariness fondness are a guide for future research with an assortment on comparatively more and strong responses. In essence of cryptography, these are termed as private-key and public-key authentication and key exchange.

An immense revolution came through the use of Public-Key Cryptography (PKC), proposed by Diffie and Hellman [1]. The PKC's techniques introduced further in various forms, where on a variety of special features in Elliptic Curve Cryptography (ECC) [2, 3] is attracted the most attention in the area of cryptography. It is well available in the literature to show with marginal enhancement on the lower communication as well as computation costs. ECC provides better security and performance than RSA/DSA algorithms for equivalent security strengths on shorter key sizes [we followed National Institute of Standard and Technology (NIST) guidelines released in 2012]. Today, ECC is considered being tenable above the key length of 224 bits up to the year 2031, corresponding to the same 256 bits key lengths unsusceptible beyond 2031 and above key lengths are not defined but is secure, (Table 1). This table is indicating the RSA algorithm using 2048 and 3072 keyed sized bits for the same security strength for 224-255 and 256-383 varied lengths keyed and its an obvious relative performance advancements indicators.

From research points of view, all PKC's approaches are generalized on commutative-based principles, but some of the researchers were looking into the fact to generalize the cryptographic approach on noncommutative basis, and the given name for the same is noncommutative cryptography or non-Abelion cryptography. It is one of the approaches based on noncommutative nature, where it is mathematically based on random arithmetic operation star (*) (holds on rotation and/or reflection) on any of the noncommutative group G of $(G, *)$, where group G may be any Group elements, Ring elements, Semiring elements, or some algebraic structural elements or its combinations. According to its noncommutative naturalness properties for two elements or combinations of [if considered order be appropriate] a and b operations of G are not resembles the same results, such as $a * b \neq b * a$. It can be achieved on the combined principles from physics and mathematics that are producing the noncommutative natural generalization.

Table 1 Equivalent security for RSA versus ECC

RSA	ECC	Protection from attack
1024	160–223	Until 2010
2048	224–255	Until 2031
3072	256–383	Beyond 2031
7680	384–511	–
15360	512+	–

1.1 Related Work and Associated Issues

Noncommutative cryptographic approach keeps a solid backbone security enrichments and better performances than the existing approaches. Using noncommutative cryptography implementations in a number of applications are based on PKC's approaches such as on RSA/DSA, Diffie–Hellman, and ECC algorithms. For the cryptographic purposes, these are working efficiently in session-key establishment, en/decryption and/or in authentication systems on noncommutative too. The discrete logarithmic is acting as an intermediary strength near to non-negligible solutions. On behalf of the open opinion on security experts, a brief observation is presented here.

For solving a discrete logarithm problem (DLP) and integer factorization problem (IFP), Shor in 1994 [4] is given a competent algorithm on the quantum basis, so likely a representation of possible security breach on commutative-based cryptography. Further, Kitaev [5] considered the same as a special case on its DLP, and analyzed on its significance, called hidden subfield or subgroup problem (HSP). The general ideas from Paeng et al. [6], Joux and Nguyen [7], and Cocks [8] are one of the important steps in making the finite Abelian group's decision separations on cryptographic groups and its equivalents on quadratic residues. Magliveras et al. [9] designed PKC's using one-way functions and trapdoors infinite groups, therefore in 2002, Stinson observed sensibly on most of the PKCs that only belong on Abelian or commutative approach, whose forthcoming future intention may be susceptible in the arena. On behalf of same, Goldreich and Lee suggested don't put all the cryptographic generalizations in single "commutative group" only. Therefore, the reason was a clear indication to look at alternative cryptography for specific purposes; this was the opening of noncommutative cryptography. Noncommutative cryptography is a generalization of a commutative approach in such a way that it doesn't follow the commutative case properties, but those are analogous to be the commutative cases. Afterward, there are session-key establishment, en/decryption, and authentication schemes on noncommutative are generalized on a variety of schemes [10, 11]. HSP over elliptic curve cryptography-DLP (ECC-DLP) is comprehensively resolved by Proos and Zalka [12]. Lee [13] in 2004 organized quantum algorithms well on the random HSP for Noncommutative group elements and it was reporting well, with respect to braid group based attacks [14]. Further, Rotteler [15] suggested to use HSP over noncommutative with proven evidence are much harder and better in the adversaries presence. Cao et al. [16] used polynomials functions to build cryptographic scheme over noncommutative semirings or ring elements. Further, the protocol application was based on non-Abelian given by Kubo [17] on Dihedral order 6, which has been considered the initial order for this group and its construction is based on revolutions of three-dimensional approaches. Reddy et al. [18] build signature schemes over modular method on noncommutative groups and semirings. Moldovyan and Moldovyan [19] constructed the cryptographic implementations on four dimensions; the major intention was to generalize the security enhancement. Myasnikov and Ushakov [20] have the crypt analyzed on encrypted texts and the authentication schemes on the

hardness tests of the Conjugacy search problem on monoids elements. An algorithm is devised to solve the same problems and got anxious on the strategies. Svozil [21] recognized the metaphorical structures with hidden variable indecisiveness on non-contextual elements that can't be figured out on cryptanalysis, and it doesn't any assembled proofs. Kumar and Saini [22] have shown the cryptographic applications on extra special group (ESG) that provides more robustness and unpredictable behavior as compared to all the known schemes using Noncommutative Cryptography on the extra special group (ESG) and applied the same in cryptographic schemes generations. Where the center of ESG is cyclic and its quotient belongs to nontrivial, i.e., the resultants are not equal to zero or identity to its group elements. Transitions from group elements to its equivalent semiring elements finish finitely on monomials (the proposed assumptions for a group and semiring elements are unique and irreversible on the proposed group) and contain all the algorithmic properties. It is designed the authentication and integrity schemes on Mono-morphism for a group and semiring elements on Dihedral Order 8 of ESG. Also, ESG defaults contain the authentication and integrity schemes on Heisenberg and Quaternion groups and finally it is illustrated on the exponential growth on Length Based Attacks and predicted almost to be unpredictable.

1.2 Motivation and Our Contribution

The issue related to security enhancement is one of the most motivational concerns, where monomials with semiring structures and Dihedral orders are presented on potential advantages to keep away the assumptions from various attacks. The monomials structured foundation is, in general, uses the equivalent semiring elements consideration takes part in the computation process, whereas main group parameters work in hidden, and it is based on polynomial modular reductions.

Our contribution highlights the monomials generations on the three dihedral orders of 6, 8, and 12. The Dihedral 6 is already presented so we didn't take into considerations, and Dihedral order 8 monomials generations for key-exchange, encryption–decryption, and authentication schemes presented in [22]. The virtual consideration for Dihedral order 12 is considered in the manuscript. In last, we have presented a scenario for length based attacks in order to investigate into Monomials Cryptographic generation approach.

1.3 Manuscript Organization

The manuscript is organized into subsequent sections, in the next section, it is presented with cryptographic assumptions on modular polynomials and further its hypothesis is presented on group and ring elements, in brief. In Sect. 3, preliminary knowledge of dihedral order 6 and 8 are presented from mathematical points of view

in justification of proposed strategies, which releases the significant contribution our proposed cryptography. In Sect. 4, a length-based attacks scenario is presented on input sequence generation and further presents scenario on attacks by the adversaries in reverse to find the original key. This represents security strength guarantees on enlarged search species.

2 Preliminaries

2.1 Noncommutative Assumptions on $\mathbb{Z}$ Modular Strategies

A PKCs over the Noncommutative cryptography on polynomials with the semiring R elements is proposed by Cao et al. [16], and this scheme is generalized with the name of $\mathbb{Z}$-modular approach. The notation for a $\mathbb{Z}$-modular structure on ring r is $\mathbb{Z}(r)$, and its structural applications available on $\mathbb{Z}^{+}[r]$ for positive elements on noncommutative R and it is as well as applicable on negative $\mathbb{Z}^{-}[r]$, where $r \in R$ is not certain on general and monomials, where group and semiring are comprehensively applicable on $\mathbb{Z}$-modular.

2.2 The Basis of Noncommutative Cryptographic Algorithm

The concerns on security strengths are based on the following two assumptions:

(i) **Conjugacy Decisional Problem (CDP)**: The definition of CDP says on given two group elements a and b of group *G*, using the random secret chosen x to generate the other group elements that satisfies for $b = a^{x}$ or to generate the Conjugacy multiplicative inverse of: $b = x^{-1}ax$. It works in the forward direction.

(ii) **Conjugacy Search Problem (CSP)**: For a group G of elements a and b, that try to finds a secret *x* if there exists x in G such that $b = a^{x}$ or $b = x^{-1}ax$. It is a reverse process to determine the random secret key as *x*.

CSP is considered to be a one-way hash function generation, i.e., the designed algorithm(s) are not able to determine the other group elements values such as $a \rightarrow b^{x}$. In modern cryptography on Noncommutative, generalized assumption is completed enough to frustrate the cryptographers. Also, CSP is well known for its unrealistic nature to solve the same probably on polynomial time.

2.3 Monomials Used in $\mathbb{Z}$ Modular Method

The $\mathbb{Z}$-Modular method is constrained to be monomials on the chosen polynomials on secrets parameters, i.e., original information of group elements are hidden with its equivalents ring/semiring elements on polynomials functions. Such participation Conjugacy assumptions are viewed as a special case. Conjugacy Search Problem is proposed under these considerations.

3 The Preamble to Dihedral Orders

3.1 Dihedral Orders 6

The dihedral is a virtual concept works on a finite set of group elements. After defined operations on it, the group elements show some specific variations that make the unique nature for cryptographic uses. The first initiated step for the noncommutative or non-Abelian group is dihedral order 6, denoted by D_3, given by Uno and Kano in [23]. In which, three colored blocks such as Red, Green, and Blue is considered as an assumption, where three actions applies as "a: swap the first block and second block from left to right, b: swap the second and third block from left to right, e: leave the block as they are, and if two actions then do the operation from right to left as specified". The set of operations works is as follows:

e: RGB $\rightarrow$ RGB or (), a: RGB $\rightarrow$ GRB, b: RGB $\rightarrow$ RBG, ab: RGB $\rightarrow$ BRG, ba: RGB $\rightarrow$ GBR, aba: RGB $\rightarrow$ BGR

Here, the block operations are represented in the form of mathematics, with considerations on R = 1; G = 2; B = 3 and arranged the same in various group elements. Further, equivalent ring elements are assigned to group elements. It shows the center of group element results on a cyclic rotation having its quotient belongs to nontrivial elements, where variables or terms that don't result on the identity or zero elements.

$$\begin{pmatrix}1&2&3\\1&2&3\end{pmatrix}\rightarrow\begin{pmatrix}1&0\\0&1\end{pmatrix},\quad\begin{pmatrix}1&2&3\\2&1&3\end{pmatrix}\rightarrow\begin{pmatrix}0&1\\1&0\end{pmatrix},\quad\begin{pmatrix}1&2&3\\1&3&2\end{pmatrix}\rightarrow\begin{pmatrix}1&1\\1&1\end{pmatrix},$$
$$\begin{pmatrix}1&2&3\\2&3&1\end{pmatrix}\rightarrow\begin{pmatrix}0&1\\1&1\end{pmatrix},\quad\begin{pmatrix}1&2&3\\3&1&2\end{pmatrix}\rightarrow\begin{pmatrix}1&1\\1&0\end{pmatrix},\quad\begin{pmatrix}1&2&3\\3&2&1\end{pmatrix}\rightarrow\begin{pmatrix}1&0\\1&1\end{pmatrix}$$

The cryptographic schemes such as key-agreement, encryption–decryption, and its authentication have presented on general and monomials generations in [24], and interested authors can go in detail with this reference.

3.2 Dihedral Order 8

The initial order for Dihedral order 8, denoted by D_4 is available in [25] and the use of this order for the cryptographic purpose is presented in [22]. These consist of the operations on the cyclic subgroup generation by rotations and reflections. For virtualization point of view Dihedral order 8 represented with an on a square of glass with the alphabetic letter "F". In the same, some defined operations have been considered, such as *e* acts as an initial assumption likely be an identity element, *a* is used for a rotation by 90° and *b* is used for reflection. To make use of cryptographic aspects, square movement makes a difference on 0°, 90°, 180°, 270° [clockwise rotations], are taken into its considerations and reflections on the other hand, as shown in Fig. 1.

This virtual concept we apply for numeric consideration for the use of cryptographic purposes. Another way to represent the dihedral order 8 concepts is still possible. The schematic representation is based on the square glass on three operations e, a, b and its corresponding mixed operations, represented in Fig. 2.

Finally, consider these group elements in a group from G_1 to G_8, like e, a, a^2, a^3, b, ba, ba^2, ba^3, which have been used in cryptography for its specific uses such as session-key generation, en/decryption as part of its resultant. A similar idea for the same has assumed for Dihedral 12 on group elements from G_1 to G_{12}, detailed decryption is not available here, but we have considered. Interested authors may refer from Kumar and Saini [22].

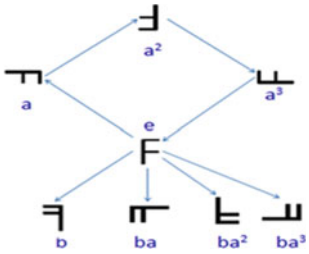

Fig. 1 Symmetries of Dihedral order-8

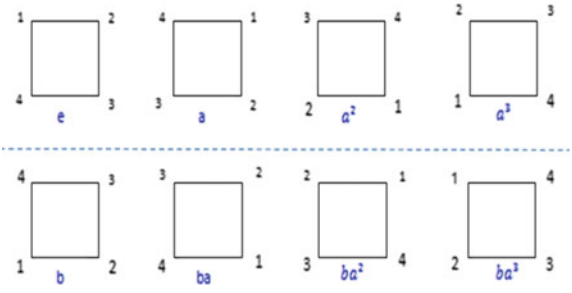

Fig. 2 Schematic representation on Dihedral 8

4 The Investigation into Length Based Attacks and Its Proposal

Length based attacks (LBA) is an approach to determine the user secret key; it works on word lengths, it is related to LBA, in Ruinskiy et al. [26], and in Myasnikov and Ushakov [27]. It is presented on Dihedral order 6 [24]. In these regards, it is one of the reverse procedures that try to recover the factors of conjugates. A good approach results in finding its Conjugator in the form of its group elements generation. The procedure is generating the Conjugators as follows for the Dihedral order of 6, 8, and 12, Fig. 3. On the input sequence and Dihedral order 6, there are 6 group elements and on the successful completion of this task a total of 36 elements to satisfy for the same. Similarly, for Dihedral 8, there are 8 group elements and a total of 64 elements. Finally, for the Dihedral 12 (hexagon element), there are 12 group elements and a total of 144 elements to satisfy for the same.

Our proposed approach is based on complexity enhancement for cryptographers (or complication) on Dihedral order of 6, 8, and 12. The group elements are $S_G = \left\{g_1^{\pm 1}, g_2^{\pm 1}, g_3^{\pm 1}\right\}$ for order 6, $S_G = \left\{g_1^{\pm 1}, g_2^{\pm 1}, g_3^{\pm 1}, g_4^{\pm 1}\right\}$ for order 8 and $S_G = \left\{g_1^{\pm 1}, g_2^{\pm 1}, g_3^{\pm 1}, g_4^{\pm 1}, g_5^{\pm 1}, g_6^{\pm 1}\right\}$ for order 12. The generation of input sequence on input $y = g_1 g_2^{-1} g_3 g_4^{-1}$, for length $n = 4$ for all the three orders as follows. On the assumption of any sequence of chosen input(s), perform operations on likely be on the 2k-ary tree. Where it does starts with an initial assumption word *e*, and generation of any further word/group elements depends on successful proceeding is one of the probable of its child generalized nodes. The successful accomplishment is based on chosen input y_n to length $y = y_1 y_2 \ldots . y_n$ traces likely as presented in Fig. 3. The nth-level contains elements on $(2k)^n$ leaf nodes. The leaf node of each one group is a potential element in any of y. The proposed work is difficult in finding its traces back on its cryptanalysis and/or decomposition of an encrypted message. The supporting group provides an unpredictable and robustness behavior on center and resultants in midair is/are rotates cyclic. Further, the assumptions are unique, irreversible and appropriate in sustaining to algorithmic properties. Therefore, for the proposed orders, it is assumed secure in reference to brute-force search.

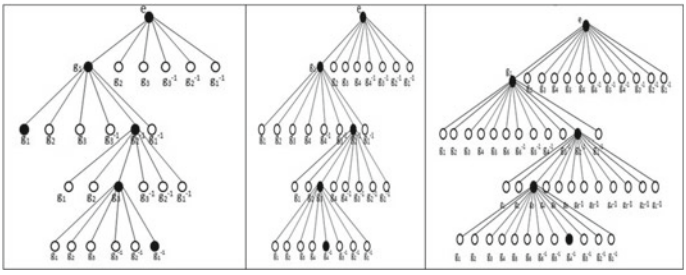

Fig. 3 The process of generating $y = g_1 g_2^{-1} g_3 g_4^{-1}$ on Dihedral 6, 8 and 12

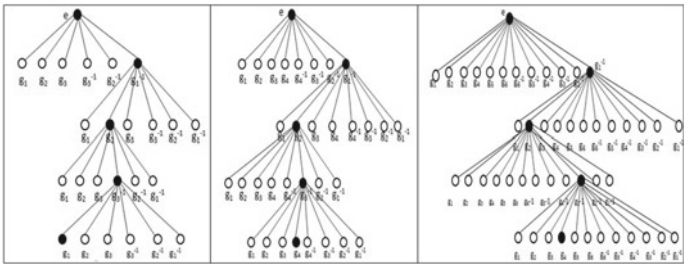

Fig. 4 Decomposition of length $y = g_1 g_2^{-1} g_3 g_4^{-1}$ on Dihedral 6, 8 and 12

Especially, when an attacker(s) tries to determine with equal child nodes, such as *P* and *Q* in same length, then the procedure have been created in such a fashion to fall for the same with insignificant solution. The general observation for Dihedral order 6, six candidates group elements forms at each level, so the time complexity work in the form to attack on the proposed strategy is $O(6^{2n})$ for all n word length, on the success or failure attempts. Next on average, 8 candidates (in Dihedral order 8) elements in each level for one group element, so the time complexity of this strategy is $O(8^{2n})$ for all n word length, on the success or failure attempts. Finally on average, 12 candidates (in Dihedral order 12, denoted by D_6) elements in each level for each group element, the time complexity of the attack algorithm is $O(12^{2n})$ for n length words, either on failure or success proceedings. The attack procedure is considered to be reversed searching the instance on the 2k-ary tree. In reference to shown Fig. 4, the decomposition on any lengths, the dark nodes are considered to be target nodes that forms paths, where this technique is suitable to find the path if it successful works. Therefore, we are able to enhance the robustness properties on its orders and accelerate the unpredictable behavior for cryptographic purposes. Its practical feasibility of the proposed idea is keeping a lot of benefits in noncommutative matrix operations on a finite group. Theoretically, the proposed approach is working; therefore interested authors and/or security agencies may apply this principle in various cryptographic applications, such as mobile techniques, online services, cloud in security, Internet of Things (IOT).

5 Conclusion and Future Scope

Due to tremendous demands on secured tools and techniques for various applications, our considered approach is one of the prime research concerns. The manuscript claims the Noncommutative cryptographic scheme on monomials generated elements. The monomials working principles are acting on Dihedral order of 6, 8, and 12. In regards to security and performance, these are reporting an immense contribution in the field of cryptography and making the proposal stronger based on the hidden subgroup

or subfields problem. For the adversary, the attacks like length based, cryptanalysis, and brute-force are likely being negligible to find.

As the proposed approach itself is a representation of polynomial functions that doesn't reveal secrets and/or finding polynomial for attacker is hard to find. The deployment considerations for applications are on high demand, designing for accelerating the algorithms, also in the area of security, is in tremendous demands.

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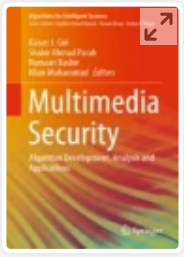

Multimedia Security pp 239–253

An Efficient Approach for Phishing Detection using Machine Learning

Ekta Gandotra & Deepak Gupta

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Abstract

The increasing number of phishing attacks is one of the major concerns of security researchers today. The traditional tools for identifying phishing websites use signature-based approaches which are not able to detect newly created phishing webpages. Thus, researchers are coming up with machine learning-based methods which are capable to detect and classify the phishing webpages with high accuracy if a large and variety of features are considered. However, building a

classification model using a large number of features takes time which hampers the timely detection of phishing websites. Therefore, it is pertinent to shortlist a set of features using a feature selection method so that high-performance classification models can be developed in less time. In this chapter, we study the role of feature selection methods in detecting phishing webpages efficiently and effectively. A comparative analysis of machine learning algorithms is carried out on the basis of their performance without and with feature selection. Experiments are conducted on a phishing dataset with 30 features containing 4898 phishing and 6157 benign webpages. Several machine learning algorithms are used for obtaining the best results. Afterward, a feature selection method is employed to improve the efficiency of the models. The best accuracy is obtained by random forest both before and after feature selection with a significant improvement in model building time. The experiments demonstrate that employing a feature selection method along with machine learning algorithms can improve the build time of classification models for phishing detection without compromising their accuracy.

Keywords

Phishing detection **Machine learning**

Feature selection **Information gain**

Random forest **Support vector machine**

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Chapter 11
An Efficient Approach for Phishing Detection using Machine Learning



Ekta Gandotra and Deepak Gupta

1 Introduction

Due to the availability of Internet at low price, people are shifting to online platforms instead of visiting banks, shops, etc. Attackers are taking advantage of this fact and trying to find their victims online to make money instead of taking risks to rob banks/shops, etc. They are making use of various attacks like phishing to steal the passwords, credit card details, etc., by misleading users to visit malicious and fake websites.

Phishing attack is one of the top security threats on the Internet today. Attackers tend to gather victims' confidential information using fake websites. According to Anti-Phishing Working Group [1], the trend of phishing attacks is increasing every year and 138,328 phishing pages were informed in 2018, 4th quarter. It causes a lot of financial losses. On the basis of the cases informed to Federal of Investigation [2], there occurred a loss of around $48 million in USA in the year 2018. In addition, phishing attacks are also becoming the top delivery method of malware [3–5]. A recent report of Microsoft security intelligence [6] reported that in 2018, phishing attack was the top web attack.

In year 2013, South Korea faced a phishing attack, in which 3 banks and 3 media companies were compromised [7]. This attack involved stealing passwords and was spread to more than 32,000 machines. In December 2014 [8], the cyber attackers were able to get the data of 80 million customers of Anthem Healthcare. The recent

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worldwide lockdown due to novel coronavirus (COVID-19) epidemic has forced many employees to work from home where they do not have cybersecurity resources as they usually have in their offices. Moreover, due to the infectious nature of the virus, there is anxiety among the people over any online information related to coronavirus. The attackers are exploiting these facts to perform phishing attacks through emails or fake websites with the aim of making money. Threat Analysis Group [9] of Google has identified attacker groups who are using subject as COVID-19 to attempt malware and phishing attacks.

There exist various tools [10–12] which attackers use to duplicate a website in order to create a phishing website. Sometimes, the websites designed in such a way are identified by anti-phishing tools because of the website's elements such as copyright, anchor link, logo or keywords of the genuine websites. There are various approaches for detection of phishing websites which are having their own pros and cons. Signature-based method is the most popular method used for detecting phishing webpages. This method maintains a database of blacklisted websites which consists of a list of phishing webpages. Any newly requested webpage is checked against this database to identify whether it is phished. Two of the important blacklisted databases are PhishTank [13] and Google Safe Browsing (GSB) [14]. This approach fails to identify the newly generated phishing websites which have not been added to the database. In case of heuristic approach, the webpage is analyzed to come up with discriminating features like process creation, page redirection, etc. [15]. However, this approach is resource-intensive. Another approach used to detect phishing websites is visual-based approach [16] in which a database of images, logos, text formatting, HTML tags, etc., is created. But this method is highly time-consuming.

Recently, researchers have started to employ machine learning and computational [17] based methods for identifying phishing websites. In this method, different types of features pertaining to phished and benign websites are extracted, and subsequently, these are used for training purpose to build the classification models. The efficiency and performance of such methods depend on the classification algorithms, number of training examples, and the feature set. Keeping the classification models and the number of training examples apart, considering a large and variety of features helps in enhancing the performance of classification models. However, it takes more time for model building which hampers the timely detection of phishing websites. Therefore, an appropriate set of features should be selected to build the classification models in less time without compromising the accuracy. Keeping this point in mind, this chapter aims to present a study on the role of feature selection methods in detecting phishing webpages. Consequently, a comparative analysis is performed on the performance of machine learning algorithms without and with feature selection.

To carry out the study, this chapter is structured as follows. Section 2 presents the recent research work in classifying the phishing webpages using machine learning techniques. Section 3 explains the methodology used in carrying out this study. Section 4 analyzes and discusses the experimental results. Section 5 provides conclusion and future scope.

2 Related Work

This section presents the recent research work pertaining to classification of phishing websites using machine learning algorithms.

Tan et al. [18] presented a method named PhishWHO for the detection of phishing websites in three stages. In first stage, the keywords are extracted from the websites (using N-gram method). In second stage, these keywords are used in a search engine to find the name of target domain. Finally, in the last stage, they used a matching system for detecting the legality of the website.

An image-based approach was proposed by Chiew et al. [19] for the detection of malicious websites. They extracted the logo and fed it into Google image search engine to check the identity of the website. They compared the webpage query with the domain name returned by Google for distinguishing a phishing webpage from the benign one. Experiments were conducted to prove the usefulness of the proposed method.

In [20], the authors analyzed various features of phishing webpages and shortlisted the most important 19 features. After extracting these 19 features from the source code of webpage, they used support vector machine (SVM), random forest (RF), neural network, logistic regression, and Naïve Bayes (NB) for classification of phishing webpages and obtained around 99% accuracy.

Rao and Pais [21] proposed a method which is based on human behavior while they get exposed to malicious webpages. This human behavior of feeding the fake credentials is automated with an additional step of applying heuristic filtering. They were able to get an accuracy of 96.38% using this approach.

In [22], the authors proposed a real-time system that makes use of the features pertaining to natural language processing (NLP). They used seven different machine learning algorithms for the classification of phishing and benign webpages. They tested their proposed system on a self-created dataset. Their results showed that RF with features based on NLP provides the best accuracy while classifying the webpages.

Xiaoqing et al. [23] presented an automatic intelligent system for the detection of phishing webpages. They analyzed the features of uniform resource locator (URL) and used NB for classification. In case of suspicious webpages, it is parsed and re-classified by using SVM. Through their results, they claim that the system gives high accuracy of detection in less time.

A similar approach was used in [24]. The authors presented a method which used a combination of SVM and decision tree model. SVM is used for training purpose and decision tree is used to generate the rules for detecting phishing websites targeting the banking domain.

"Cantina + " [25] approach was used as an extension of "Cantina" [26] (based on textual content of a webpage and term frequency-inverse document frequency algorithm) where additional features were used to detect the phishing webpages. In this approach, the authors used eight features. They used search engines, document

object model, and the services from the third party along with machine learning algorithms for the detection of phishing webpages.

Joshi et al. [27] proposed a system which selected important URL features and machine learning algorithms for the detection and classification of phishing webpages. They concluded that ReliefF and RF algorithms worked well than other combinations.

Wu et al. [28] presented a phishing detection tool that is developed by combining the URL of the webpage and its source code. They used Levenshtein method for computing the string similarity and SVM as a machine learning model in their proposed system for detection of phishing webpages.

Zamir et al. [29] analyzed the features of phishing data by using features selection methods. They proposed two features by combining various attributes. They used various machine learning and stacking techniques for detecting phishing webpages.

Almseidin et al. [30] presented a study where they employed various machine learning algorithms and features selection methods to improve the efficiency of their system. The experiments conducted on a phishing dataset of 48 features containing 5000 benign and 5000 phishing webpages. They concluded that RF algorithm with only 20 features gives the best accuracy.

Yerima and Alzaylaee [31] presented an approach based on deep learning for detecting phishing webpages. They used convolutional neural networks (CNN) for this purpose and evaluated on a dataset consisting of 6,157 genuine and 4,898 phishing websites. They compared their results with traditional machine learning algorithms and concluded that their approach using CNN gives much better results than conventional machine learning algorithms.

Basnet and Doleck [32] proposed a heuristic approach using URL-based features. Experiments were carried out on a dataset containing 138 features which were extracted from 31,000 malicious and 16,000 phishing webpages. These 138 features belong to four groups, namely search engine, reputation, lexical, and keyword-based. They used seven different machine learning algorithms for classification purpose. Random forest achieved the best accuracy.

Recently, due to the growth of multimedia systems [33, 34], there is an exponential growth in cyber-attacks. In order to protect the digital media, there is a need to develop the techniques to prevent their unauthorized distribution [35]. These involve digital signatures and water marking. A lot of research is being reported by the researchers on authentication of the content [36, 37].

From the literature, it is found that the research community has worked on improving the classification accuracy by considering a variety of large number of features for the classification of phishing webpages. However, it seems that there is less focus on the problem related to the building time of any classification model without compromising the accuracy. This chapter offers a study which compares the classification performance and efficiency of detecting phishing webpages using various machine learning algorithms without and with feature selection. It makes use of information gain method for selecting an appropriate set of features.



Fig. 1 Workflow of methodology used for proposed phishing detection system

3 Methodology Used

This section provides a description of the methodology used for discriminating benign webpages from the malicious ones. Figure 1 demonstrates the proposed design of phishing detection system. After downloading a suitable dataset, eight machine learning-based algorithms are employed to classify the phishing webpages. Afterward a feature selection method is deployed to choose top rank features. These selected features are then deployed to classify the webpages. Subsequently, the experimental results are compared by considering building time and performance of the models—before and after feature selection. The detailed steps of the proposed system are described in the following sub-sections.

3.1 Data Acquisition

Dataset used in this study is downloaded from [38, 39]. It is composed of 30 features (other than index and class label) extracted from 6157 legitimate and 4898 phishing webpages. Benign webpages are collected from Alexa [40] while phishing webpages are taken from PhishTank. This dataset is chosen in the present study because it is the most recent dataset available in the public domain.

3.2 Classification before Feature Selection

In this work, we have used a free data mining tool—Waikato Environment for Knowledge Analysis (WEKA), version 3.8.4 for Windows Operating System [41]. We used eight machine learning classifiers, namely IB1, NB, J48, AdaBoost, decision table (DT), bagging, RF, and sequential minimal optimization (SMO) for classifying phishing webpages. In this step, all 30 features present in the original dataset are used for constructing the classification models. A brief description of these algorithms is given below:

- IB1 is a classifier that stores the training data and starts building the classification model only when it gets the test data. Due to this reason, it is also known as lazy learner. It is based on nearest-neighbor classifier which makes use of a similarity measure, i.e., Euclidean distance to find the training example which is closest to the

specified test data. Euclidean distance between two points having coordinates (x, y) and (a, b) is computed by using the equation given below.

$$\text{Dist}((x, y), (a, b)) = \sqrt{(x-a)^2 + (y-b)^2}$$

- NB method is originated from Bayes' theorem with Naïve independent conventions. It predicts the probability of an instance of a dataset belonging to a specific class. The posterior probability of a class *c*, given attribute *x,* is computed by using the equation mentioned below.

$$P(c|x) = \frac{P(x|c)P(c)}{P(x)}$$

where $P(x|c)$ represents the probability of attribute x given its class c. $P(x)$ and $P(c)$ are the prior probabilities of attribute x and class c respectively.
J48 [42] is a WEKA classification package of C4.5. It builds the decision tree based on the labeled training data using the concept of entropy.
The main aim of adaptive boosting (AdaBoost) [43] is to transform a group of weak classifiers into a strong classifier. It is a weighted grouping of weak classifiers. It assigns equal weights to all the examples in the dataset. Then the weights of wrongly classified instances are modified. At last, weighted mean of all weak classifiers is considered to take the final decision about the class of an instance.
DT is a type of classifier in which specific features are selected while performing the learning process. It is done by computing cross-validation performance of the table for different sub-sets of attributes and selecting the sub-set which is the best performer. Cross-validation error from a decision table is obtained by manipulating the class counts related to entry of the table. Best first search is usually used to search the feature space.
Bagging (bootstrap aggregation) is a meta-classifier which combines the output of different models to make the final decision more reliable by reducing the variance error [44]. It increases the predictive performance over a single model. A general way to predict the final class is to calculate the weighted average for numeric prediction problems and take a weighted vote for classification problems.
RF is an ensemble method which comprises of various decision trees. It can run effectively on a large dataset. It gives highly accurate results than a single decision tree as it reduces the overfitting [44]. Every decision tree is generated using a random selection of attributes. The class of unknown data is predicted using the aggregation (voting scheme) of predictions made by individual decision trees.
SMO [45] is an optimized version of SVM from WEKA library. It is an optimization algorithm which is used to solve the problem which arises while training SVM. The name of the problem is the quadratic problem. SVM [44] is based on computing a hyperplane with the maximal margin between the data dimensions.

3.3 Feature Selection

A feature selection method is deployed for the selection of top-ranked features which helped in discarding the irrelevant ones. Building a classification model with a lesser number, but a relevant set of features helps in improving its generalization and learning speed. In this work, we have used information gain (IG) [46] method for selecting the top features. It is defined as the extent of information obtained from a feature and is based on the degree of randomness (entropy) in the data. It is calculated by finding the difference between the entropy of data distribution after and before the split.

$$\text{Entropy} = -\sum_i P_i \log_2 P_i$$

where P_i is the class probability.

Ranker algorithm is used for ranking the attributes. Figure 2 shows the top 15 attributes after applying IG + Ranker algorithm. These top rank attributes are used for classification purpose.

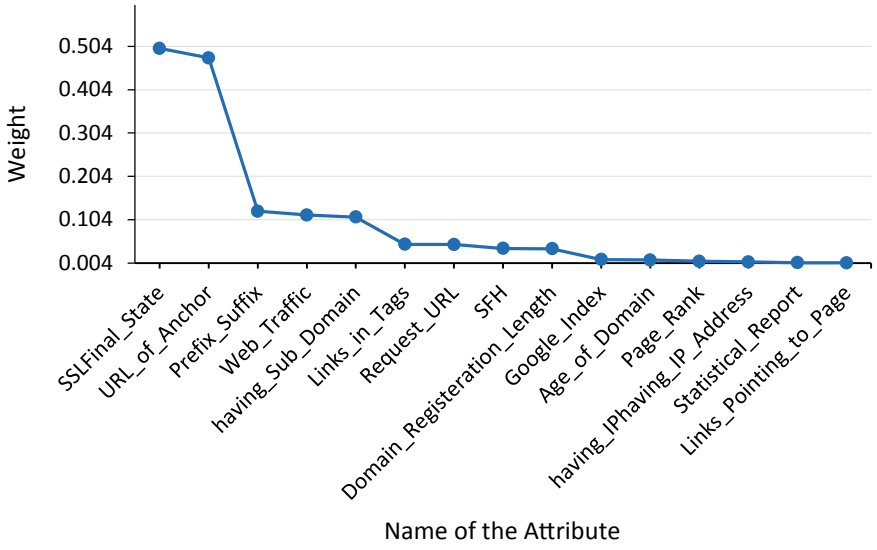

Fig. 2 Top 15 features after feature selection

3.4 Classification after Feature Selection

The selected top 15 features are then employed for building the classification models using the same set of eight algorithms as described earlier. When experiments are performed on both datasets before and after feature selection, the model building time is recorded for carrying out the comparative analysis.

3.5 Evaluation and Validation

A tenfold cross-validation technique has been used for conducting the experiments. This technique works on dividing the original dataset randomly. Firstly, the original dataset is split into ten equal parts. Thereafter, nine parts are used for training and one for testing purpose. The same process is repeated ten times with different combinations. The averaged result is used to measure the performance of algorithms. In order to evaluate machine learning algorithms, we have used various evaluation parameters. These are true positive rate (TPR), false positive rate (FPR), precision, F-measure, accuracy, and Matthews correlation coefficient (MCC) [47]. These are computed by using the fields of confusion matrix as described in Table 1.

- **TPR**: It is also known as recall and is defined as the rate of correctly identified phishing webpages.

$$\text{TPR} = \frac{\text{TP}}{\text{TP} + \text{FN}}$$

- **FPR**: It is the rate of incorrectly recognized benign webpages.

$$\text{FPR} = \frac{\text{FP}}{\text{FP} + \text{TN}}$$

- **Precision**: It is a degree of exactness.

Table 1 Confusion matrix

Actual	Classified/predicted as		
	Class	Phishing	Benign
	Phishing	True positive (TP) Phishing webpages predicted correctly as phishing	False negative (FN) Phishing webpages predicted incorrectly as benign
	Benign	False positive (FP) Benign webpages predicted incorrectly as phishing	True negative (TN) Benign webpages predicted correctly as benign

$$\text{Precision} = \frac{\text{TP}}{\text{TP} + \text{FP}}$$

- **F-Measure**: It is defined as the harmonic mean of recall and precision.

$$\begin{aligned} \text{F} - \text{Measure} &= \frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \\ &= \frac{2 \times \text{TP}}{2 \times \text{TP} + \text{FN} + \text{FP}} \end{aligned}$$

- **Accuracy (%)**: It is the percentage of correctly recognized phishing and benign webpages.

$$\text{Accuracy}(\%) = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{FN} + \text{TN} + \text{FP}} \times 100$$

- **MCC**: It is used to evaluate the performance of machine learning algorithms for binary classification. It measures the correlation between the actual and predicted labels and takes the values between -1 and $+1$.

$$\text{MCC} = \frac{\text{TP} \times \text{TN} - \text{FP} \times \text{FN}}{\sqrt{(\text{TP} + \text{FP})(\text{TP} + \text{FN})(\text{TN} + \text{FP})(\text{TN} + \text{FN})}}$$

4 Experimental Results

This section provides a comparative analysis of experimental results along with their pictorial visualizations. All eight classifiers are employed to classify phishing websites by considering the dataset containing 30 features. Table 2 shows the weighted average values of TPR, FPR, precision, F-measure, MCC, and accuracy for

Table 2 Classification results before feature selection (with 30 features)

Classifier	TPR	FPR	Precision	F-measure	MCC	Accuracy (%)
IB1	0.958	0.044	0.958	0.958	0.915	95.78
NB	0.907	0.098	0.907	0.907	0.811	90.7
J48	0.958	0.044	0.958	0.958	0.915	95.82
AdaBoost	0.925	0.077	0.925	0.925	0.848	92.47
Bagging	0.956	0.045	0.956	0.956	0.911	95.59
DT	0.934	0.074	0.935	0.934	0.867	93.41
RF	0.965	0.034	0.965	0.965	0.927	96.52
SMO	0.928	0.077	0.928	0.927	0.853	92.75

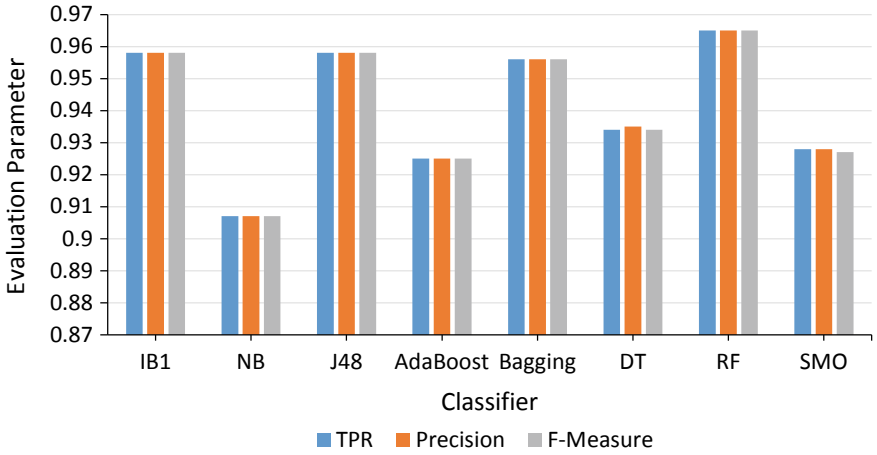

Fig. 3 Comparison of classifiers on the basis of TPR, precision, and F-measure before feature selection

Table 3 Classification results after feature selection (with 15 features)

Classifier	TPR	FPR	Precision	F-measure	MCC	Accuracy (%)
IB1	0.952	0.05	0.952	0.952	0.902	95.16
NB	0.907	0.097	0.907	0.907	0.812	90.73
J48	0.95	0.052	0.95	0.95	0.899	95.03
AdaBoost	0.925	0.077	0.925	0.925	0.848	92.47
Bagging	0.955	0.047	0.955	0.955	0.909	95.5
DT	0.931	0.076	0.932	0.931	0.861	93.13
RF	0.963	0.04	0.963	0.963	0.925	96.3
SMO	0.921	0.087	0.921	0.92	0.839	92.06

the eight machine learning algorithms using 30 features, i.e., before feature selection. It shows that RF provides the highest accuracy of 96.52% followed by J48, IB1, and bagging with 95.82%, 95.78%, and 95.59% accuracy, respectively. RF gives the maximum value of MCC, i.e., 0.928. NB provides the least accuracy of 90.7% with MCC value as 0.811. Figure 3 visualizes the comparison of various classifiers on the basis of TPR, precision, and F-measure before feature selection.

Afterward, the top 15 features are selected using IG feature selection method, and the same set of classification models are again used for the classification purpose. Table 3 shows the weighted average values of TPR, FPR, precision, F-measure, MCC, and accuracy for the eight machine learning algorithms using 15 features selected after employing a feature selection method. It shows that RF provides the highest accuracy of 96.3% followed by bagging, IB1, and J48. Once again, the minimum accuracy is provided by NB, i.e., 90.73%. RF gives the maximum value of MCC,

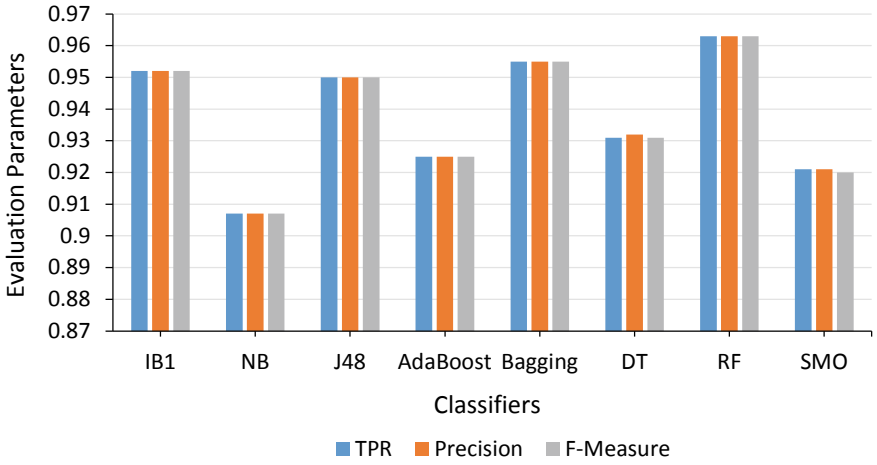

Fig. 4 Comparison of classifiers on the basis of TPR, precision, and F-measure after feature selection

i.e., 0.925. Figure 4 visualizes the comparison of various classifiers on the basis of TPR, precision, and F-measure after feature selection.

Figure 5 depicts the comparison of classifiers on the basis of accuracy before and after features selection. It shows that for almost all the machine learning algorithms considered in this work, the accuracy remains either same or there is insignificant decrement before and after feature selection. It means that the features which are shortlisted by using IG feature selection method are the most relevant ones for the

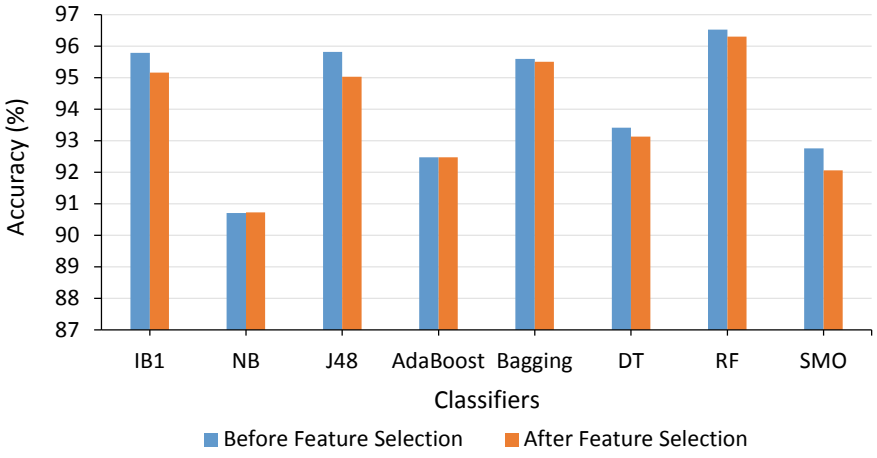

Fig. 5 Comparison of classifiers on the basis of accuracy before and after feature selection

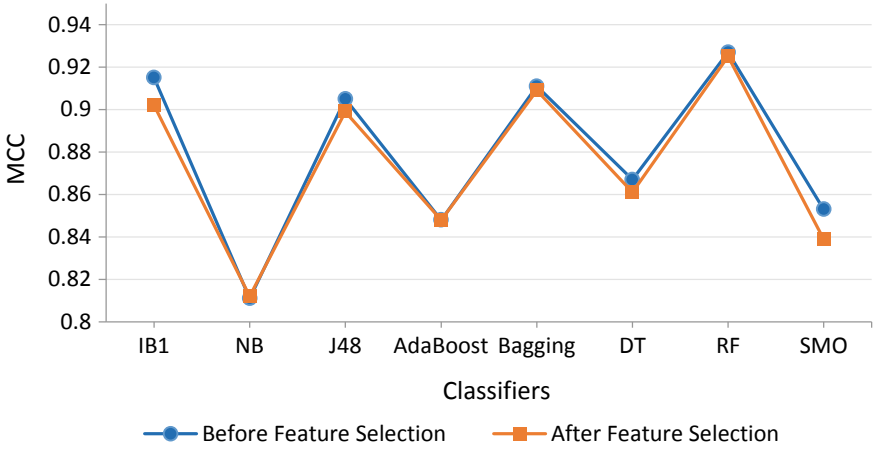

Fig. 6 Comparison of classifiers on the bases of MCC before and after feature selection

Table 4 Model building time (in sec.) before and after feature selection

Classifier	Model building time (in sec.)	
	Before feature selection	After feature selection
IB1	0	0
NB	0.28	0.06
J48	0.62	0.3
AdaBoost	1.14	0.33
Bagging	2.75	1.06
DT	5.39	2.11
RF	5.53	3.43
SMO	19.91	9.27

classification of webpages. A comparison of MCC before and after feature selection is depicted in Fig. 6.

Table 4 shows the build time of classification models while carrying out the classification experiments before and after feature selection. Figure 7 illustrates the comparison of model building time. It shows that for all classifiers, the time taken to build the models is reduced after feature selection. The model build time for IB1 is 0 as it is a lazy learner.

The improvement in model building time does not seem to be as significant since the experiments are conducted using a small dataset. If a large dataset or big data [48, 49] is considered, it would take more time for model building and thus there would be a significant improvement.

In order to detect the new phishing websites, the researchers have used machine learning algorithms. To improve the classification accuracy, they considered a large number of features. However, they do not focus on the problem related to the building

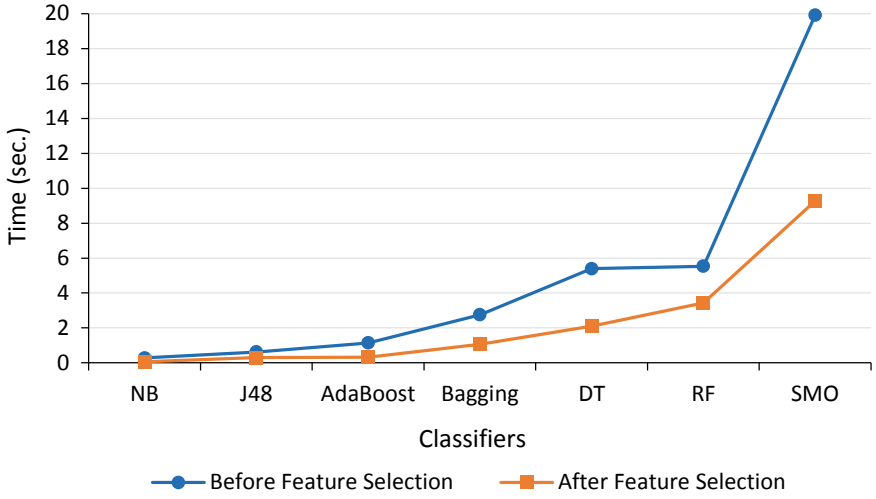

Fig. 7 Comparison of model building time before and after feature selection

time of classification models without compromising the accuracy. In this work, we used a feature selection method to select an appropriate set of features for improving the efficiency of the models without compromising with the accuracy.

5 Conclusion and Future Scope

This chapter presented an efficient system for the detection of phishing websites. It makes use of a feature selection method apart from machine learning algorithms for the purpose of classification. The performance of eight machine learning algorithms is compared before and after feature selection for the classification of webpages into phishing and benign. The experimental results clearly depict that use of a feature selection method for selecting a relevant set of features improves the building time of classification models without a significant reduction in the accuracy for the detection of phishing webpages. Further, the results show that RF gives the best accuracy for both before and after feature selection.

As future work, we intend to use an ensemble of algorithms to compare the accuracy rates with the individual machine learning algorithms. The experimental study can be further extended to understand the performance of deep learning algorithms. We may also enhance our study on large phishing datasets including IoT-based phishing attacks using big data technologies to uncover such attacks more quickly than existing methods.

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Analysis of Graph Cut Technique for Medical Image Segmentation

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Abstract

Segmentation plays an important role in image analysis as it is used to identify and differentiate foreground and background regions. Image segmentation in brain MRI analysis performs several roles like extraction of abnormal region for better diagnosis of the disease aiding in the therapy planning. Various brain tumors comprise diverse properties like their shapes, intensity distribution and location, hence reducing the possibility of developing a single general algorithm.

In this paper authors have illustrated two methods for performing extraction which includes histogram thresholding and centroid based graph cut segmentation. On the basis of their potential, advantages and limitation comparison is made, that emphasize better performance of centroid based graph cut segmentation method. To measure the performance some quality parameters are evaluated. This paper also solves the problem of initial seed selection by using graph cut segmentation technique.

Keywords

Segmentation **Threshold**

Fuzzy C-Mean clustering **K-mean clustering**

Split and merge **Graph-Cut**

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Analysis of Graph Cut Technique for Medical Image Segmentation

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Abstract. Segmentation plays an important role in image analysis as it is used to identify and differentiate foreground and background regions. Image segmentation in brain MRI analysis performs several roles like extraction of abnormal region for better diagnosis of the disease aiding in the therapy planning. Various brain tumors comprise diverse properties like their shapes, intensity distribution and location, hence reducing the possibility of developing a single general algorithm. In this paper authors have illustrated two methods for performing extraction which includes histogram thresholding and centroid based graph cut segmentation. On the basis of their potential, advantages and limitation comparison is made, that emphasize better performance of centroid based graph cut segmentation method. To measure the performance some quality parameters are evaluated. This paper also solves the problem of initial seed selection by using graph cut segmentation technique.

Keywords: Segmentation · Threshold · Fuzzy C-Mean clustering · K-mean clustering · Split and merge · Graph-Cut

1 Introduction

In the last few decades one of the most growing technique for providing the non-invasive image analysis for the diagnosis is Magnetic Resonance Imaging (MRI) technology. The huge amount of data analysis with good quality aids the expert radiologist in the study of brain anatomy. This huge brain data analysis maybe tedious with various difficulty due to the complex brain stricture but MRI is the most convenient and useful application in the imaging technology.

The formation of brain tumors is due to the irregular growth of the tissue mass that destroys the brain cells. The early diagnosis of tumor helps in increasing the survival rate [1]. Different growth rate of the tumor distributes the tumor in various grades belonging to the benign and malignant classes [2]. All these classes comprise different intensity distribution, locations and vary in size [3]. Brain tumor are one the most fatal disease and a high death rates have been observed in the developed countries [4]. Various Computer aided diagnosis methods provided for benefitting the clinicians with better diagnosis and testing are developed. Among them image segmentation is popularly used as it segments the image into different fragments generating a better

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diagnosis of targeted region. Some of the conventional methods employed redundantly are intensity based, clustering based and some hybrid techniques.

A binary conversion of the MR image is done in threshold based segmentation [5–7] method. The iterative methods such as split and merge, region growing [8] are intensity dependent and only considers uniformity of the homogenous regions. Region growing method initializes with seed points and grouping is performed through pre-defined criteria such as similar intensity, color and texture. The selection of seed points is a hurdle and many algorithms are illustrated by researchers [9, 10]. The second iterative method is the split and merge technique [11] divides the complete image in smaller region and merges all the homogenous region to form one single targeted region. Some of the hybrid approaches studied by the authors [12, 13] include region growing and edge detection. The popular and most generally used clustering methods are: k-mean Clustering and Fuzzy clustering. A membership function is given to all the pixels that provide amount of degree present in an element in the fuzzy clustering also known as soft clustering [14]. On the other hand in k-mean Clustering [15] popularly also known as hard clustering generates different grouping of the image in such a way that each group shall depict highest similarity or minimum Euclidean distance from the mean value of every group. These techniques are completely dependent on the initial points that is the biggest struggle [16–18] and are iterative in nature. Due to the iterative nature, these methods are time consuming and face the problem for the initial seed point selection.

One of the prominent technique used is the graph based method proposed by Boykov *et al.* [19]. In graph cut technique minimum value of the objective function is obtained on the formation of the segmented image. Authors in [20] developed a graphical representation of the image that used cost function enabling the division of the images. The objective function introduced by authors [21–24] provided identical segmentation even though different combinatorial algorithm are used for evaluating minimum cut. Authors analyzed the efficiency in [23] for illustrating all the problems involved when both the 2D and 3D images are used for segmentation. Graph cut extends up to ND segmentation of images due to its ability of integrating the regional and boundary term. Other techniques like live wire and intelligent scissor [25, 26] evaluate the lowest weighted edge for the partition.

In this research paper we have compared two segmentation technique and evaluated the performance metric. The first technique is one of the simplest technique that is thresholding. The second technique is graph cut segmentation that has limitation of seed selection for the initialization of the algorithm. This limitation is avoided in the proposed framework by developing an automatic graph cut segmentation.

The organization of the paper is given as: detail explanation along of the two techniques along with their algorithms and mathematical explanation are described in Sect. 2. The simulation result, image database is described in Sect. 3. Quality measure of the segmented image is verified by four parameters which are briefly described and the values calculated are framed. Conclusion for obtained results from the proposed framework is explained in the Sect. 4.

2 Methodology

In this section flow diagram, algorithm and a detail explanation for the threshold segmentation and proposed framework for graph cut segmentation is provided. In the histogram thresholding method threshold value is evaluated from the histogram of difference intensity values. These values project the pixel location where the tumor may have occurred then, partition is done based on the threshold value and binary values are assigned to different regions. Many region based methods face problem for the initialization of seed points. To overcome this problem, graph cut segmentation explains image in a graphical form and automatic centroid/seed values are evaluated by exploiting the symmetrical nature of the brain. Different labelling is done for the object and the background region. Partition is performed by breaking the edges with lower thickness and s-t graph is formulated. Both methods are compared using mean square error (MSE), peak-signal-to-noise ratio (PSNR), similarity index (SSIM) and dissimilarity index (DSSIM). Experimental results show that our approach of centroid based graph cut segmentation outperforms the histogram thresholding technique.

2.1 Histogram Thresholding

Thresholding technique is one of the popular techniques due to its simplicity. It converts MR image into a binary image, distinctly displaying the segmented region. Complete process of thresholding relies on the selection of the threshold value. This value is evaluated by means of number of pixels corresponding to a particular pixel value which are obtained by histogram. There are three types of thresholding technique: global threshold, variable threshold and regional threshold. In this paper global thresholding is employed and a single threshold value is evaluated by Otsu's method for the entire image.

Flow diagram of the histogram thresholding algorithm is given in Fig. 1. The MR image which is in RGB form is converted into gray scale image. Single threshold value is calculated for the entire image in two steps: the image is divided vertically, then, difference in the pixel intensity between the vertical sections is calculated and their histogram is computed. Using Otsu's method, the difference value is used to calculate the threshold value. All the pixels are compared about the threshold value. Pixels are labelled as '1' (representing white intensity value) if they belong to object region and as '0' (representing black intensity value) if they belong to background region. Hence, this algorithm provides a binary partition of the MR images. This partition is only possible if the accurate knowledge of the threshold value is obtained. If a single threshold value is selected, then the image is partitioned in binary form but on selecting higher value of the threshold the number of regions formed also increase. Therefore, the accurate knowledge of the threshold value is of critical importance. After the pixels are labelled the targeted tumor region is extracted from the MRI image and finally the segmentation is done.

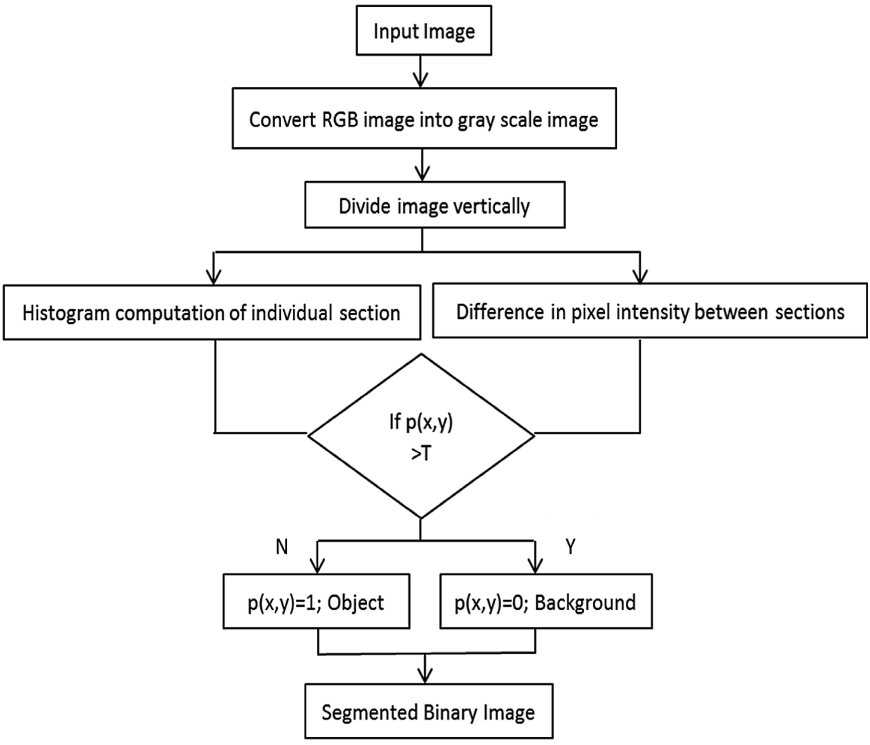


Fig. 1. Flow diagram of overall algorithm

2.2 Graph Cut

This segmentation technique divides the complete set of the image in two subgroups in such a way that the targeted region is presented as the foreground and the remaining as the background region. Graph cut represents the image in a graphical form such that each pixels are represented as nodes, illustrated in Figs. 2 and 3.

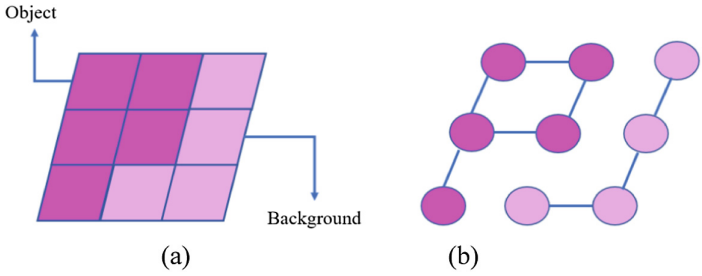


Fig. 2. (a) Graphical form of image (b) segmented image.

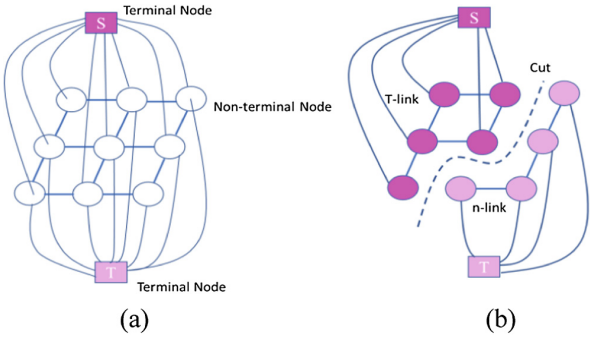


Fig. 3. (a) Source terminal and sink terminal (b) cut to segment object and background.

The basic representation of the image in the graphical form is given in Fig. 3(a) was proposed by Boykov *et al.* in [27] as:

$$G = < V, E > \tag{1}$$

$$\mathcal{V} = \{s, t\} \cup \mathcal{P} \tag{2}$$

where, graph G contains nodes/pixels $\mathcal{V}$ and edges/neighboring distance $\mathcal{E}$. The pixels $\mathcal{P}$ are nodes and the seed values are the non-terminal nodes (s, t) (s: source/object terminal; t: sink/background terminal) that are connected to each other via link. There are two types of links present: $t - link$ and. The $t - link$ connects the terminal nodes to the non-terminal nodes and $n - link$ connects all the neighboring nodes to each other. The partition takes place when two homogeneous regions are formed that show the highest similarity with the terminal nodes. This cut is shown in Fig. 3(b) that provides two exclusive regions. The flow diagram of this methodology is depicted in Fig. 4. The RGB image is converted into gray scale image and the image is divided in vertical sections as previously done in histogram thresholding. Both the symmetrical halves are compared and the pixel values with highest difference are obtained. These are the centroid points that provide the seed point for initializing the graph cut segmentation. Once the seed points are known the segmentation is performed by assigning the weights and labels are assigned corresponding to them.

3 Simulation Results and Discussion

3.1 Study Area and Dataset

The experiments were performed on MATLAB 2013a on the standard database [28, 29]. The clinical data was provided from radiology department of PGI Chandigarh as shown in Fig. 5(c). The sizes of three images are 180×218, 800×450 and 960×1280 respectively as given in Fig. 5(a), (b) and (c).

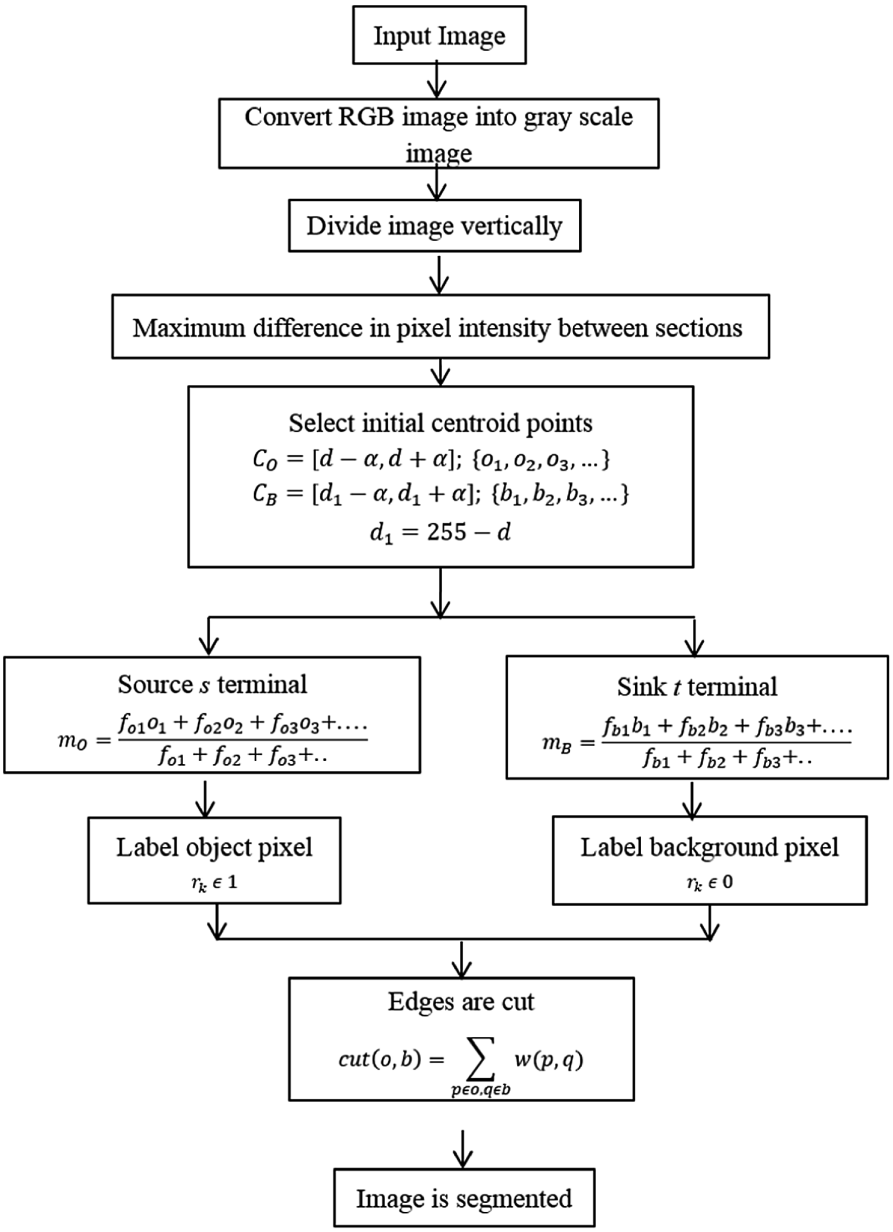
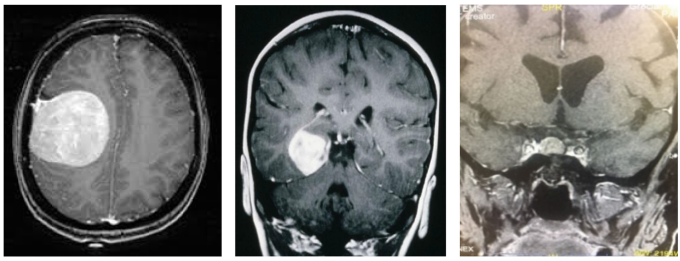


Fig. 4. Flow chart of automatic graph cut.



(a) (b) (c)

Fig. 5. Different set of original images (a), (b) and (c)

3.2 Quality Measure

For the performance analysis and quality measurement of the image, following parameters obtained from literature are evaluated: Peak Signal to Noise Ratio (PSNR), Structural Similarity Index (SSIM) and Dissimilarity Index (DSSIM).

3.2.1 Mean Square Error

MSE measures the average difference of the pixels throughout the image. Higher value implies greater difference of the segmented image from the original image. It is calculated as follows:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(I_{xi} - I_{yi}\right)^2 \tag{3}$$

where, n, is the total no of pixel, I_{xi} is the intensity value of the original image and I_{yi} is the intensity value of the segmented image.

3.2.2 Peak Signal to Noise Ratio

PSNR computes how much noise is present in the resultant image due to segmentation and it is measured in decibel. It is computed as follows:

$$PSNR = 10\log\frac{255 * 255}{MSE} \tag{4}$$

Ideally the PSNR value is infinite but practically it is 20 to 30 dB.

3.2.3 Structural Similarity Index (SSIM)

Authors in [30] presented SSIM as a quality measure parameter that calculates any disturbance in the segmented region of interest if created by the simulation. It correlates the local patterns of pixel intensities that are normalized.

$$SSIM = \frac{\left(2m_x m_y + K_1\right)\left(2\sigma_{xy} + K_2\right)}{\left(m_x^2 + m_y^2 + K_1\right)\left(\sigma_x^2 + \sigma_y^2 + K_2\right)} \tag{5}$$

where, $\boldsymbol{m_x}, \boldsymbol{m_y}$ are the mean value of the original region of interest (infected region in the original image) and the segmented region of interest (infected region in the segmented image) respectively, σ_x, σ_y are the variance respectively. K_1, K_2 are the substitution values, in this paper we have taken these values 0.01 and 0.03 which are calculated by Wang *et al.* in [30]. The values should range between 0 and 1, exhibiting higher similarity if the values are nearby 1 and lower similarity for values nearby 0.

3.2.4 Dissimilarity Index

This parameter evaluates the pixels that have dissimilar intensity value from the original image. It computes adverse effect from the SSIM. Similar to SSIM its value also range between **0** and **1** but differs in the implications. For values near to **0** represent lower dissimilarity and value near to **1** show higher dissimilarity. This value is calculated as follows:

$$\boldsymbol{DSSIM} = \mathbf{1} - \boldsymbol{SSIM} \tag{6}$$

3.3 Results and Discussion

In this research work, tumor affected MRI image is segmented by thresholding and graph cut method as shown in Fig. 6. In threshold segmentation resulting image is binary image that is segmented at threshold value of T = 0.489. It is observed that region of interest is extracted but erroneous pixels also get included and it is difficult to differentiate between tumor region and other part of the brain. Whereas, the brain segmented by graph cut technique has a clear visibility of the tumor region. The segmented image is not binary, and extracted region's intensity values are similar to the tumor region in the original image.

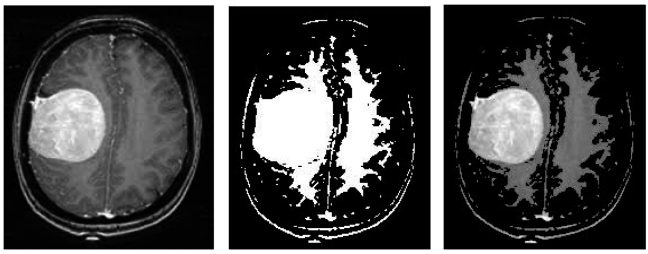


Fig. 6. Segmentation results of Image 1 (a) original image, (b) thresholding, (c) graph cut

Segmented results of the Image-2 are shown in Fig. 7. The original MRI image is of a young child who is diagnosed by astrocytoma which occurs due to the astrocyte cells. Image segmented by threshold technique is a binary image. Tumor region is not

extracted properly due to inclusion of pixels whose intensity value is close to the pixels in the tumor region. On the contrary, image obtained by graph cut segmentation has a clear picture of tumor region and no erroneous pixels are included in the ROI.

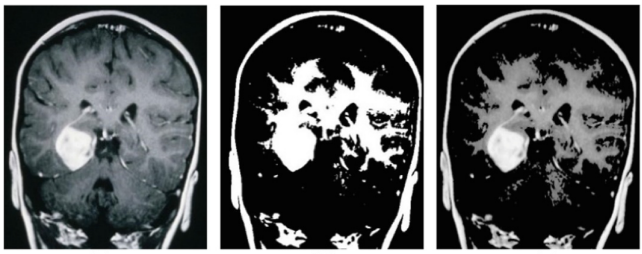


Fig. 7. Segmentation results of Image 2 (a) original image, (b) thresholding, (c) graph cut

In Fig. 8 segmented results of the third image are shown using both the techniques. Image obtained by thresholding technique is binary but it is very difficult to locate the tumor region. Most of the region are holding the value 1 hence majority region in the image is white.

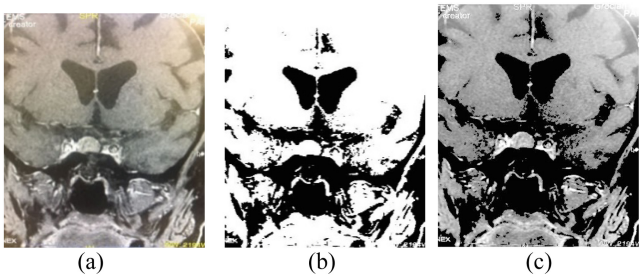


Fig. 8. Segmentation results of Image 3 (a) original image, (b) thresholding, (c) graph cut

This implies that majority region in the original image are of high contrast. Tumor is successfully segmented by the proposed Graph cut segmentation technique. From the results it is observed that resultant image obtained by thresholding process extracts the tumor portion completely comprising of binary intensity values i.e. 0 and 1.

Threshold value of $T = 0.4980$ is obtained by calculating difference between two horizontal half of the image. Although this technique is one of the fast, simplest and oldest but the infected tumor region loses its original intensity value and returns value **0** or black color in the infected region. In the second method object and background

centroid are automatically initialized, where 20 seed points for object/tumor region and 40 seed points for the background region are selected in this method. Variation in number of seed points results in similar mean/centroid value. It is observed from the images that the ROI/tumor region hold their original pixel value which is an advantage for the clinical application where the pixel intensity of the region of interest is measured to calculate the various parameter for the diagnosis of tumor. To analyze performance of the two methods MSE and PSNR quality measure are evaluated and are tabulated in Table 1. It is observed that MSE values for threshold segmentation method are very high for all three images. High MSE signifies that difference level between resultant images and original images is very high. The results also show very low PSNR value for threshold segmented images which ideally should be between 20 to 30 dB. However, results of graph cut segmented images show better result as the MSE is low and PSNR value is between 20 to 30 dB. These quality measures illustrate that graph cut method gives better result than threshold segmentation method.

Table 1. MSE and PSNR values of segmented images (by Threshold and Graph Cut method).

	Image-1		Image-2		Image-3	
Parameter	Threshold	Graph cut	Threshold	Graph cut	Threshold	Graph cut
MSE	36252.75	29.284	36018.45	37.506	26307.72	48.78
PSNR	2.503	27.202	2.218	26.197	3.895	25.125

In Table 2 similarity and dissimilarity index of the three images are evaluated. It is observed that SSIM values for threshold segmented images have very low similarity index and a very high dissimilarity index. This implies that the extracted image is quite different from the original image. Whereas, graph cut method shows high similarity index and low dissimilarity index as shown in Table 2.

Table 2. SSIM and DSSIM values of segmented images (by Threshold and Graph Cut method).

	Image-1		Image-2		Image-3	
Parameter	Threshold	Graph cut	Threshold	Graph cut	Threshold	Graph cut
SSIM	0.603	0.007	0.709	0.008	0.058	0.009
DSSIM	0.397	0.993	0.291	0.992	0.942	0.991

For ease of better clarification and understanding of performance of both techniques on the basis of quality measure are represented in graphical representation. The comparison of the two techniques with respect to the parameters in Tables 1 and 2 are shown in Figs. 9 and 10 respectively.

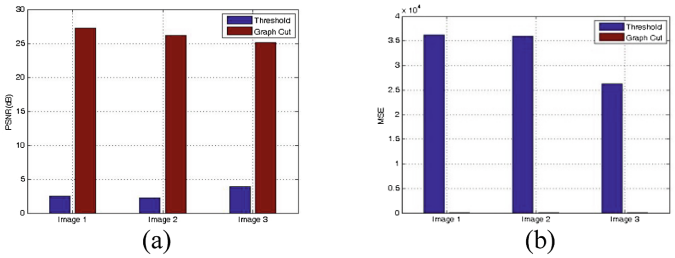


Fig. 9. Comparison of threshold and graph cut segmentation on the basis of parameter (a) MSE and (b) PSNR

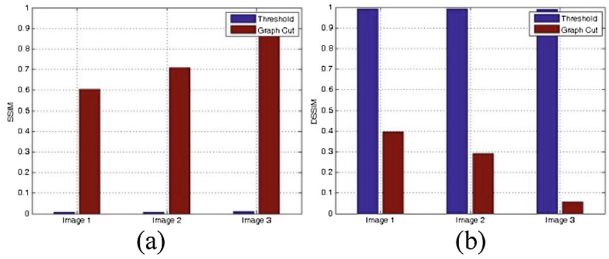


Fig. 10. Comparison of threshold and graph cut segmentation on the basis of parameter (a) SSIM and (b) DSSIM.

4 Conclusion

In this paper we have proposed two techniques for image segmentation and evaluated the effectiveness on the basis of quality measure parameters. In the first technique single threshold value is used for segmenting the three images and corresponding binary images are obtained it is observed that tumor region is not clearly visible for all three images. This is because erroneous pixels are included in the infected region which may result in false diagnosis. This is validated by the evaluated MSE and PSNR. Better segmentation is observed from the second technique of automated graph cut method that generates the seed points resulting in the efficient and most accurate segmentation. The quality measure evaluated for the validation of automated graph cut method for MSE, PSNR parameter are 29.3, 27.2 for image 1; 37.5, 26.2 for image 2 and 48.8, 25.1 for image 3 respectively. The SSIM and DSSIM values obtained are 0.007, 0.993 for image 1; 0.008, 0.992 for image 2 and 0.009, 0.991 for image 3 respectively. The evaluated results imply effectiveness of the proposed graph cut segmentation irrespective of any irregular tumor shape and a clear visibility of extracted tumor.

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Assessment of Corrosion in Rebars by Impressed Current Technique



Meenakshi Dixit and Ashok Kumar Gupta

1 Introduction

In the construction industry, reinforced concrete has its own significance as the most used material due to its economic value, versatility and performance [1–3]. Today, durability has become a critical issue in the management of RC structures [4]. RC structures get deteriorated in many ways. Corrosion of steel rebar is the costliest mechanism which affects the service life and integrity of these structures [5, 6]. Bhaskaran et al. [7] studied economic loss in India due to corrosion during the period of 2011–12 using NBS input/output economic model. This study explained the capital loss as a result of corrosion sectorwise. In 2011–12, the cost of corrosion was $26.1 billion as the direct cost expenses which was 2.4% of Indian gross domestic product (GDP) and indirect expenses was $39.8 billion which was 3.6% of Indian GDP. According to NACE International IMPACT Study 2016, India's total cost of corrosion is $70.3 billion, which is 4.2% of GDP of $1260 billion. As corrosion is an electrochemical process, it is to be noted that steel rebar in good quality of concrete is never going to corrode in the higher alkaline environment, even if the ample amount of oxygen and moisture is available required for the reactions to take place as a result of the formation of a passive layer (iron oxide film) [8, 9]. This film is protective in nature to steel rebar blocking the ion exchange between steel and concrete needed for corrosion, thereby decreasing its rate and preventing the damage to steel [6]. But there are some reasons which can cause the destruction of this passive layer such as the introduction of chlorides in the concrete environment or any cause due to which pH could be reduced in surrounding concrete such as carbonation or acid [2, 5, 6, 9]. The corrosion process has so many steps, but it starts in imperfect regions where there is higher or lower density in rebar's crystal structures. Corrosion products such as iron oxide could be 2–4 times in volume of iron which causes pressure on the concrete

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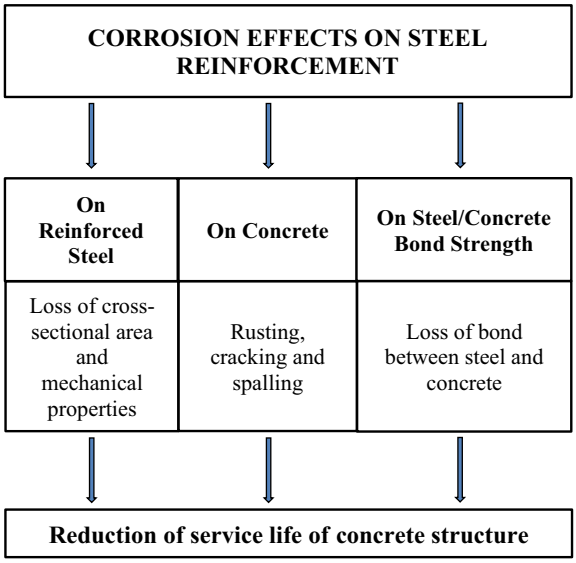

Fig. 1 Effect of corrosion on a reinforced concrete structure

and eventually results in spalling and cracking of concrete which can further cause the ultimate failure of the whole structure [10, 11]. So, the formation of corrosion products on the rebar's surface causes the reduction in its cross section which results in the lesser load bearing capacity and affects the durability and service life of the structure. The process of corrosion can be completely stopped by restricting the entry of dissolved oxygen in the pore water which is not practical. The corrosion products formed initially on the steel surface first increase the bond between steel and concrete, but as corrosion further increases, the bond weakens that ultimately results in cracking in concrete [12, 13]. Figure 1 explains the effect of corrosion on concrete, steel and their bond strength.

There have been so many attempts made by researchers to explore the ways to detect, monitor, and protect the concrete from corrosion. The conventional methods adopted by researchers take a long time span of a structure to monitor the corrosion process. Researchers have adopted various accelerated corrosion techniques to get fast results [14–20]. Impressed current technique is one of them, which gives the results in the short time span. Austin et al. [14] assessed impressed current technique and concluded it an effective method to accelerate chloride-induced corrosion. Caré et al. [15] recommended that while performing ICT concrete specimens should be immersed in sodium chloride solution and not in pure water, then only the corrosion of steel rebars will follow Faraday's law. Ha et al. [16] investigated the corrosive effect of steel rebars in concrete made by fly ash cement using ICT. Yuan et al. [17] concluded that the corroded surface characteristics of the embedded steel bar are different when corrosion is induced by ICT than when corrosion occurs in the natural environment. Benito et al. [18] investigated the corrosive effect of fresh water and brackish water and concluded that corrosion in RC specimens in fresh water is

not so active compared to brackish water. Nguyen et al. [19] demonstrated that higher current densities cause more localized corrosion. Also, the degree of corrosion by calculating the loss in diameter is not a reliable method as it is very difficult to measure the diameter with utmost precision after corrosion. Zhang et al. [20] analyzed that there is a decrease in coefficients of expansion of corrosion products when the applied impressed current density increases.

The main aim of this study is to find the corrosive effect in reinforced steel by using ICT as an accelerated corrosion method. The main benefit of using the ICT is that the occurrence of corrosion in rebar is fast, so mass loss also is estimated in RC in lesser days. It can be said that ICT's results are more noticeable and in a controlled manner.

2 Experimental Program

2.1 Preparation of Specimen

Cylindrical-shaped specimens with M30 grade of concrete were casted using 20 mm diameter size steel reinforcement. Two sets of cylindrical specimens dimensioning 100 mm diameter and 200 mm height providing 40 mm cover and 120 mm diameter and 200 mm height providing 50 mm cover were made. The length of reinforcement is not greater than length plus ten times diameter embedded concentrically in a concrete cylinder and here taken as 35 mm.

2.2 Impressed Current Technique Setup Used for Inducing Reinforcement Corrosion

The corrosion of steel rebars in RC structures is generally a long-term process and sets aside a long opportunity to research. Hence, ICT is used to permit accelerated corrosion in a shorter period. Impressed current technique used for inducing corrosion in steel rebar embedded in concrete comprises of a direct current power supply source, a counter electrode (cathode) and an electrolyte solution. The positive terminal of direct current power supply is directly connected to rebar acting as the anode, and the negative terminal is attached to the copper plates acting as cathode in 3% sodium chloride (NaCl) solution as the electrolyte. The current is impressed from copper plates to the rebars embedded in concrete with the help of NaCl solution. Following immersion of specimens in the electrolyte, accelerated corrosion process (impressed current) starts applying constant current till the advancement of the first noticeable surface crack. The ammeter to screen and control the current was attached to DC source. The electrolyte solution in the tank is replaced with new after every 3 days. The setup is made with the aim that the reinforcement steel works as an anode and

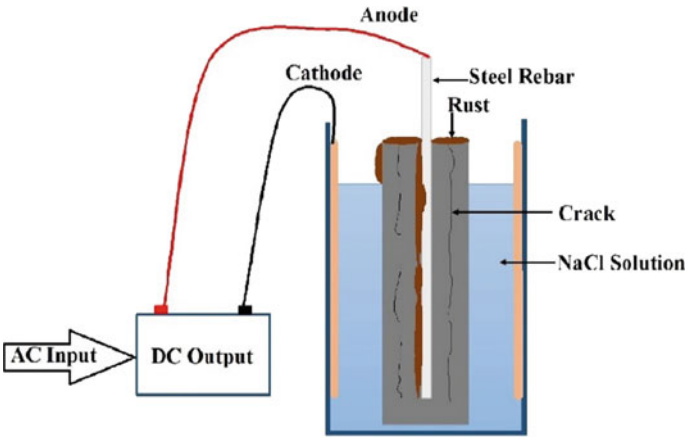

Fig. 2 Impressed current technique setup

copper plates as cathode placed in sodium chloride solution, and the arrangement is shown in Fig. 2. Each RC specimen was studied for corrosion with different applied currents varying from 2 to 4 mA/cm^2 at experiment days after casting and curing.

3 Results and Discussions

3.1 Time for the First Crack Development

Time for the first crack development on the surface of RC specimen is taken by visual inspection. Cracks generated were oriented parallel to the embedded rebar in most of the specimens visible through naked eye as shown in Fig. 3.

Figure 4 represents a plot between applied current density and time taken for the first surface crack development after 7, 14 and 28 days of casting and curing of specimens. It shows that the time is continuously decreasing as the applied current density increases despite different casting and curing days. Also, time taken is increased when the cover is increased.

3.2 Mass Loss

Theoretical mass loss as a result of corrosion is evaluated using Faraday's law. It can be modeled such that it is directly proportional to applied current per unit surface area of steel rebar and time taken for the development of the first surface crack in RC specimen. The steel rebar is extracted from concrete specimen by breaking it

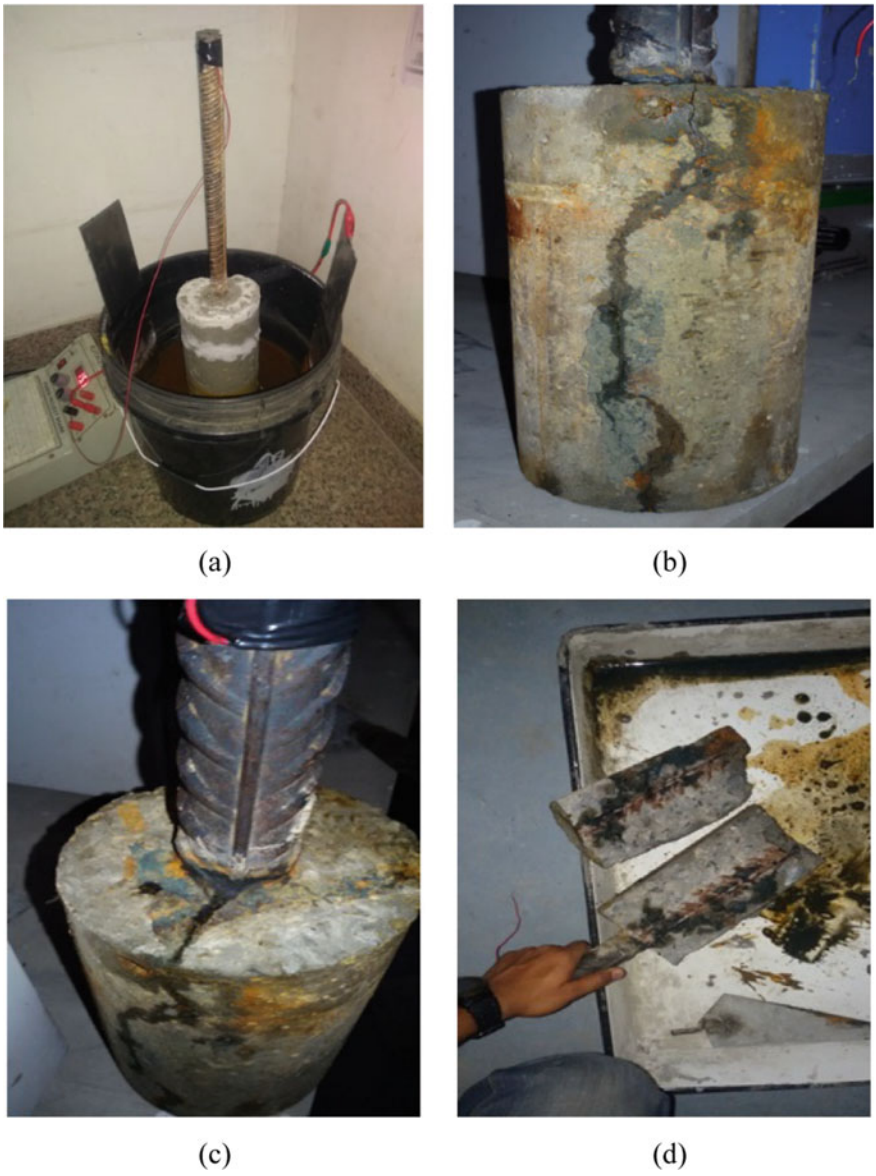

Fig. 3 (**a**) Laboratory ICT setup, (**b**) crack propagation along the surface, (**c**) crack initiation from free top surface along the steel bar, (**d**) steel bar removal after breaking of RC specimen

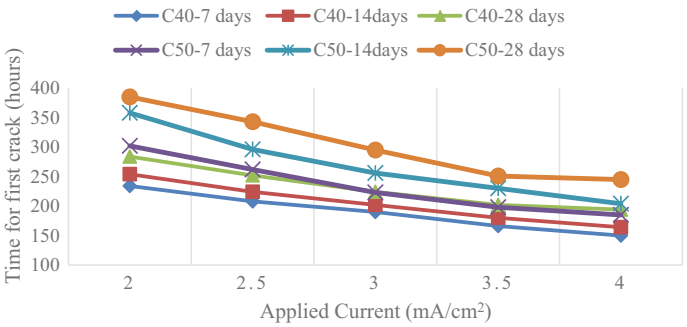

Fig. 4 Time for the first crack at different applied current densities after 7, 14 and 28 days of casting and curing for 40 and 50 mm cover

after the first noticeable crack on the surface of the specimen and cleaned. The actual mass loss of rebar or the actual mass of rust (corrosion product) per unit surface area of rebar is evaluated by gravimetric test.

Figures 5 and 6 represent plot between applied current density and mass loss (theoretical and actual) after 7, 14 and 28 of casting and curing of specimens for 40 mm and 50 mm cover, respectively. Actual mass loss that is measured by gravimetric analysis is always smaller than theoretical mass loss. Considering actual to theoretical mass loss ratio and the fact that concrete specimen gains its strength after every passing day up to 28 days, applied current density of 3.5 mA/cm^2 can be taken as optimum to give satisfactory results.

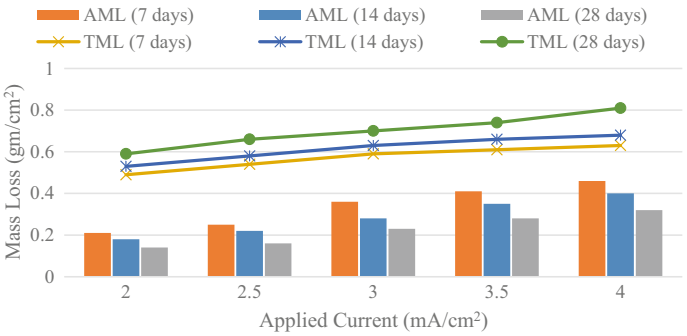

Fig. 5 Theoretical and actual mass loss at different applied current densities after 7, 14 and 28 days of casting and curing for 40 mm cover

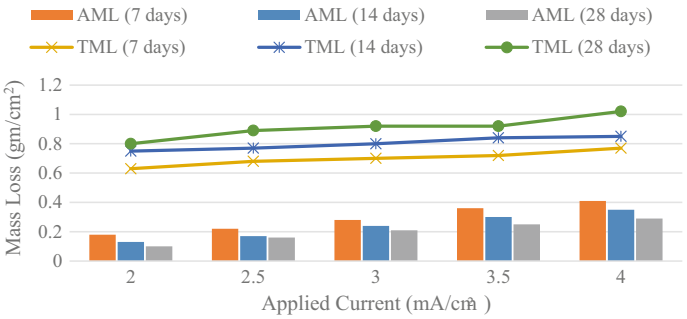

Fig. 6 Theoretical and actual mass loss at different applied current densities after 7, 14 and 28 days of casting and curing for 50 mm cover

3.3 Degree of Corrosion

The degree of corrosion induced due to the constant applied current can be evaluated in terms of the actual percentage mass loss of steel rebar.

3.4 Induced Corrosion Current

The induced corrosion current density can be evaluated mathematically by equating that the theoretical and actual mass loss of steel rebar. It is directly proportional to the actual mass of rust measured and inversely proportional to the time for development of the first surface crack.

Figures 7 and 8 represent a combined plot between the applied current density and induced corrosion current and degree of corrosion after 7, 14 and 28 of casting and curing of specimens for 40 mm and 50 mm cover, respectively. The plot shows

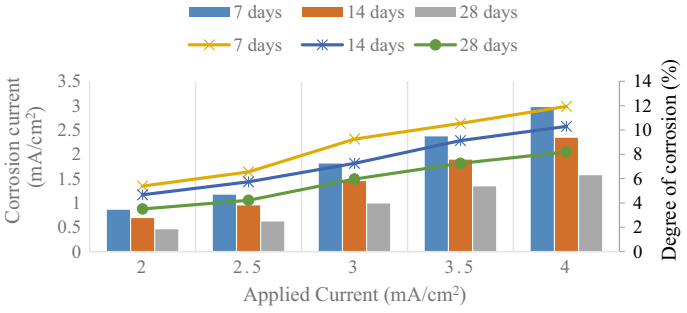

Fig. 7 Induced corrosion current and degree of corrosion at different applied current densities after 7, 14 and 28 days of casting and curing for 40 mm cover

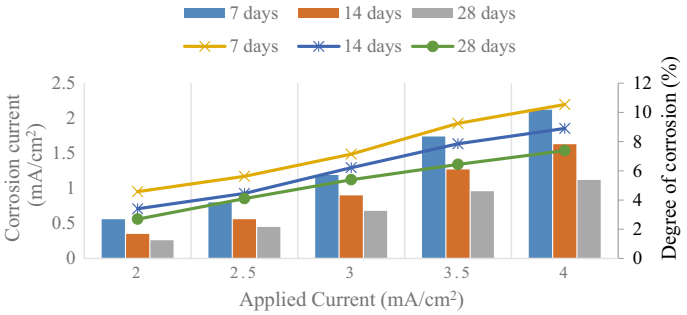

Fig. 8 Induced corrosion current and degree of corrosion at different applied current densities after 7, 14 and 28 days of casting and curing for 50 mm cover

that though there is an increment in the degree of corrosion induced as the applied current density increases, it is not linear. Similarly, there is an increment in corrosion current density induced, but it is not linear and after the applied current density of 3.5 mA/cm^2 is very less.

4 Conclusion

ICT has not been used so often to accelerate corrosion in steel reinforced embedded in concrete and to reduce the time for development of the first surface crack. In this study, it is used experimentally to evaluate the time needed for the first surface crack development in RC specimens at a different applied current and corresponding mass loss of steel rebar due to accelerated corrosion. Based on the analysis, the following conclusions can be made:

1. Time required for the initiation of the first noticeable surface crack of the test specimen decreases with the increase in applied current and increases with the increase in experiment days after casting and curing for a constant applied current. It increases as the cover increases.
2. There is not a good correlation between the actual experimental and theoretical mass-loss rates.
3. Degree of corrosion increases as the applied current increases. But the increment is not linear, and there is no correlation between the degree of corrosion and applied current.
4. Degree of corrosion decreases with an increase in experiment days after casting and curing for a constant applied current. It decreases as the cover increases.
5. Corrosion current increases as the applied current increases. But the corrosion current decreases with the increase in experiment days after casting and curing for a constant applied current. It decreases as the cover increases.

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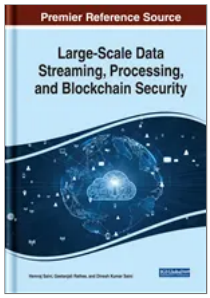

Large-Scale Data Streaming, Processing, and Blockchain Security

Hemraj Saini (/affiliate/hemraj-saini/336343/), Geetanjali Rathee (/affiliate/geetanjali-rathee/336342/), Dinesh Kumar Saini (/affiliate/dinesh-kumar-saini/312048/)

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Data has cemented itself as a building block of daily life. However, surrounding oneself with great quantities of information heightens risks to one's personal privacy. Additionally, the presence of massive amounts of information prompts researchers into how best to handle and disseminate it. Research is necessary to understand how to cope with the current technological requirements.

Large-Scale Data Streaming, Processing, and Blockchain Security is a collection of innovative research that explores the latest methodologies, modeling, and simulations for coping with the generation and management of large-scale data in both scientific and individual applications. Featuring coverage on a wide range of topics including security models, internet of things, and collaborative filtering, this book is ideally designed for entrepreneurs, security analysts, IT consultants, security professionals, programmers, computer technicians, data scientists, technology developers, engineers, researchers, academicians, and students.

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Chapter 11
Electronic Voting Application Powered by Blockchain Technology

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ABSTRACT

India is the largest democracy in the world, and in spite of that, it faces various challenges on a daily basis that hinder its growth like corruption and human rights violations. One of the ugliest phases of corruption and political mayhem is visible during the election process where no stone is kept unturned in order to gain power. However, it is the common citizen who suffers most in terms of clarity as well as security when it comes to his/her vote. Blockchain can play a very important role in ensuring that the voters registering their votes are legit and the counting of votes is not manipulated in any way. It is also needed in today's times where the world is available to people in their smart phones to also give them the opportunity to register their votes hassle free via their smart phones without having to worry about the system getting hacked. Therefore, in this chapter, the proposed layout will be based on a smart contract, using Ethereum software to create an e-voting app. In this chapter, the authors have proposed a secure e-voting framework through blockchain mechanism.

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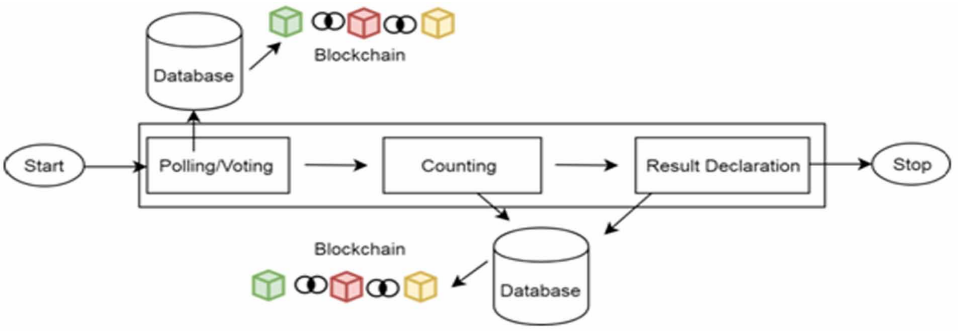
INTRODUCTION

Lately, Blockchains have pulled in overall consideration. A Blockchain is characterized as an immutable, successive chain of records called blocks. The record can contain transactions, documents or some other information, and are fastened together utilizing hashes (Iansiti & Lakhani, 2017; Crosby et al., 2016). It is executed and overseen by a peer-to-peer network of computers (also called peer nodes) spread everywhere throughout the globe. Blockchain likewise called distributed ledger which utilizes independent PCs (nodes) to record, share and synchronies transactions in their particular electronic ledgers, rather than keeping information incorporated on a server as in a customary record.

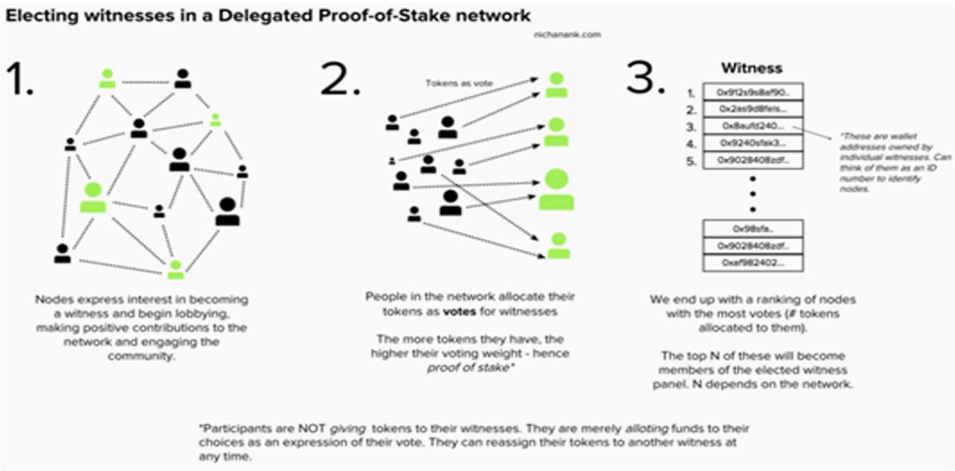
Figure 1. Schematic outline of e-voting using Blockchain



Blockchains have the potential to disrupt any industry that employs the use of a trusted middleman and give direct control back to the end user. In any case, similarly as with any technological revolution and the paradigm shift that joins it, there is a procedure of trial and error. What works and what does not and we are as of now in that stage with Blockchain advancements (Zyskind, & Nathan, 2015; Eyal et al. 2016; Pilkington, 2016). 99% of the business sectors are filled by unadulterated hypothesis. There are no completely useful Blockchain items that can oblige the requests of the majority. Blockchains must be less expensive, snappier, simpler to utilize and similarly as versatile, if not more thus, than the present frameworks set up. The coming of the web drove the technological revolution of the 90's and the industrial upheaval was in the late eighteenth century. These quantum jumps in human capacity and accomplishment change our whole reality and disturb pretty much every settled industry. They change the manner in which we travel, cooperate, communicate, business with one another, even think. All that we once knew is flipped on its head and life gets improved, making things a lot less demanding and

progressively productive. The same is the appearance of Blockchain technology where the component of trust is the whole sudden put under the control of target numbers and PCs. Blockchain is the initial step at placing trust into PCs. Sounds kind of terrifying and we would state that it is. Rest guaranteed however, the seasons of skynet and eliminators are far away and except if we create methods for keeping self-aware robots from turning into a reality, at that point we ought to be safe. In a vibrant and large democracy like India which holds the title of conducting the biggest electoral practice in the world, issues of political mayhem and electoral malpractice are becoming grim year after year with this once considered a holy festival of our republic touching its low ebb (Cachin, 2016; Rathee et al. 2019). It is needed to ensure fair and free election across the globe in democratic countries, by allowing voters safety to cast their free decisions. In democratic countries, voting is a process where people choose their government by making their decisions through registration and cast their votes (Tsang & Wei, V.K, 2005; Christian & Carter, 2005). However, it is much necessary to avoid manipulations and provide integrity during voting process. Further, security and privacy of voters during their voting casts where paper based scheme was used before introduction of EVM. The EVMs or Electronic Voting Machines came into being, that had marvelous advantages over paper ballots however, voters have to cast their votes at polling stations only (Zissis & Lekkas, 2011; Moynihan, 2004; Keller, 2006). Elections anywhere in the world are a very daunting affair where individuals use every kind of manipulation to gain seats in the office. In India especially, some of the risks involved is voter manipulation, spreading of fake news, hacking and extreme files of violence basing damage to property and life. EVM counters many such issues for example Bogus voting, cost saving and providing faster result but there is still room for expansion and more security. Blockchain can play a very important role in ensuring that the voters registering their votes are legit and the vote counts are not manipulated in any way. Further, it is desired in current times where the world is accessible to people in their smart phones to also offer them the chance to register and cast their votes irritate free via their smart phones without worrying about the system receiving hacked. Blockchain is a distributed ledger that stores information in the form of blocks where each block associated to the next via cryptography (Yavuz, 2018; Goguen & Meseguer, 1984). It is distributed, decentralized and immutable that makes it nearly unfeasible to tamper with. When blockchain is applied in the procedure of voting will have a proper user account for every valid Voter ID holder and will therefore nullify the risk of a single person voting multiple times. Also, once every individual has an application in their smart phones, it is not requisite to stand in long line in the polling stations and panicking any kind of poll aggression. It will provide a kind of transparency that will not let the results be questioned and provide a new poise to the voters as depicted in Figure 1.

Figure 2. Proof-of-work using Blockchain in voting application



Blockchain technology is still without a doubt so in its earliest stages. Blockchains are moderate, user unfriendly, unscalable, and costly. For instance, DApps created on Ethereum require the end user to initially buy Ethereum and afterward pay a transaction fee each time they accomplish something in the DApp. Then again, EOS expects developers to buy over the top expensive RAM to build up a DApp while the users get transaction fee, simply after the user gets some EOS, downloads an EOS wallet from github, makes a key pair and sends EOS to that key pair. Not to speaking to the average consumer who could think less about decentralization. The fact of the matter being that Blockchain technology needs to develop before mainstream adoption happens (Hjálmarsson, 2018; Aitzhan, & Svetinovic, 2016). UI will be absolutely critical thus will administrations. A Blockchain that takes care of an enormous real-world problems, finds a harmony among decentralization and administration while giving speed, scalability, cost viability, and an overall smooth user experience will be the Blockchain that ascents above them all. 2018 was an incredibly dynamic year for Blockchain and crypto currencies. Numerous jumps in advancement were made and Blockchain is entering the worldwide awareness increasingly every day (Wüst & Gervais, 2018; Taylor et al. 2019). The subject of mass selection is when, not in the event that it occurs. We unquestionably observe this occurrence very soon, however as things remain at the present minute, the Blockchain space still makes them develop agonies to traverse. All the weaknesses of the Blockchain can be removed using three different consensus protocols named proof-of-work, proof-of-stake and proof-of-useful-work. A brief summary of these three protocols are given in Figure 2.

The proposed layout is based on a smart contract, using Ethereum to generate an e-voting app. The users have to create an account with proper confirmation done via id and other biometric schemes. Every transmission done via this account which in this case will be registering vote will be verified by a miner. The miner further has taken into account the voter's permanent address depends on voter id and thereby conveying that vote to a vote pool of that constituency. Every vote registered will be done via biometric schemes and the miner will verify the authenticity of the vote. This will counter the issue of bogus votes. Biometric data will remain in the peer to peer network and will be very difficult to obtain otherwise. Once the election date of the electorate has passed and there is any other vote registered, the miner may cancel the request. Similarly, if the biometric authentication has failed for the user, the request will be cancelled by the miner.

The remaining organization of the paper is defined as follows. Section II illustrates the literature work. The e-voting application using blockchain technology is described in section III. Further, the performance metrics of e-voting application is presented in section IV. Finally, section V concludes the paper.

RELATED WORK

This section illustrates the number of security methods in voting procedures proposed by several scientists/researchers. For instance, Salahuddin et al., 2018 have projected an agile and softwarized system for providing a secure, flexible and cost efficient, privacy IoT deployment system in smart healthcare services and applications. Further, kang et al., 2019 have proposed a blockchain enables security system by addressing the security and privacy issues among Internet-of-Vehicles (IoV). They have proposed a two-stage solution that is data verification and miners selection by designing a reputation based voting approach and past summary interactions. The selection of miners is done by analyzing behavior of each device and consulting their previous interaction before including them in communication process. The proposed reputation and blockchain based approach was simulated over different data sharing results in IoV. Though, wireless networks ensured a vital role in the support of IoT solutions, however, the comparison is not adopting them properly. The reason of not adopting the IoT with wireless networks is various privacy and security challenges. Though researchers have proposed various security solutions to avoid these limitations.

She et al., 2019 have projected trusted approach using blockchain technique to identify the malicious behavior of communicating nodes in wireless environment. They have proposed a trust based scheme with the integration of blockchain to provide transparency and immediate identification of malicious devices. Further, the authors

have realized the detection of malicious devices through smart contracts and node's quadrilaterals. The simulated graphs depicted the efficiency that is able to trace and identify every single malicious behavior in real time environment. Moreover, the management and efficiency enhancements, several oil and gas companies have shifted towards digitalization by simply adopting blockchain. In addition, Lu et al., 2019 have reviewed the importance and usage of blockchain in oil and gas industries in several aspects such as trading, management, supervision and cyber security. Finally the authors have also highlighted the usage of blockchain at just in their initial levels because of their new systems, transformations and techniques.

Lamas et al., 2019 focused on reviewing various blockchain integrated applications by emphasizing on their security and privacy challenges. They have discussed various business models creating and car economy disruption and their solutions with blockchain integration. In addition, they have highlighted the threats, strengths and weaknesses by recommending various companies and guidelines in futuristic developments. Further, Jarodi et al., 2019 have focused on only one application of blockchain i.e. industries by highlighting or discussing various challenges, benefits and opportunities in other use cases also. They have highlighted various implementation requirements for integrating the blockchain technique in industries. The authors have integrated the blockchain usage in financial areas where digital payments for verifying the financial transactions deployed on various proxy nodes are integrated through blockchain mechanism. They have projected several probability based metrics for realizing the rigorous operations and demonstrated the feasibility with near field communication on raspberry pi mobile wallets and mining nodes applications. For reducing the redundancies and inconsistencies in voting phenomenon, e-voting has altered traditional voting schemes. However, the e-voting further leads to several security and privacy issues with the growth of time. Shahzad & Crowcroft, 2019 have applied blockchain in voting procedures by block sealing to provide transparency. The proposed approach described the hash utility, information accumulation, polling generation, creation, sealing in blocks till the declaration of results. The proposed scheme has claimed the security and management of issues by ensuring an enhanced digital voting approach. Kdhetri & Voas, 2018 have projected a blockchain based e-voting process by increasing the access rights to voters and reducing the access rights to other entities. The registered voters are allowed to casts their votes through online such as computer based or smart phones through blockchain. The authors have presented a proof id of each voter's to ensure transparency during votes. The proposed scheme is further highlighting various potential challenges. Further, Anjum et al., 2017 have discussed and illustrated several blockchain use cases to highlight their importance in today's era. They have tracing of products, smart healthcare, industries and other verification processes. Though the continuous increment of shifts in health services, information is secured by limiting their access rights and

applies crypto schemes to further identify privacy and security concerns. Further, the authors Esposito et al., 2018 have projected the blockchain usage that may clearly provide the security in health services over the clouds. In addition, Espocito et al., 2018 have described the potential issues with their future perspectives.

PROPOSED SOLUTION

Our application determines the vote count of the voter for certain people who are to be selected. Firstly, in this application, we determine the illegibility of the voters using blind signatures. For high availability and result immutability of privacy using double private block chain and using bit coin logic to redesign transactions and new protocols to cast a vote. The proposed system will contain 1) Anonymity, 2) Check flag for voter's illegibility, 3) Voting integrity with the system and 4) Vote Verification.

Different Phases in the System

Publishing phase

It's a dummy approach to publicize the system and generating candidate ballots. The Authority has eligible bling signature which are communicated securely to prevent any attacks like DOS, Men-in-the-middle Attack

Login phase

After the publishing phase, the voters will login and then verification will be done for eligibility. This phase also deals with the impersonation and EIDs establishment.

EID generation phase

This phase will be used to generate public private key for electronic identity. For every identity made, an EID password will be established in order to prevent tampering and impersonation. Generation of OTP can also be done.

Voting phase

For the generation of Block chain transactions, our Voting phase will ensure data consistency and isolation.

Figure 3. Implementing blind signatures



Blind signatures

These digital signatures are heavily used in our application for transactions working. Eligible voter sign and extract public and private keys and encrypt them in Ballot. This Ballot is sent to Electoral Authority (admin) and verifies the source of the ballot, removes outer envelope and Encrypt the keys and sends back to the eligible voter as depicted in Figure 3.

System Protocol

This phase depicts the working of voting application using different phase.

Threat Model

Various models have been taken in care for the full functionality of the Block chain without any foreboding of threat initiation. As Block chain helps with Decentralization, and impenetrable security level, various threats are seldom to be seen. Some of the most common threats are DDoS Attack, Sybil Attack, Freak Attack, Malwares, Cross Site Scripting (Xss) etc. the compete proposed solution of e-voting through blockchain is depicted in Figure 4.

Evaluation

After the completion of the project, we will study all the sufficient properties of the proposed system design and these are availability of the project, Integrity with the OS and web page, Uniqueness, Accuracy, and Election secrecy.

Figure 4. Proposed complete Solution



Some Other Security Analysis and Legal Issues

Security Analysis

i. DDoS: For the application to fail under DDOS Attack, the attacker must perform it on every node in the network. But tampering with the boot nodes will eventually inform the institution and the location could be found out. For locating failed blocks, we can use fault tolerance algorithm
ii. Authentication Vulnerability: As the value of the hash will be unique to each and every individual or eligible voter, there is seldom chance of multiple voting process by the voters. This will not only helps with the ease to finalize the output result with incrementing by +1, but also eradicates out the total chances of the system malfunctioning.
iii. Sybil Attacks: The consensus algorithms implemented in the project are prone to these attacks. Furthermore, with the incoming of the strong cryptography features and limited access to the ledger, Block chain solves today's most often security problems

Legal Issues

i. Transparency: No method of transparency can be offered to the voters in today's electoral scheme. Without some other tech involvement, the transparency In the system is a very tedious task with formulation of new law by government officials.

ii. Voter Privacy: Voter privacy in pen and paper scheme is meandering which may involve leakage of voter credentials and vote to the party or the candidate. To satisfy the privacy, initiation of non-traceable vote will be prominent to implement.

iii. Remote Voting: To prevent coercion resistance in the election, remote voting could be of good use. If the results can be used in websites, or mobile applications, there is no chance of misconfigured results, but on the negative side, people with good hacking skills can take down host website and different threats can be introduced. This requires security. We can use Block chain features to subdue these affects.

Comparison

Traditional Blockchain Solution: In the traditional Blockchain solution, we can observe the common implementation of lit coin, dash, ripple and many other programming languages based bit coin implementation. There is less privacy though, if implemented in suitable domain of programming languages.

Proposed Blockchain Solution: Our platform implements all the solution in Ethereum, solidity and other bitcoin consensus protocols to be in use, usage of RSA algorithm can also be implemented with the generation of private keys. Table 1 depicts the comparison among traditional and proposed blockchain voting application.

As the scope of this paper does not end till execution as more functionality can also be appended such as login-logout scenarios, more data related storage for large count of voters.

Table 1. Traditional Blockchain Solution Vs Proposed Blockchain Solution

Traditional blockchain solution	Proposed blockchain solution
Operated with decentralized property	Operated with decentralized property
Programming tools: Native Programming Languages (Java, Python, C++, ASP.NET, C#)	Programming tools: Ethereum, Solidity, web3.js
Time of Transaction: Minutes	Time of Transaction: Seconds
Implementing client server architecture and RDBMS	Facilitates P2P architecture and smart contracts; no RDBMS required

The main idea of proposing this Blockchain solution for voting system is to make electoral system cheaper and quicker. By doing this, the barrier between voter and officials to be elected will be an endgame. Furthermore, with the ease in operation, we can assure a direct form of democracy as people will be in more ease

to use it and give a better result in return without any involvement of central agency. In the report, we implemented a simple voting application using smart contracts (solidity, Ethereum) for proper conduct of system execution while maintaining security features like privacy and authentication verification. By comparing with the current process of electoral system, we can observe that block chain technology has a new future for democratic countries where most of it are pen and paper based. Using the Ethereum private block chain, we can transmit hundreds of transaction in one second, for countries with bigger democracy; this system can provide well executed result with seldom chances of result tampering. With the use of modern hash algorithms makes the data fetching impenetrable and isolated within each and every block. Decentralization has made the platform much more secret and private than that of centralized systems. Our proposed system will ensure that all the block chain concepts will be executed properly resulting in better approach to implement the platform practically in the provinces or the region.

PERFORMANCE ANALYSIS

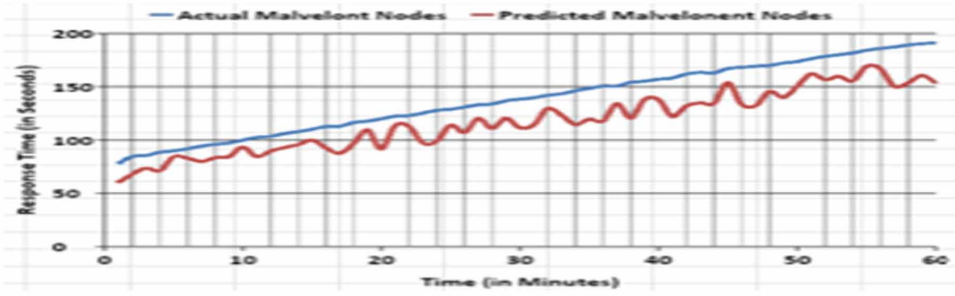
System State

For providing the verification and validation of proposed approach, the numerically simulated results are verified over NS2. The analyzed metrics are analyzed against various security measures over various metrics. Though, security analysis of e-voting is considered to be a very challenging task. In this manuscript, we have proposed a blockchain based voting method which not only ensures node's security but also provides transparency in the network. In the proposed voting frameworks, network simulator version 2.5 having predefined various nodes is executed. 500*500 network area is generated having various numbers of nodes. Further, for verifying the security procedures, nodes metrics are measured where most of them are hacked by various attackers. The malevolent devices are further added on probability basis. The response time and accuracy based on malevolent node prediction is analyzed against varying number of nodes. The execution of proposed framework is accomplished for one minute.

Evaluated Performance Metrics

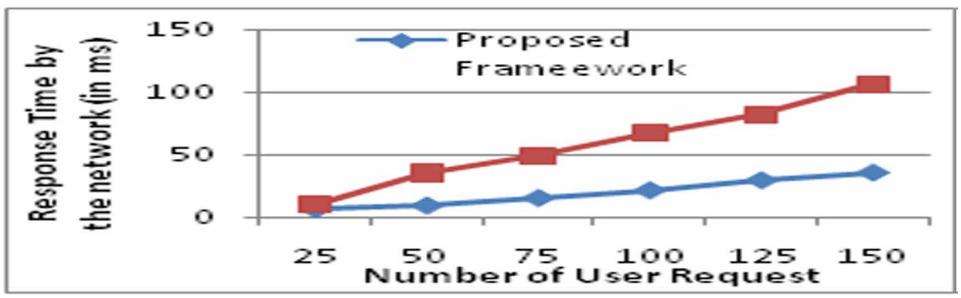
Number of measuring parameters such as response time, accuracy, number of processed request and resource utilization are evidenced on mentioned test bed. The depicted figures represent proposed and traditional mechanisms over certain metrics. The depicted graphs 5 and 6 shows the accuracy and response time of

Figure 5. Accuracy to predict malevolent nodes



detected malicious nodes over varying number of nodes. Proposed scheme close to 83% accuracy against malevolent system is predicted. In addition, it is supposed the response time of proposed approach augments better results than traditional mechanisms. Traditional approaches are not able to productively able to guarantee transparency that may further cover way to reduce response time and accuracy of individuals who cast their voters and voting counts. Whilst proposed mechanism that is based on Blockchain that successfully able to remove and detect the malicious activities of devices.

Figure 6. Response Time with presence of malicious devices

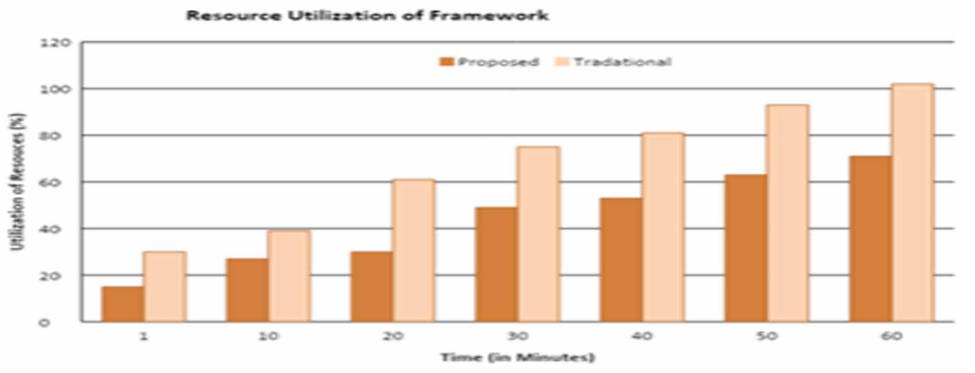


In addition, the transparent feature of proposed approach provides the trust among polling/ voting procedures. The framework analysis is further measured against resource utilization as revealed in Figure 7, 8. All the depicted figures clearly realistic that the nodes augmentation is linear and the processed requests also enhances linearly.

Proposed scheme is close to 83% accuracy for the malicious devices prediction which may be further enhanced if simulation runs for longer time. Further, it is

alleged that proposed scheme response time from sensors will augment as depicted in Figure 7 shows better values than existing system.

Figure 7. Resource Utilization in Fog Environment 1



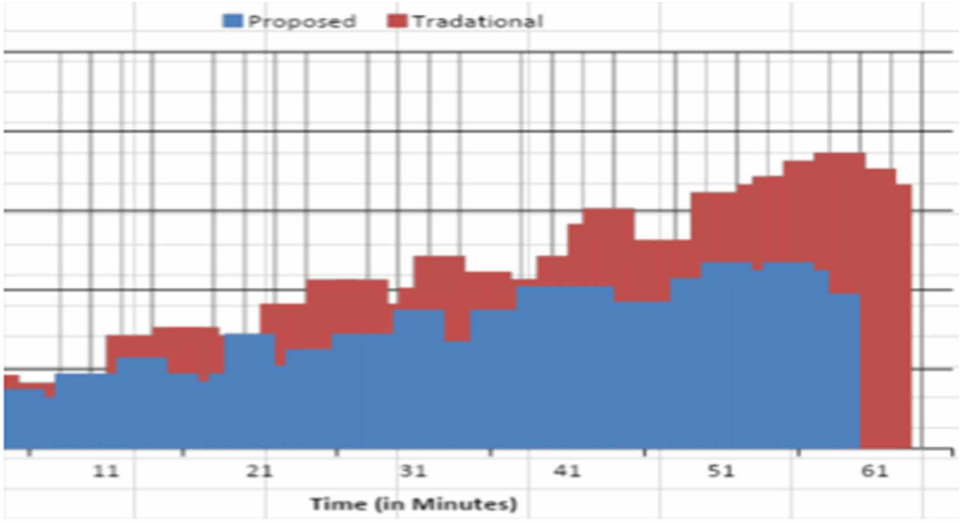
Here, traditional schemes are not efficient to identify or able to eliminate malevolent nodes from the environment that further escort to increase in response time of the traditional system. However, in proposed phenomenon that detects any malevolent node and able to instantly remove it from the network so that it does not obstruct the performance. This analysis further results in improved response time and resources utilization as revealed in Figure 6, Figure 7. Moreover, Figure 8 depicts the number of processed request by the proposed system regarding linear trend for all three networks. It can be clearly practical augmentation is linear the proposed requests also lead to linear time.

Discussion on Evaluated Results

The proposed and traditional voting schemes have been detected over various numbers of devices. The simulation evaluation is victorious where various several results over certain metrics were recorded. The evaluation of simulation conduction was victorious where numbers of concerned results against several parameters were recorded. The proposed blockchain based voting approach behaves as preferred having an optimized analyzed metrics over traditional procedures. In addition, the accuracy of Blockchain based on voting scheme enabled framework reached to 83% that can be further improved and superior over increased period of time. Moreover, remaining metrics such as response time, processed request during malicious environment provides better results. The removal and detection of malevolent nodes in proposed scheme is entirely based on Blockchain technique to provide transparency

and security among all the devices. Any alteration and change in polling process may immediately change the remaining polling stations and authorized individual's information.

Figure 8. Number of processed request by each network through a linear line



CONCLUSION

This manuscript has proposed a secure online voting mechanism based on Blockchain approach. The proposed framework provides the security by intimating and capturing each and every illegal and legal activity of the voters and counting EVM's. The proposed Blockchain voting framework has considerably enhanced the accuracy, response time, number of processed request and resource utilization against traditional mechanisms in the presence of malicious nodes. Furthermore, the simulated results of proposed scheme show 83% accuracy compared to traditional voting procedures. The real time situation where EVM can instantly detect the malevolent activity and blocked will be reported in future directions.

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Chapter · January 2019

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Chapter 3
Implementation and Performance Assessment of Biomedical Image Compression and Reconstruction Algorithms for Telemedicine Applications: Compressive Sensing for Biomedical Images

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ABSTRACT

Compression serves as a significant feature for efficient storage and transmission of medical, satellite, and natural images. Transmission speed is a key challenge in transmitting a large amount of data especially for magnetic resonance imaging and computed tomography scan images. Compressive sensing is an optimization-based option to acquire sparse signal using sub-Nyquist criteria exploiting only the signal of interest. This chapter explores compressive sensing for correct sensing, acquisition, and reconstruction of clinical images. In this chapter, distinctive overall performance metrics like peak signal to noise ratio, root mean square error, structural similarity index, compression ratio, etc. are assessed for medical image evaluation by utilizing best three reconstruction algorithms: basic pursuit, least square, and orthogonal matching pursuit. Basic pursuit establishes a well-renowned reconstruction method among the examined recovery techniques. At distinct measurement samples, on increasing the number of measurement samples, PSNR increases significantly and RMSE decreases.

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INTRODUCTION

With the advancement in information and communication technology, data traffic generates noticeably massive amount of information data especially in biomedical area. Radiological medical imaging methods (MRI and CT-Scan experiments) are used to inspect and analyze the inner structure of human body. These methods generate a large amount of scientific information which is digitally stored in the form of medical image that can be easily accessible. Clinical imaging records are significantly high as a typical hospital generates terabytes of information per year (Ravishankar & Breler, 2011). Clinical imaging data is certainly excessive and needs more storage space thus medical image compression is essential. Compression is a proficient solution for illustrating compact and robust data representation to facilitate efficient transmission and storage. File size is reduced, less bandwidth is utilized and the transmission speed is accelerated using compression techniques. Predominant goal of compression is to lessen the redundant and irrelevant bits of data for efficient data storage and transmission. Compression may be extensively categorised into two classes, Lossy and Lossless Compression. Lossy compression is appropriate for the applications where a slight loss of information is permissible like for natural pictures, text images, etc. For lossy compression techniques, compression ratio is high but the image quality is low. In case of lossless compression, the reconstructed image is the exact replica of the actual image as there is no data loss in lossless compression technique. Compression ratio achieved for this approach is not always high but the recovered image is of better-quality as compared to that of the lossy compression approach.

Data loss is not tolerable in scientific field like biomedical image processing as it can lead to wrong diagnosis. Many hospitals have small clinics situated in the far flung regions where distance is a vital issue to deliver the health care facilities. Patient residing in remote, rural and semi-urban areas find tough time to travel to far away hospitals particularly for diagnostic functions. For the convenience of patients suffering from severe diseases, the hospitals make use of telemedicine practices to provide health care facilitates in such areas. These tele-radiology applications allow the technician at the remote centres to capture a series of medical image data (MRI or CT scan) and transmit it to the principal health centre situated at the city where the diagnostic radiologist can examine the image and send back the diagnostic information to the clinical prognosis and the patients (Vijaykuymar, & Anuja, 2012).

In conventional image capturing systems, sampling is primarily based on Nyquist criteria wherein the original signal is sampled at a rate more than or equal to two times the maximum frequency of the signal. This sampling rate is too high for certain applications thereby increasing the complications in terms of complexity during compression. The increased rate of sampling adds directly to the complexity of the sensing hardware and this leads to wastage of power resources (Zhao, *et al*., 2017; Wiegand, *et al*., 2003). So, to facilitate the need of image compression for contemporary applications it is required to have a system with decreased acquisition complexity and flexible process for decoding. Compressive Sensing (CS) technique emerges as a new idea for signal acquisition, compression and reconstruction which has become main focus of researcher's interest. It is a far unique technique employing sub-Nyquist sampling criteria overcoming the drawbacks of the conventional strategies (Donoho, 2006; Candes, *et al*., 2008; Romberg, *et al*., 2006). CS utilizes the sparse signal recovery using fewer linear measurements and convex optimization approach for approximate recovery relative to standard schemes utilizing the complete ensemble of signal space (Candes & Romberg, 2007).

The concept of CS was at first introduced by Emmanuel Candes, collectively with Justin Romberg and Terry Tao (Donoho, 2006; Candes, *et al*., 2008; Romberg, *et al*., 2006; Candes, *et al*., 2007). Signals fulfilling the requirement of sparsity in any domain can be recovered using CS approach, may it be an audio, image or a video signal. In (Nahar & Kolte, 2014) it was seen that CS was a progressive approach for signal acquisition and restoration. The key advantages of CS are faster data acquisition from very few sparse samples, reduced computational complexity, low power transmission, small traffic extent, etc. X. Zhang, *et al.* have used Orthogonal Matching Pursuit (OMP) reconstruction algorithm in (Zhang, Wen, Han, & Villasenor, 2011) applying the set of rules to recover an image. It was found that OMP has negligible additional complexity however enabling overall performance improvement in the reconstruction. Combined sparsifying transforms were used in (Qu, Cuo, Guo, Hu, & Chen, 2010) to achieve CS for MRI imaging by enforcing the sparsity of image using Total Variation (TV), wavelet approach, etc. It was seen that smooth L_0 norm method have NP hard problem which was then replaced by Basic Pursuit (L_1) norm minimization. Predefined information was used in (Liang & Ying, 2010) for CS reconstruction that utilises partially known spatial and temporal frequency domains from motion patterns of MR images. Reconstruction was done using L_1 norm minimization technique which was the best approach for image sample recovery. A real time MRI recovery technique was proposed in (Majumdar, Ward, & Aboulnasr, 2012) and the residual (the difference image between the previous and the current image) was taken. M.M Sevak, *et al.* (Sevak, Thakkar, Kher, & Modi, 2012) have implemented wavelet transform for the generation of a set of sparse components and CS approach for compression and later they combined the two techniques. Various Non- Linear Mapping Techniques are compared with OMP technique in (Zhang & Wen, 2012). As compared to the other convex optimization approaches, OMP was less complex approach providing faster running speed, lower power consumption and optimal reconstruction. Guaranteed reconstruction was however provided by convex optimization based recovery algorithms. Scan time for MR image acquisition was improved by T.D.Tran *et al.* (Tran, Duc, & Bui, 2010). In this paper authors combines CS approach along with the wireless transmission mechanism which was based on 802.11 providing bit rate requirement at 11Mbps. An improvised L_1 norm reconstruction method for CS-MRI was proposed in (Chang & Ji, 2010) investigating the previously developed approaches like SMASH and SENSE recovery algorithms. A better recovery algorithm; L_1 norm minimization approach was used in this paper to provide precise details, sharp edges and accurate recovery for MRI image reconstruction. This approach yields lower Normalised Mean Square Error (NMSE) producing a better quality recovered image with less computation complexity. A new set of parameters consisting of different auxiliary measurements, low pass filter coefficients, ordering index, etc. are proposed in (Lakshminarayana & Sarvagya, 2016) for improving the performance of CS algorithm. Authors (Lakshminarayana & Sarvagya, 2016) show that L_1 reconstruction approach was used to recover the signal using the concept of sparsity. A better performance was achieved maintaining the trade-off between compression ratio and medical image quality as compared to the existing literature in this field. Some of the other state of the art literatures are summarized in Table 1.

The main motivation of this chapter is reduction in file size using CS approach for biomedical image compression so as to minimize the storage and bandwidth requirements. The main goal of this chapter is to find an efficient method for reconstruction of images and evaluate recovery algorithms to maintain the balance between image quality and compression ratio. A modified approach for better acquisition, compression and reconstruction using CS technique provides better reconstruction and least distorted compressed image.

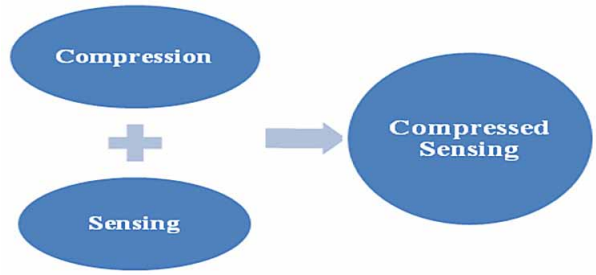
Table 1. Literature review of CS techniques

S. No.	Authors	Utilized Techniques	Implication Drawn and Estimated Parameters	Demerits
1.	(Shiqian M., *et.al.*, 2008)	L_1- norm minimization, Total Variation approach and Wavelets	Error of image and Signal-to-Noise-Ratio	Requirement of better image quality and storage space.
2.	(Nagesh P., Baoxin L., 2009)	Compressed sensing Technique (CS)	Recognition rate and percentage of storage space	Multiple views of scenes are used.
3.	(Wright J., *et.al.*, 2009)	L_1- minimization technique for sparse representation	Sparsity Concentration Index (SCI)	Detection of object is also required.
4.	(Sen P., Darabi S., 2011)	Compressive rendering for finding pixel values	MSE is evaluated. Scheme gives better quality reconstruction.	Sampling densities employed are very less.
5.	(Jing C., Wang Y., & Hanxiao W., 2012)	Real time video surveillance CS tracking and motion detection algorithm	Better recovery at high resolution for fast tracking utilizing less storage space.	Outcomes are not evaluated on benchmark datasets.
6.	(Hemalatha R., *et.al.*, 2013)	BinDCT and Noiselet based CS approach is utilized for Energy consumption analysis	Compression ratio, PSNR and reduced bit rate	More energy consumption reduction is required.
7.	(Yipeng L., *et.al.*, 2013)	Biomedical signal recovery using L_1-Total Variation approach and Nuclear norm minimization	Technique employed provide accurate signal recovery and Mean L_1 error is evaluated	Outcomes are not evaluated on benchmark datasets.
8.	(Tremoulheac B., *et.al.*, 2014)	L1 norm minimization with Fourier transform in temporal direction and Alternating Direction Methods of Multipliers (ADMM)	Normalized MSE for intensity and motion	Method is not optimized and run-time elapsed is more.
9.	(Xie S., Guan C., & Lu Z., 2015)	ADMM with variable splitting strategy	MSE is calculated	Datasets are not standardized and approach is computationally complex
10.	(Zhang Q., *et.al.*, 2016)	CS theory is applied from down-sampled l-space data and a wavelet tree-based recovery algorithm is proposed	SNR is calculated for MR images	Can be extended for recovery of dynamic MR sequences
11.	(Bilala M., *et.al.*, 2017)	L1 norm approximations are employed	SSIM, Gaussian noise level in MR images, RMSE of recovered MR images	Complex architecture
12.	(Shrividya G. & Bharathi S.H., 2018)	CS-MRI technique is used along with Total Variation algorithm	MSE, PSNR, SSIM and Sampling percentage of MR images	SSIM value can be improved more to get quality

COMPRESSIVE SENSING

CS plays a significant role in numerous fields like biomedical, scientific imaging and satellite imaging to reconstruct the signal using fewer samples (Foucart, *et al*., 2013; Madhukumar, *et al*., 2015). CS techniques produces better results in terms of high imaging speed, high Compression Ratio (CR) and better quality image (Wang, Bresler, & Ntziachristos, 2011). This technique exploits the samples of sparse signal of interest rather than collecting the entire ensemble of signal samples (Baraniuk, 2007). CS approach intend to acquire sensing and compression in a single step by converting the sensing paradigm (Madhukumar & Baiju, 2015). Figure 1 shows the block diagram of CS technique which is the combination of sensing and compression.

Figure 1. Block diagram of Compressive sensing



Sensing and Sampling

Sensors are used to sample and analyse the signal by taking a linear measurement of signal space. The whole ensemble of this signal space is not exploited for CS recovery but the CS technique works on alternating present vectors using already known vector space. This sampling consists of measurement samples having decreased dimensions than the original signal. Let the highest frequency component f (in hertz) is maximum for an analog signal then according to Nyquist, the sampling criteria should be at least $2\times f_{max}$, or twice the highest frequency component. If the sampling criteria is not fulfilled or if the sampling rate is less than the twice of maximum frequency component then highest frequency components does not provide the correct representation of an analog input signal.

The sub-Nyquist sampling has involved a lot of concentration in both fields of mathematics and computer science. Sub-Nyquist sampling, also known as compressed sensing refers to the problem of recovering the signal by its samples. It can also recover the signal from the fewer samples than required by Nyquist sampling criteria. Recovery principles involved in Compressed Sensing approach to recover the signals are briefed in the next section.

Principles of Compressive Sensing Reconstruction

The two recovery principles involved in CS recovery are Sparsity and Incoherence. To implement CS theory, signal of interest is represented by sparsity and an isometric property of incoherence which limits the sensing modality.

Sparsity

Sparsity expresses an idea, that a continuous time signal has the rate of information much lower than expressed by the signal bandwidth. Similarly for a discrete signal to be sparse, the degree of freedom should be much lower than the finite length of the signal. Sparse signals have many zero coefficients and few non-zero coefficients. Fewer non-zero coefficients consist of majority of signal information and the other coefficients are not exactly zero however having very less value. Signal estimation for a sparse signal is done by considering only the larger coefficients consisting of majority information and other least significant coefficients are ignored during computation (Park & Wakin, 2009). A signal can be sparse or compressible having a concise representation in a proper sparsifying (Ψ) basis. Threshold-

ing algorithms also depend on sparsity to estimate the signal. For systems of linear equations, sparse approximation theory deals with sparse solutions. Several variations for sparse approximation problem are structured sparsity and collaborative sparse coding.

1. **Structured Sparsity:** In the original version of sparsity, any of the coefficients of the problem domain can be selected but in case of structured sparsity model, group of coefficients are chosen instead of picking individual coefficients (Eldar, Kuppinger, & Bolcskei, 2010).
2. **Collaborative or Joint Sparse Coding:** Original version of the problem is defined only for single signal but in collaborative sparse coding a set of signal is available and each of them is converged from the same set of coefficients (Tropp, Gilbert, & Strauss, 2006).

Incoherence

The duality between time and frequency domain is expressed by incoherence which basically presents the idea that the signal having sparse representation in sparsifying domain (Ψ) and must be spread out in the sampling domain in which they are acquired. Incoherence for sparse signals is implemented through isometric property. Coherence basically evaluates the maximum correlation between any two elements of entirely two different matrices. Incoherence refers to the property which signifies that there must be minimum correlation between the elements of two different matrices. Considering two different domains, a signal is considered to be compressible if it has high sparsity in Ψ domain and is incoherent in sampling domain (Baig, Lai, & Punchihewa, 2012). Low correlation enables the signal reconstruction of sparse signal with few samples whereas it is impossible for high correlation samples regardless of signal sparsity.

Imaging Modality

A particular imaging technique or a system in the area of Computed Tomography Scan (CT-Scan), nuclear medicine, ultrasound, projection radiography and Magnetic Resonance Imaging (MRI) is termed as imaging modality. Modalities like CT-Scan, projection radiography and nuclear medicine make use of ionization to visualize the interior human body structure. High frequency sound signals are fired into the human body for ultrasound imaging and the echoes are received from the structures within the body. High strength magnetic field and radio waves are combined to acquire MRI images and it exploits the property of nuclear magnetic resonance. The main tool used in biomedical imaging field for acquiring the interior structure of human body is MRI. Notable visualization of human body and its contrast mechanism is employed to obtain the body structure using MRI scan (Ravishankar & Breler, 2011). MRI is different from CT-Scan as this process does not use radiations and CT-Scan uses ionizing radiations which can harm the human body. MRI provides the detailed view of human body which is not indicated in X-Ray, CT-Scan or ultrasound images. Magnetic resonance imaging approach provides better contrasted image and clear diagnostic quality than other imaging modalities like X-Ray and CT- Scans.

MRI Scan

MRI imaging utilizes magnetic resonance scanners exhibiting the properties of Nuclear Magnetic Resonance (NMR). The nucleus of the hydrogen atom tends to align itself in the presence of strong magnetic

field. As the vast numbers of hydrogen atoms are present in the human body, it leads to net magnetization of the human body structure. Selective excitation of different regions within the body is also possible by inclining the group of these magnets away from the magnetic field direction. General categories of MR-Scanners are functional MRI (*f*MRI) and Magnetic Resonance Spectroscopic Imaging.

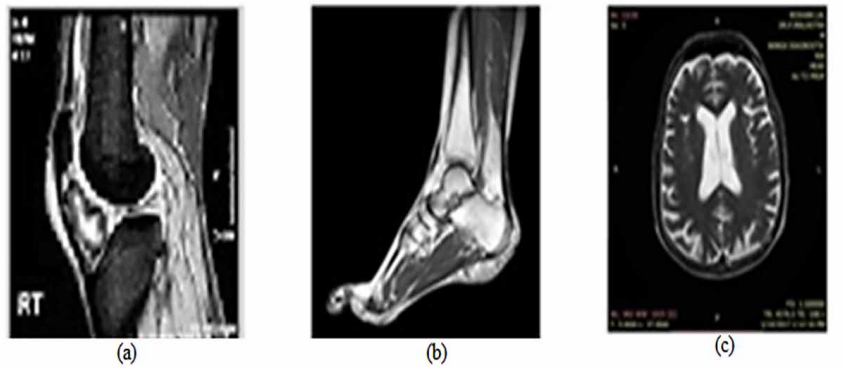
1. **Functional MRI (fMRI):** This scanner, images the blood oxygenation of the human brain by using oxygenation sensitive pulse sequence. fMRI employing an advance MRI in such a way that blood flow is increased to activate regions of brain. Standard MRI-Scanners do not actually detect blood flow as fMRI.
2. **Magnetic Resonance Spectroscopic Imaging:** It is termed as a non-invasive imaging technique as it gives spectroscopic information along with the image. Besides imaging the hydrogen atom, other nuclei are used for magnetic resonance spectroscopic imaging. This can be used to infer the cellular activity information from the human body. Different MRI scan images (leg, foot and brain) are shown in Figure 2.

CT-Scan

CT-Scans make use of X-Rays which are collimated (restricted in their geometrical spread) to travel in a 2D 'fan-beam' approximation. Tissues in the 2D cross-section of the human body create the X-Ray beam which is detected by a number of small detectors. The projections of X-Ray beam are collected from varying angular orientations of the detectors and the X-Ray tube as they rotate around a stationary subject (patient). Different CT-Scan modalities are helical CT and multi-slice CT which are currently being used for 3D imaging.

1. **Helical CT:** This CT-Scan modality is named as helical CT because the X-Ray tube slices out a helix. The detectors and the X-Ray tubes rotate around a circle and the patient is also continuously moving through the circle's center. It can acquire 3D Scan of the whole body very rapidly (in less than a minute).

Figure 2. Different MRI images (a) Leg MRI, (b) Foot MRI, (c) Brain MRI



2. **Multi-Slice CT:** It consists of several rows of detectors to speedily gather a cone of X-Ray data which comprises of 2D projection of patients. The quick rotation of X-Ray source and the detectors helps to produce 3D images using CT-Scanners. The different types (leg, foot and brain) of CT scan images are shown in Figure 3.

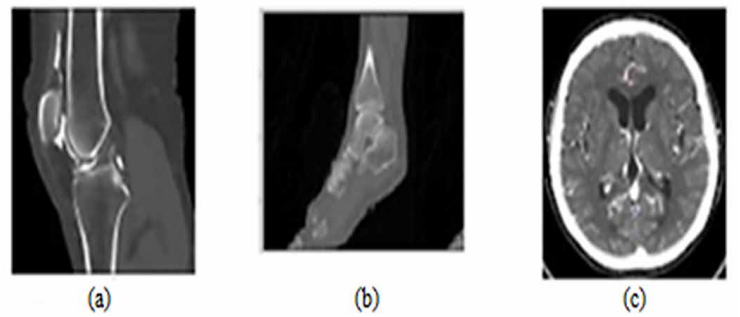
Compressive Sensing for Medical Images

Biomedical technology is progressing and clinics need to store huge volume of medical data in the form of images and signals to diagnose the current condition of the patients. A standard 12 bit X-ray of size 2048×2560 pixels interpreting 10,485,760 bytes of file size is very huge (ME, et al., 2012). Storage and transmission problem of higher quantity of data can get a breakthrough if the biomedical images are compressed in such a way that not only better quality image is obtained but also less transmission time is required without utilizing high bandwidth.

CS shows the considerable development in the field of biomedical engineering. As an improved framework for sampling and recovery, it is implemented on sparse signal of interest (Liu, Liang, Liu, & Zhang, 2012). In widespread mechanism, radiological images are captured from coupled devices which differentiate it from other information capturing mechanism. Because of presence of external artifacts, massive quantity of noisy data is also present within the informative data which is not required for diagnostic process. As the data is subjected to compression, medical information is compressed along with the undesirable noisy data, but in case of CS, only the desired information is decomposed (Wang, et al., 2011). Medical images like MRI and CT scan takes a long scanning time and these scans are indicative of patient's coronary heart rate, breathing pattern and position which may change time to time leading to degraded diagnosis quality. CS might also reduce poor effects of heart rate variation, pattern of respiration and also reduces the imaging time providing appreciated involvement in medical imaging field (Sevak, *et al*., 2012).

After applying CS for compression the original medical image is also needed to be recovered and its quality is to be assessed so that these images can be utilized for diagnosis purpose. For this reason different recovery algorithms are implemented and their performance is assessed based on image quality parameters and compression ratio.

Figure 3. Different CT-scan images (a) Leg_CT Scan, (b) Foot_CT Scan and (c) Brain_CT Scan



Recovery Algorithms

For optimal reconstruction of signal certain key requirement which should be satisfied are stability, speed, uniform guaranteed reconstruction and efficient performance. Convex optimization technique has gained the popularity due to its better efficiency, highly accurate reconstruction and guarantees the successful reconstruction (Liu, De Vos, Gligorijevic, Matic, Li, & Van Huffel, 2013). Numerous reconstruction strategies are available in the literature and they are detailed below.

Minimum L0 Norm Reconstruction

The exact solution of linear equations for minimum L_0 norm minimization is guaranteed by defining a set of rules. For a signal which is sparse in spasifying domain, the precise recovery is possible by using $2m$ random measurements. Every combination in m-sparse vector space is checked to find the exact solution in an N- dimensional space to satisfy the linear system of equations. This reconstruction technique is complex to implement and leads to NP-hard problem (Satyan, 2013).

$$\min \left\| x \right\|_0 \text{ subject to } y = \Phi \times x \tag{1}$$

here x is the original signal, y is the measurement vector which is obtained by multiplying measurement matrix Φ with the original signal x.

Basic Pursuit (L1 Minimization)

It is a convex optimization technique which is also termed L_1 minimization and it provides guaranteed recovery over sparse domain. L_1 minimization technique is not a speedy technique as massive numbers of iterations are involved in this method but it provides robustness for approximating the sparse signal. This technique is not optimally rapid but conversely it is a favourable approach as it gives better quality of reconstruction (Bhatt & Bamniya, 2015). As per the definition of the norm, L_1-norm of signal x is defined as,

$$\left\| x \right\|_1 = \sum_i \left| x_i \right| \tag{2}$$

L2 Norm Minimization

L_2 norm minimization reconstruction algorithm finds the minimum energy solution for minimizing the system of equations. This approach is easier to implement as compared to any other recovery algorithm but the solution provided by this approach is not accurate. Pseudo inverse is calculated to find the solution of L_2 norm but the calculated solution is far away than the optimally correct solution producing the undesired aliasing effect (Candes, *et al*., 2006; Blumensath, *et al*., 2009). L_2-norm is also well known as Euclidean norm, which is used to measure a vector difference and its equation is given by,

$$\left\|x\right\|_2 = \sqrt{\sum_i x_i^2} \tag{3}$$

Minimum Total Variation Reconstruction

Total Variation (TV) minimization is a modification in L1 minimization technique that is especially successful in case of imaging applications. It is considered that the image is sparse in its gradient and therefore the image has very few variations in intensity.

$$\min \left\|s\right\|_{TV}, \text{ subject to } \left\|\Phi s - y\right\|_2 \leq \in \tag{4}$$

Eq. (4) defines the TV-minimization reconstruction approach for recovering the gradient sparse signal and here s denotes the transform vector containing k non-zero coefficients, Φ is the measurement matrix, y is the measurement vector and ϵ denotes the upper bound of tolerance for reconstruction error energy (Candes, et al., 2006).

Greedy Method

Compressive sample matching pursuit, orthogonal matching pursuit and stage-wise orthogonal matching, etc. falls into the category of greedy algorithms. Greedy technique presents more rapid reconstruction than simple basic pursuit method but delivers least recoverable sparsity as compared to other reconstruction algorithms like L1 norm minimization. Greedy pursuit often provides uniform guarantee and stability but on the cost of quality. One of the most commonly used greedy algorithms for the recovery of nearly sparse signal is Orthogonal Matching Pursuit (OMP). For each of the new iteration, OMP works iteratively by initially choosing a column with the maximum projection onto the residual signal and then adding it to the already chosen columns. Once choosing a replacement column vector, representation coefficients with respect to the column vectors are chosen and observed through the least square optimization method. This method is not optimally stable but is a speedy reconstruction algorithm as compared to the other recovery approaches (Tropp, 2004).

For performance assessment of these recovery algorithms on medical images, various evaluation parameters are used and they are detailed in the next section.

Performance Evaluation Parameters

There are various performance assessment parameters. In this chapter we are using Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Compression Ratio (CR) and Structural Similarity Index (SSIM) for evaluation of CS recovery algorithms. PSNR is an image quality parameter calculated using MSE and these are inversely related to each other. Higher PSNR value indicates the higher quality of image. SSIM is based on arithmetical values of image and it is based on mean and variance and its value lies in between 0 to 1. The recovered image is structurally similar to the original image if its value leads toward 1. Ratio of compressed bits to the original image bits gives CR of an image (Bhardwaj, *et al*., 2017; Ji, *et al*., 2017).

Compressive Sensing: Scope and Its Applications

This section briefs about the various fields and applications where CS technique can be optimally used.

Biomedical Imaging

The technique of creating a visual perception or representation of internal body organs or tissues for medical evaluation and clinical intervention is referred as biomedical imaging. Clinical imaging seeks to reveal the inner body system detailing the pores, skin and bones which are used to diagnose and deal with the diseased body parts. Medical imaging additionally establishes a database of ordinary anatomy and body structure to make it viable to discover abnormalities. Thus better image compression is needed for screening and better diagnosis for biomedical imaging.

Telemedicine

Telemedicine practices allow the clinical services to be used from a distance by the means of modern telecommunication and information technology facilities. Electronic medical information is transferred over a distance to the main diagnostic centre where the information is processed and diagnosed.

Patients residing in the rural areas can take the benefit of medical care facilities without visiting the far away situated hospitals and this helps in removing the distance barriers. Therefore better image compression is required to serve this purpose of telemedicine facility without using much bandwidth and transmission time providing prompt clinical healthcare services.

Multimedia

Multimedia makes use of a combination of variety of contents like audio, video, images, text, animations, etc to make the multimedia applications more interactive. It is different from normal media applications, which makes use of basic conventional computer display like text-only, printed or hand-written material. Multimedia can be recorded, played, displayed, interacted with or accessed via facts content material processing gadgets, which includes automatic and digitally computerized gadgets, but also can be used as a part of live performances. Subsequently arising the need for better image compression to facilitate the multimedia applications to provide an ease to access various facilities.

Virtual Imaging or Digital Photography

An arrangement of electronic photo-detectors is used to capture images in virtual imaging or digital photography. This electronic photo detector is focused by a lens and is exposed on a photographic film to capture a digital photograph. The captured Images are digitized and stored as a computer file equipped with further digital processing, viewing, virtual publishing or printing equipments. Thus there is a need for higher image compression to aid virtual photography.

ALGORITHMS AND IMPLEMENTATION

In this chapter, CS technique is proposed for efficient compression, storage and transmission of MRI and CT-scan medical images. Dataset of MRI and CT-scan benchmark images is acquired from www.physionet.org to test the effectiveness of CS algorithm. For better image recovery different reconstruction algorithms are used and a comparative analysis is done. The following section gives a brief overview of CS algorithm and different recovery algorithms. Implementation and critical performance validation is also done in this section.

CS Algorithm

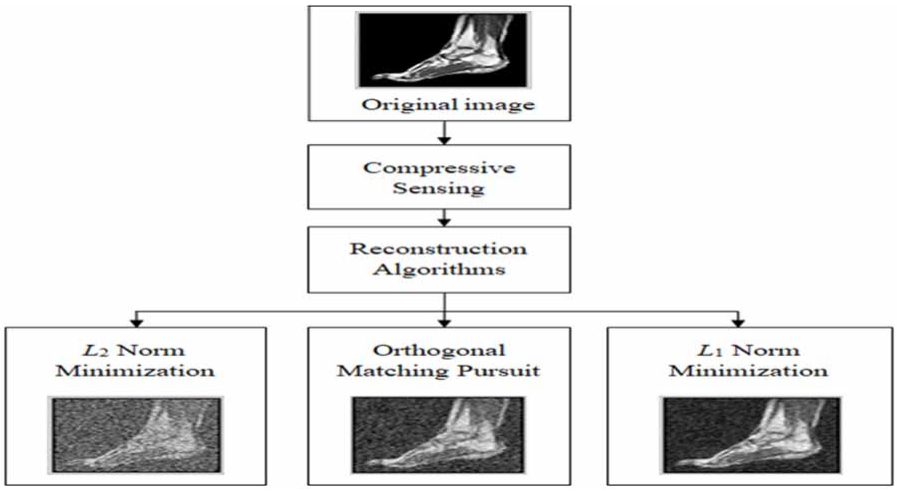
For the implementation of CS algorithm, consider an input image (x) of dimensions $n \times 1$ and a randomly generated measurement matrix (Φ) of dimensions $m \times n$. If Φ matrix is generated randomly, some useful information might become disoriented so Gaussian distribution is used for random variable generation having mean (μ) as 0 and variance (σ) as 1. Later x and Φ are multiplied to obtain the compressed sized measurement vector y having dimensions $m \times 1$. Steps followed for CS reconstruction are depicted in Figure 4.

Measurement vector y represents the CS sampling procedure and is computed by multiplying the measurement matrix Φ with the original image x.

$$y = \Phi \times x \tag{5}$$

The two main conditions which must be satisfied to recover an image using CS theory are illustrated below. Sampling process structure of CS matrices is depicted in Figure 5 and Figure 6 shows the complete arrangement of CS matrices.

Figure 4. Different steps for Compressive Sensing reconstruction



First Condition: Input image (x) should be sparse in some domain for the accurate image reconstruction utilizing few samples. For accurate recovery of an original image, x should fulfil the condition of sparsity i.e., it should be sparse in some domain. Let us consider a sparsifying matrix domain Ψ with dimensions (n× n) and a transform vector s having k significant non-zero coefficients (k<<n). The equation of sparisty is given by,

$$x=\Psi\times s \tag{6}$$

where, Ψ is the sparsifying matrix (n× n) and s is the transform vector containing k non-zero coefficients and k<<n.

Second Condition: The isometric property of incoherence should be satisfied by measurement matrix (Φ) and sparsifying matrix (Ψ) for CS recovery. Signal is more compressible if Ψ is incoherent to Φ and it is stated by the isometric property of incoherence [27]. Incoherence enables a sparse signal to be recovered using less number of samples. The condition of incoherence is denoted by θ in Eq. (7).

$$\theta = \Phi\times\Psi \tag{7}$$

The overall process of sampling is represented by θ' and it becomes,

$$\theta' = \Phi\times\Psi\times s \tag{8}$$

here, Φ is the measurement matrix, Ψ is sparsifying marix and s is transform vector.

Signal recovery for CS technique is achieved using minimization norm equation. By solving the Eq. (9), *x* can be recovered using sparse transform vector *s*,

$$x = \min\left\|\Psi^{-1}\times s\right\|_p \tag{9}$$

where, *Ψ* is sparsifying matrix, *s* is the sparse transform vector and *p* is the signal sparsity.

Figure 5. Sampling process structure of CS matrices

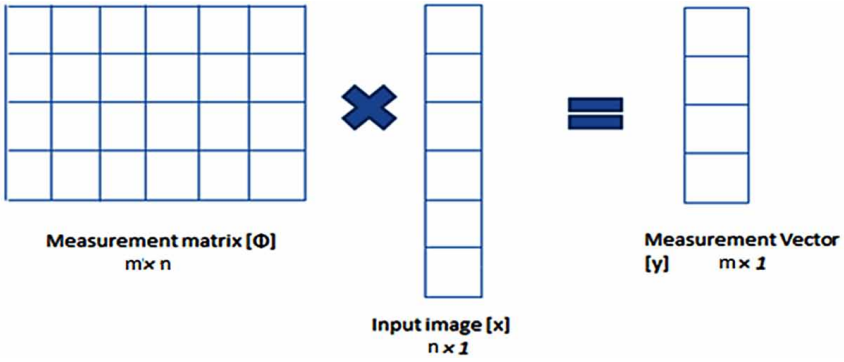
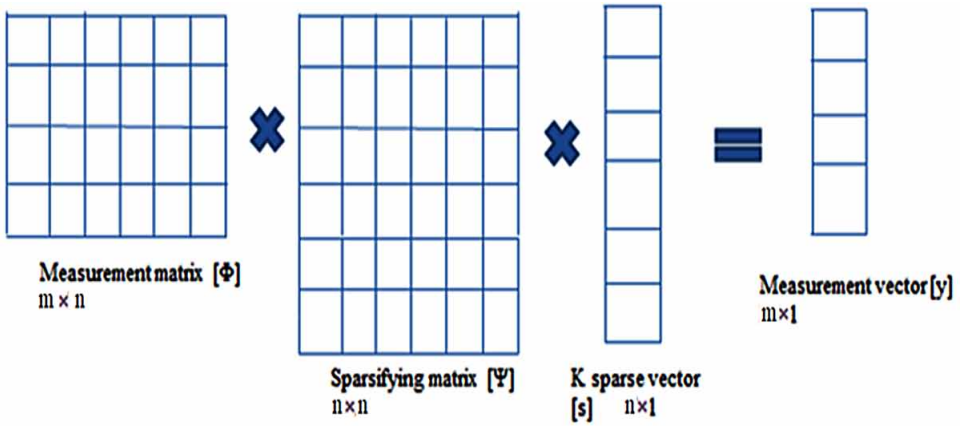


Figure 6. Complete arrangement of CS matrices



The above equation is reduced to L_0 norm minimization if $p= 0$ but it leads to NP hard problem. To resolve this problem, L_1 norm minimization technique is used for reconstruction.

Before analyzing two dimensional (2D) signals, CS is applied on one dimensional (1D) signal to validate the CS algorithm. Consider a 1D signal generated on MATLAB 2013. CS technique is applied on 1D signal having total number of samples (n) = 256 and number of peaks (P) = 6 are considered in the original signal. Keeping n and P constant, measurement samples (m) are varied to recover the original signal using fewer samples than the total number of samples ($m<<n$). Measurement Samples (m) are varied from 16 to 64 to analyze the accurate reconstruction and maintain a trade-off between the sampling rate and accuracy recovery.

Waveforms of 1D signal when CS recovery is applied are shown in Figure 7 to Figure 9 for measurement samples of 16, 32 and 64 respectively. In Figure 7 to Figure 9, x-axis denotes number of samples and y-axis denotes the amplitude of the signal. Three subplots in Figure 7 to Figure 9 represents the original signal, measurement samples considered and recovered signal respectively.

Signal reconstruction for varying number of measurement samples m is shown in Figure7 to Figure 9. It can be seen from Figure 7 that signal is reconstructed with visible distortions if m is considered as 16. On increasing the number of samples, accurate recovery is observed for m as 32 which can be seen in Figure 8. For the value of m ranging from 32 to 64, signal recovery is same as that of original signal. For better signal recover, m should be adjusted in such a way that there is balance between signal quality and sampling rate.

After analysis of CS technique on 1D signal it is applied on medical image samples (2D signal) and the images are recovered using three reconstruction algorithms (L_2 norm minimization, OMP technique and L_1 norm minimization). A detailed discussion of different reconstruction algorithms along with the results obtained are illustrated in the following sections.

CS Recovery Using Least Square Method (L2 Norm Minimization)

The commonly used method to solve the equation ($y = \Phi x$) and to find the minimum energy solution is L_2 norm minimization. The main advantage of this scheme is its simple implementation but it has a drawback that it does not provide the accurate solution producing the image with “aliasing-effect” [32,

Figure 7. Waveforms for m=16

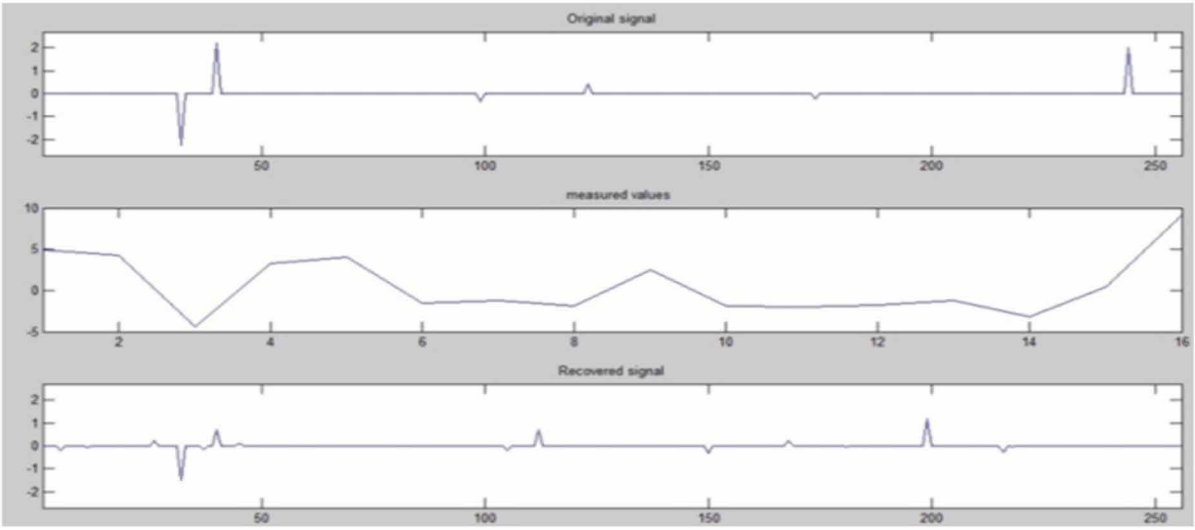
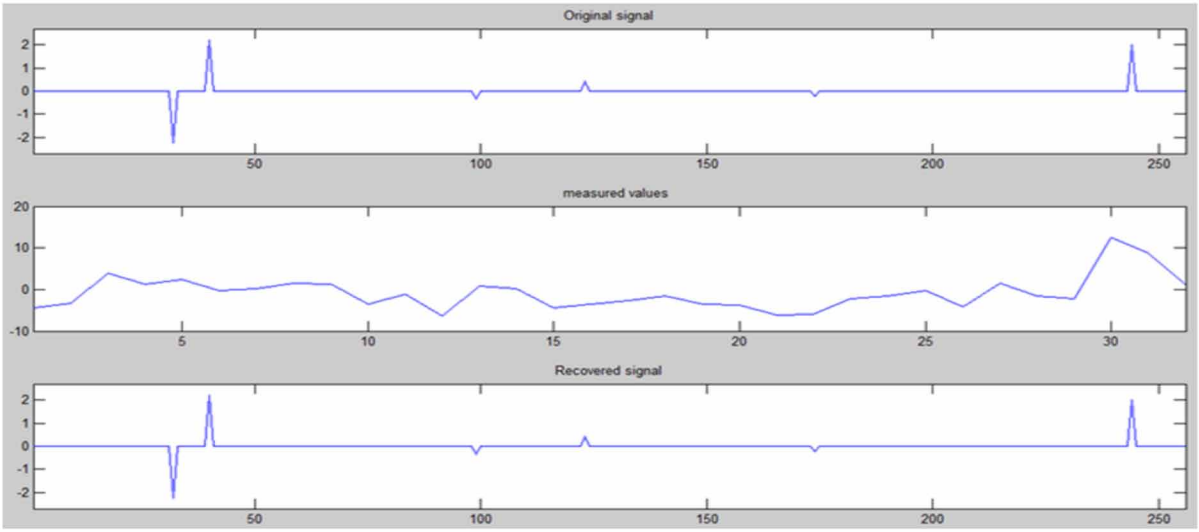


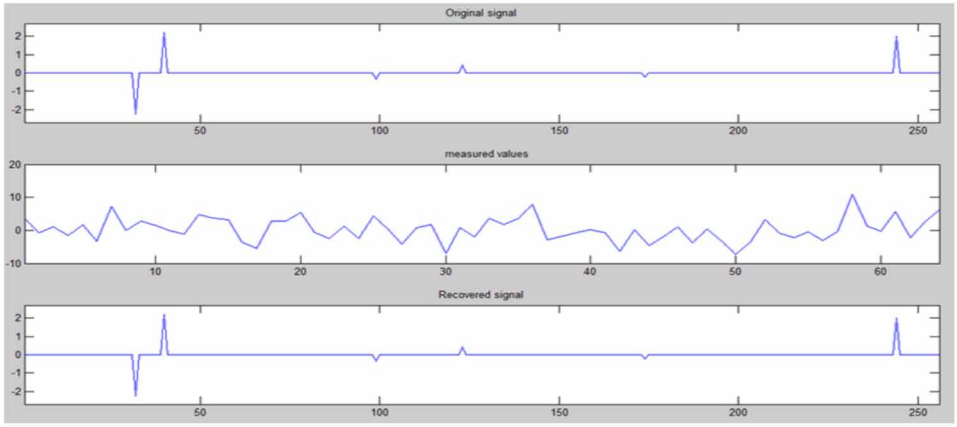
Figure 8. Waveforms for m=32



33]. This norm method works on the pseudo inverse based principle. L_2 norm minimization steps are detailed below;

1. Consider $y = \Phi x$ as the system of underdetermined linear equation where y is the measurement vector, x is the original signal, Φ is measurement matrix and $\Phi \epsilon R^{m \times n}$ here ($m<n$).
2. One particular solution for L_2 norm is given by the following equation ;

Figure 9. Waveforms for m=64



$$\tilde{x} = \Phi^T \left(\Phi\Phi^T\right)^{-1} \tag{10}$$

here $\Phi\Phi^T$ is invertible since Φ is a full rank matrix.

$\breve{x}$ is the solution of $y = \Phi \times x$ that minimizes x and provides the solution of optimization problem.

Figure 10 (a) depicts the original foot MRI image and Figure 10 (b) depicts the reconstructed image obtained using Least Square method (L_2 norm minimization). Figure 10 (c) and Figure 10 (d) shows the respective histograms of original and reconstructed images respectively. In the Figure 10 (a), (b) and Figure 11 (a), (b) x axis and y axis shows horizontal and vertical dimensions of the image. Figure 10 (c), (d) and Figure 11 (c), (d) x axis shows dynamic range of grey scale ranging from 0 to 255 and y axis represents intensity value. Similarly, the original foot CT-Scan image and recovered image using L_2 norm minimization is depicted in Figure 11 (a) and Figure 11 (b) respectively. Figure 11 (c) and Figure 11 (d) shows histograms of original and reconstructed CT-Scan image respectively. It is clear from the

Figure 10. (a) Original image of foot MRI-scan, (b) reconstructed image obtained from Least Square (L_2) and (c) histogram of original image and (d) histogram of reconstructed image

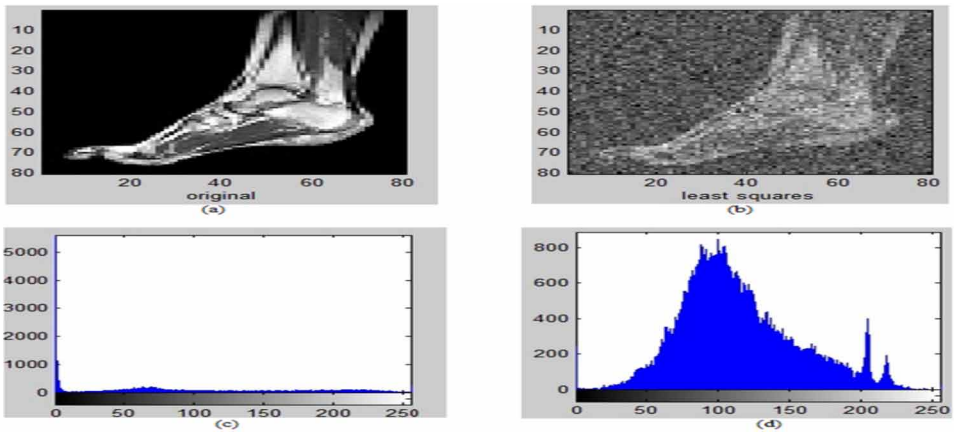
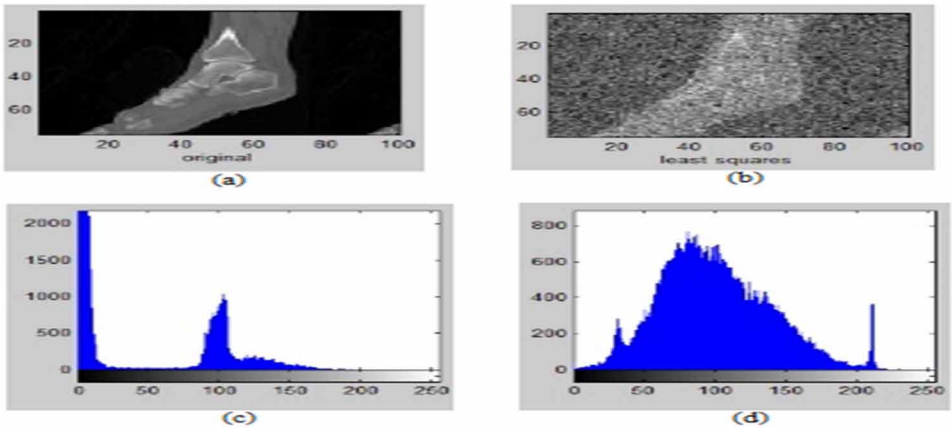


Figure 11. (a) Original image of foot CT-scan, (b) reconstructed image obtained from Least Square (L_2) and (c) histogram of original image and (d) histogram of reconstructed image



visual representation that the image recovered by L_2 norm minimization is not of better quality and this is further validated after calculating different performance assessment parameters obtained in Table 2. For evaluation purpose we have used 5 images of MRI and 5 images of CT-Scan.

RMSE calculated for L_2 reconstruction method gives a high RMSE value which in turn provides a lower value of PSNR in dB indicating poor image quality. SSIM index is human vision perception based structural similarity index and its value for L_2 norm method is more near 0 indicating less structural similarity to that of the original image.

CS Recovery Using Orthogonal Matching Pursuit (OMP)

Algorithms of matching pursuit like CS Matching Pursuit, Regularization Orthogonal Matching Pursuit and stage-wise Orthogonal Matching Pursuit all falls into the category of greedy algorithms. An estimated signal is obtained by finding the correlation between the columns of Φ measurement matrix and

Table 2. Different performance parameters obtained for L_2 recovery algorithm

Image Samples	RMSE	PSNR (dB)	SSIM
Img1_MR	55.82	12.62	0.43
Img2_MR	52.15	13.33	0.27
Img3_MR	89.79	10.89	0.20
Img4_MR	50.69	13.23	0.44
Img5_MR	46.33	14.65	0.31
Img1_CT	81.16	9.75	0.19
Img2_CT	43.60	14.40	0.21
Img3_CT	39.33	15.91	0.17
Img4_CT	90.12	8.87	0.20
Img5_CT	93.27	7.08	0.17

the measurement residual (r). The new estimated signal (x_k) is highly correlated with the residual [34, 35]. The steps of OMP algorithm are detailed as follows;

1. First of all the residual is initialize, $r_0 = y$ and Column C_0 is set as Φ for iteration count $k=1$.
2. Column vector Φ_{ck} of Φ is obtained using approximation a_c i.e., highly correlated with the residual and the equation is given by;

$$\Phi_{ck} = \max_c \left|\left\langle r_{k-1}, a_c \right\rangle\right|, c \in [n] \tag{11}$$

3. Least square problem is solved by:

$$x_k = \left\| y - \Phi_{ck} \times x \right\|_2 \tag{12}$$

4. To remove the contribution of a_c (approximation), the residual is updated by

$$r_k = y - \Phi_{ck} \tag{13}$$

5. Increase the iteration count k, and repeat steps 2-4 until stopping criterion is met.

Figure 12 (a) depicts the original foot MRI image and Figure 12 (b) depicts the reconstructed image obtained using Matching Pursuit method (OMP). Similarly, the original foot CT-Scan image and recovered image using OMP is depicted in Figure 13 (a) and Figure 13 (b) respectively. It is clear from the visual representation that the image recovered by OMP reconstruction method gives better recovered image as compared to the L_2 norm minimization and this is further validated after calculating different performance assessment parameters for OMP reconstruction algorithm obtained in Table 3.

Figure 12. (a) Original image of foot MRI-Scan, (b) reconstructed image obtained from Matching Pursuit (OMP) and (c) histogram of original image and (d) histogram of reconstructed image

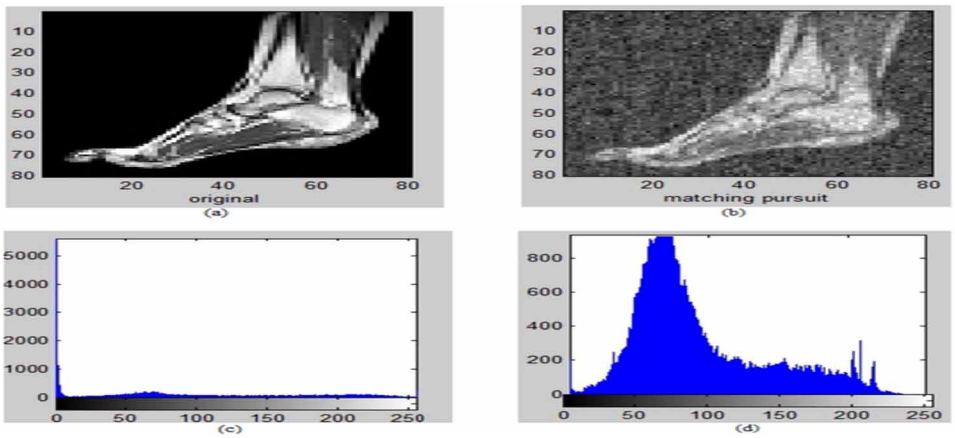


Figure 13. (a) Original image of foot CT-Scan, (b) reconstructed image obtained from Matching Pursuit (OMP) and (c) histogram of original image and (d) histogram of reconstructed image

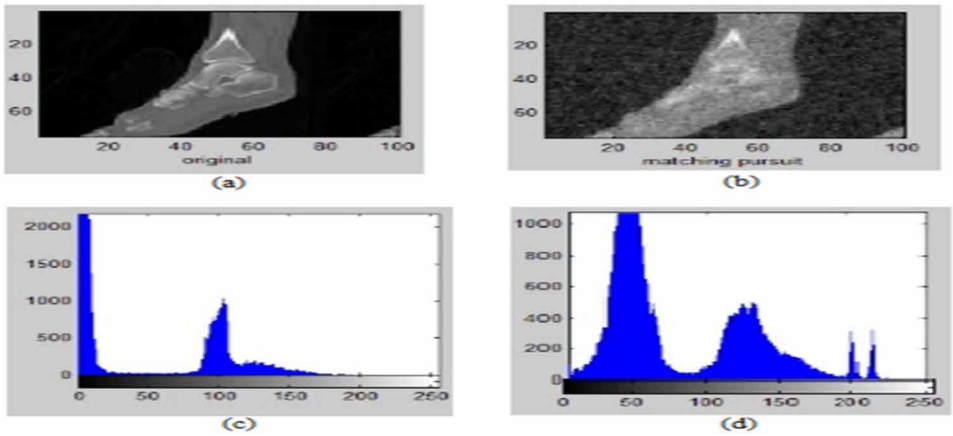


Table 3. Different performance parameters obtained for OMP recovery algorithm

Image Samples	RMSE	PSNR (dB)	SSIM
Img1_MR	39.19	15.84	0.51
Img2_MR	30.16	18.00	0.53
Img3_MR	41.32	15.42	0.49
Img4_MR	36.32	16.48	0.64
Img5_MR	31.26	17.53	0.46
Img1_CT	31.01	17.13	0.48
Img2_CT	14.39	22.32	0.51
Img3_CT	15.31	26.71	0.40
Img4_CT	37.74	16.17	0.44
Img5_CT	53.45	13.26	0.49

RMSE calculated for OMP was less than L_2 reconstruction method thus OMP recovery method provides greater value of PSNR in dB indicating better image quality. Structural similarity index is also near to 0.5 which shows that the recovered image is 50% similar to that of the original medical image. Image recovered using OMP reconstruction method gives better results as compared to L_2 norm minimization method in terms of image quality indicative by image pixel values and also in terms of visual perception based similarity parameter.

CS Recovery Using Basic Pursuit (L1 Norm Minimization)

The best established reconstruction technique is Re-weighted L_1 norm minimization that is used for CS image recovery in contrary to the other reconstruction technique. Uniform guaranteed recovery and stability is provided by L_1 norm minimization approach [32]. There is no linear bound on run time for this

technique and it provides better recovery but it is optimally slow. On solving the following minimization problem, x is recovered by solving the equation,

$$x = \min \left\| \Psi^{-1} \times s \right\|_p \tag{14}$$

where, Ψ is sparsifying matrix, x is the original signal and p is the signal sparsity.

L_1 norm minimization recovery steps are as follows:

1. Weight (w) is initially given by $w_i^{(0)} = 1$, for $i = 1 \ldots N$. $w_i^{(0)}$ is the weights on pixels, the iterative count is set to 0.
2. By using equation (12), the weighted L_1 minimization problem is solved.

$$\min \left\| W \times s \right\|_1, \text{ s.t., } y = \Phi \times x \tag{15}$$

where W_s are the total number of weights in transform domain s.

3. Weights are then updated for i=1… N,

$$w_i^{(j+1)} = \frac{1}{\left| \tilde{s}_i^{(j)} \right| + \in} \tag{16}$$

Here, s is the sparse transform vector. ϵ is a positive number and use to prevent zero-valued denominator and j refers to number of iterations.

4. After that a specific maximum number of iteration j_{max} is attained by j and convergence terminates; otherwise increase j and repeat step 2-3.

Figure 14 (a) depicts the original foot MRI image and Figure 14 (b) depicts the reconstructed image obtained using Basic Square method that is L_1 norm minimization. Similarly, the original foot CT-Scan image and recovered image using L_1 norm minimization is depicted in Figure 15 (a) and Figure 15 (b) respectively. This is further validated after analysing the different performance assessment parameters for L_1 reconstruction algorithm obtained in Table 4.

Analysis of performance metrics like RMSE, PSNR and SSIM is done in Table 4 for different medical image samples recovered using L_1 recovery algorithm. L_1 recovery algorithm gives high value of PSNR and lower RMSE value as compared to the previously evaluated recovery methods; L_2 and OMP recovery techniques. Higher value of SSIM is obtained from the L_1 recovery technique out of three evaluated techniques. It is estimated that recovered image is much similar to the original image when L_1 recovery method is used and higher values of performance parameters are also obtained for L_1 reconstruction technique.

Figure 14. (a) Original image of foot MRI-Scan, (b) reconstructed image obtained from Basic Pursuit (L_1) and (c) histogram of original image and (d) histogram of reconstructed image

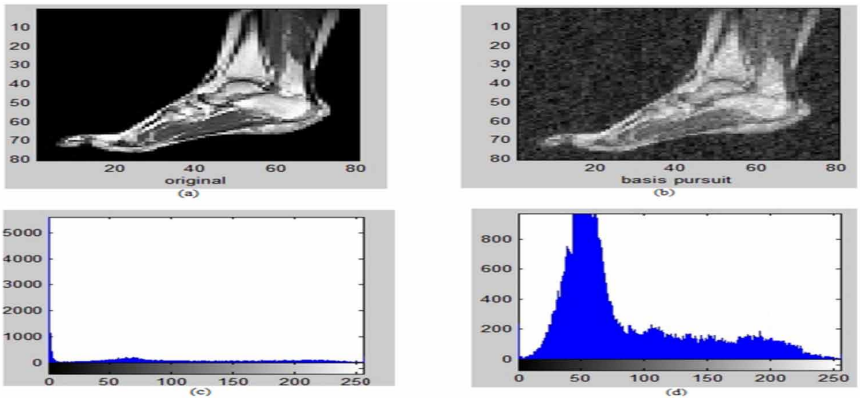


Figure 15. (a) Original image of foot CT-Scan, (b) reconstructed image obtained from Basic Pursuit (L_1) and (c) histogram of original image and (d) histogram of reconstructed image

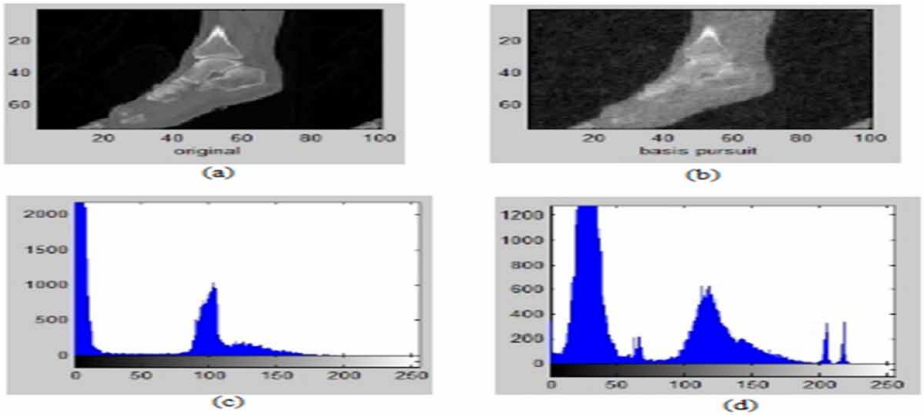


Table 4. Different performance parameters obtained for L_1 recovery algorithm

Image Samples	RMSE	PSNR (dB)	SSIM
Img1_MR	23.38	20.06	0.69
Img2_MR	19.61	21.87	0.65
Img3_MR	22.34	20.22	0.71
Img4_MR	20.15	21.17	0.72
Img5_MR	18.62	22.91	0.66
Img1_CT	21.34	20.05	0.61
Img2_CT	11.83	25.92	0.64
Img3_CT	9.03	28.87	0.60
Img4_CT	22.50	19.93	0.61
Img5_CT	36.31	17.49	0.64

Compression Ratio (CR) is calculated when CS is applied on image samples and it is obtained by taking the ratio of original image bits to the recovered image bits. There should be a trade-off between CR and image quality of an image. CR should be maintained in such a way that there is no degradation of reconstructed image quality. Space saving and CR for different compressed MRI images are graphically represented in Figure 16, graphical representation for different CT images is shown in Figure 17.

Effect of Measurement Samples on Different Image Samples

Foot MRI testing and recovery at varying measurement samples (m) employing L_1, L_2 and OMP reconstruction techniques is shown in Figure 18 to Figure 20 and it shows significant change in recovered images at different m samples. Previously, the effect of m measurement samples are verified for 1D signal and here in this section effect of varying m samples are verified for 2D signal (image). For an image, value of m measurement samples is considered less than the total number of pixels in an image.

Figure 16. Compression ratio and space saving from Compressive Sensing technique for different MRI images

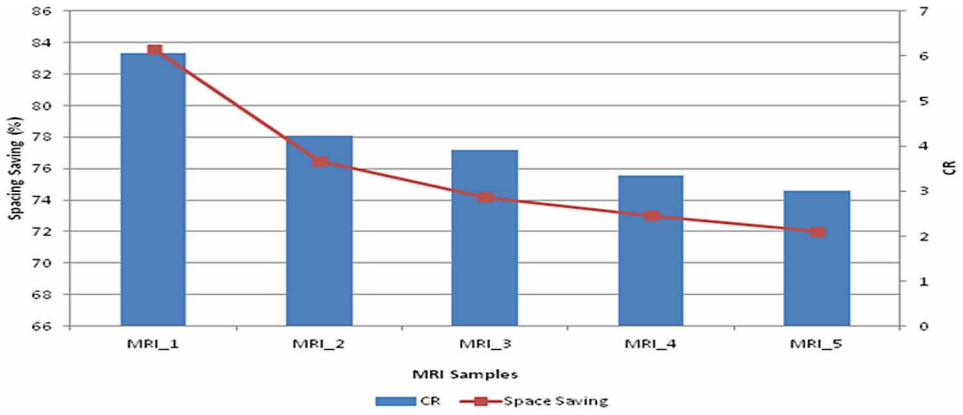
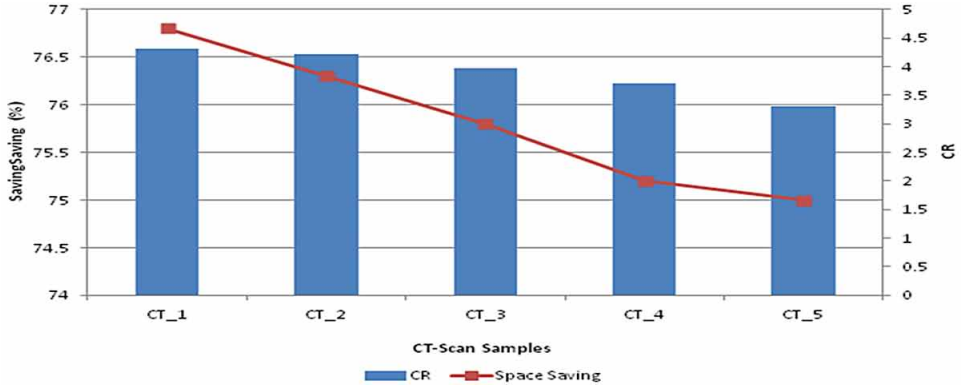


Figure 17. Compression ratio and space saving from Compressive Sensing technique for different CT images



For e.g., for an image having dimension 80×80, *n* number of samples are 6400 and *m* can be any value less than 6400. To verify the effect of varying *m* measurement samples for better image recovery, *m* is considered 1000, 2000 and 4000 for an image of resolution 80×80. Only single brain MRI image analysis for varying measurement samples is shown in the following figures however the analysis is done for different image modalities.

It is clear from the above figures from Figure 20 to Figure 22 that quality of recovered image is improved when number of *m* samples is increased. In Figure 20, number of *m* samples is less i.e., *1000* so the recovered images from all three recovery techniques are of low quality. When number of samples (*m*) is increased from *1000* to *4000* as shown in Figure 21 and Figure 22, quality of recovered image

Figure 18. (a) Original MRI image of foot, reconstructed image using (b) Least Square (L_2), (c) Matching Pursuit (OMP) and (d) Basic Pursuit (L_1) reconstruction methods at measurement samples m=1000 samples over original image samples n=6400

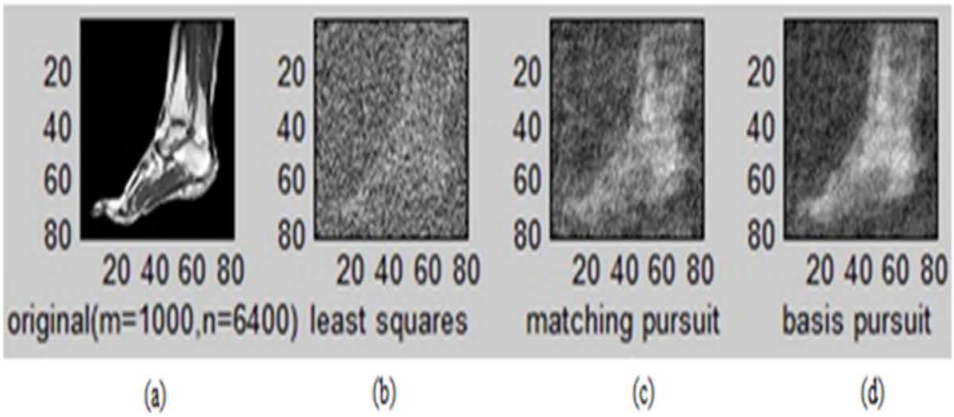


Figure 19. (a) Original MRI image of foot, reconstructed image using (b) Least Square (L_2), (c) Matching Pursuit (OMP) and (d) Basic Pursuit (L_1)reconstruction methods at measurement samples m=2000 samples over original image samples n=6400

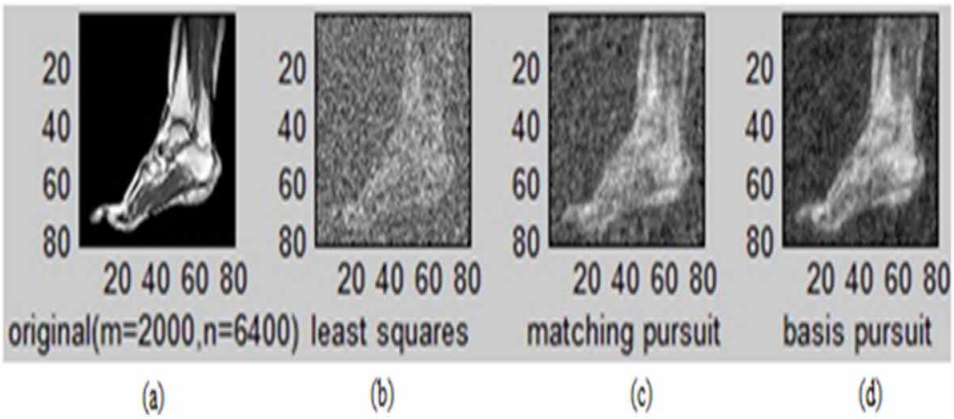
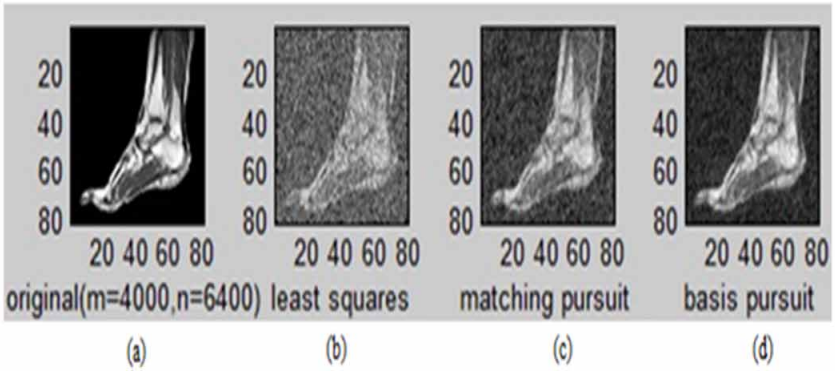


Figure 20. (a) Original MRI image of foot, reconstructed image using (b) Least Square (L_2), (c) Matching Pursuit (OMP) and (d) Basic Pursuit (L_1) reconstruction methods at measurement samples m=4000 samples over original image samples n=6400.



is improved. So number of samples (m) should be adjusted in such a way that there is balance between quality of recovered image *(PSNR)* and compression performance *(CR).*

The effect of performance metrics PSNR and RMSE is seen with variation in measurement samples. At different measurement samples for MRI of brain, PSNR and RMSE are calculated. For all three recovery algorithms, PSNR is obtained at $m = 1000$, 2000 and then at 4000 when total number of samples (n) are 6400 (resolution of foot MRI) and m can be any number less than n. It is estimated that value of PSNR increase when number of measurement samples increases. Hence m should be selected such that the recovered image is of high quality with higher value of CR.

When $m = 1000$, it is seen that PSNR value is around 9 to 15 dB and when it is varied from 1000 to 4000 then PSNR value increases with increase in m. Change in PSNR value for recovered images obtained using L_1, L_2 and OMP algorithms is shown in Figure 21 for varying number of samples from 1000 to 4000.

RMSE should be minimized to obtain better image quality. At m=1000, higher value of RMSE is obtained for all three recovery algorithms and when m is increased from 1000 to 4000, RMSE starts

Figure 21. Measurement samples v/s PSNR for brain MRI

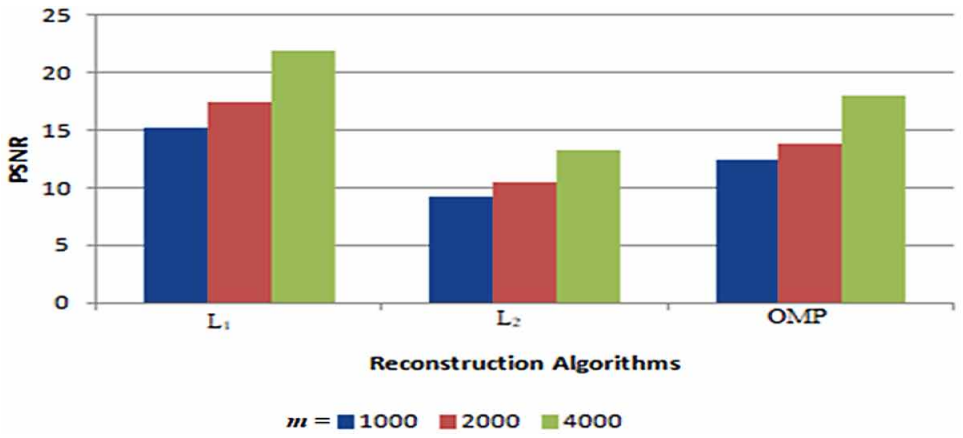
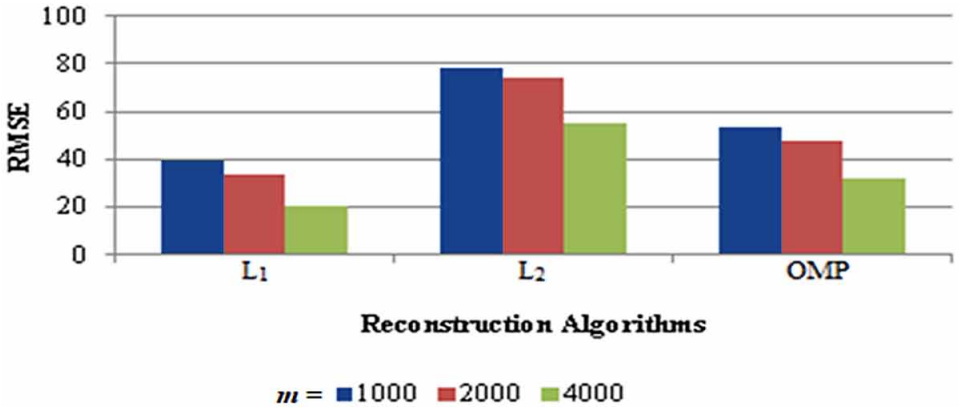


Figure 22. Measurement samples v/s RMSE for brain MRI



decreasing. RMSE values obtained for L_1, L_2 and OMP recovered images are graphically shown in Figure 22. Out of these three recovery algorithms, the image recovered using L_1 technique provides minimum RMSE value which indicates that the quality of image recovered by L_1 is better than other two algorithms.

CONCLUSION

CS performance is estimate for 1D signal and different medical image samples of MRI and CT- Scan. It is observed that the value of samples should be taken in such a way that there is appropriate balance between the recovered image quality and sampling rate. Quality metrics are obtained for L_1, L_2 and OMP algorithms for different image samples and it is estimated that L_1 technique is better than other reconstruction algorithms in terms of PSNR, RMSE, SSIM and CR. Perfect image recovery is possible by L_1 technique as it resembles more to the original image in comparison to L_2 and OMP reconstruction methods. It is concluded that all quality metrics are better obtained by L_1 and this is the best recovery technique among other implemented algorithms. Thus for a CS based system, L_1 recovery algorithm is considered as a good compression technique that enables a compromise between compression performance and recovered image quality. It is also concluded that the algorithm performance is also altered by the number of measurement samples taken for reconstruction. Value of PSNR increases with increase in number of measurement samples and RMSE value decreases. CS based recovery algorithms can also be implemented for various other medical samples of varying resolution and modality to obtain improved quality image by achieving higher value of PSNR. Compressed sensing concept can also be applied to video signals and the future scope in this field will focus on attaining maximum value of CR along with accurate reconstruction.

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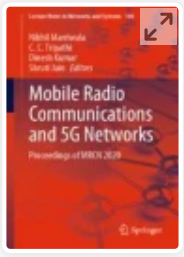

Mobile Radio Communications and 5G Networks pp 389–399

Optimum Digital Filter Design for Removal of Different Noises from Biomedical Signals

Shailu Srivastava & Shruti Jain

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Keywords

Digital filters **Low-frequency noise**

High-frequency noise **Window technique**

Butterworth filter

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Optimum Digital Filter Design for Removal of Different Noises from Biomedical Signals



Shailu Srivastava and Shruti Jain

Abstract The denoised signal with enhanced quality is utilized for correct analysis of biomedical signal. In real-time applications, these signals are mostly affected by distinct types of artefacts. The objective of this research paper is to design the optimum digital filter for the elimination of noises lies in high- and low-frequency bands. The proposed methodology is implemented using approximations and windowing techniques. The results of frequency responses of both the designed filters are evaluated and compared on the basis of pole–zero plot and gain. It is interpreted from the simulated results that the design technique with the help of Kaiser window results in −61.75 and −56.89 dB for high-frequency and low-frequency signals, respectively, while assuming shape parameter as 0.5. The proposed design method can be used in different digital signal processing applications.

Keywords Digital filters · Low-frequency noise · High-frequency noise · Window technique · Butterworth filter

1 Introduction

Signal processing is performed in most of the systems for biosignal interpretation and analysis [1]. Nowadays, biomedical signal processing has been close towards objective or the quantitative analysis of physiological systems and phenomena through signal evaluation [2]. These signals contain valuable clinical information in real time which is hampered by different noises such as electrode contact noise, instrumental noise, baseline noise, motion artefacts, power line interference and electrosurgical noise [3]. Different types of digital filters are used for the removal of artefacts from signal components. It is very tedious to reduce random noises having fixed coefficients.

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The situations which include motion of the patient (running or walking), breathing, interplay among the electrodes pores and skin are the reasons of occurrence of low-frequency noises/baseline wandering [4]. The signal gets drifted with a high degree from baseline and is known as baseline wander. The presence of muscle noise is due to high-frequency noise/electromyography (EMG) noise that represents a fast rate trouble in most of the applications, particularly in recordings acquired during exercise, for the reason that low amplitude waveforms may turn out to be absolutely obscured. EMG noise occurs due to the shrinkage of muscles other than the cardiac muscular tissues [3, 4]. The degree of crosstalk is always in proportion to the amount of muscular contraction that takes place either due to the probe quality or movement. The frequency of the EMG noise lies in between 100 and 500 Hz or further taken to the higher frequencies. Muscle noise, baseline wander and 50/60 Hz noise are not always removed by using narrowband filtering. This affords a much extra filtering trouble because of the spectral content of muscle activity.

To remove the artefacts from the biomedical signals, different techniques were proposed in the last twenty years. To get the important data which is present in a specific frequency range, digital filters may be used [5]. In general, these techniques can be categorized into adaptive and non-adaptive filtering [6]. The non-adaptive filtering consists of infinite impulse response (IIR) filter, finite impulse response (FIR) filter and the notch filter. The FIR filters are considered for removing the noise and spectral effectively from the biomedical signal. An FIR filter includes multipliers, delays and adders to get the output [7–9]. As the order of the filter increases, there is an increase in the execution time and complexity. Theoretical and experimental results using the windowing technique are almost similar due to the availability of a well-structured equation [10].

In this paper, authors have studied distinct research papers on specific filtering strategies [11]. Alarcon et al. implemented algorithms for high-pass and low-pass three-pole recursive Butterworth filters at particular cut-off frequency [12]. Gaikwad and Chavan suggested that digital IIR filtering approach is best suited for the removal of high-frequency noise from ECG Signal [13]. Rahman et al. [14] remove the baseline wandering by using the wandering path finding algorithm. Authors in [15] worked on FPGA-based FIR low-pass filter for the removal of EMG noise from electrocardiogram. Authors in [16] discussed the various noises present in biomedical signals and different techniques to remove these noises.

The main utility of a filter is to discard unnecessary signal components [17, 18], like baseline wander noise or EMG noise. The main aim of this research work is to design an optimum digital filter for removal of noises lies in high- and low-frequency bands. For the smoother transitions, better gain and ability to control the ripple content, authors have implemented different digital filters using LabVIEW. The main requirement of this method is to maintain physiological characteristics after denoising. Gain (in dB) is calculated for different digital filters. The pole–zero plot and frequency responses of both the filters were also analysed.

The rest of the paper is structured as follows: Sect. 2 explains the methodology segment, Sect. 3 explains the results and discussion which are followed by the conclusion and future scope in Sect. 4.

2 Methodology

Various types of filters are categorized primarily based on signal processing, elements type, construction filters, impulse response and frequency range. The transfer function for a time-invariant, linear digital filter known as the recursive filter can be expressed in z- domain and is represented by Eq. (1).

$$H(z) = \frac{B(z)}{A(z)} = \frac{b_0 + b_1 z^{-1} + b_2 z^{-2} + \ldots b_N z^{-N}}{1 + a_1 z^{-1} + a_2 z^{-2} + \ldots a_M z^{-N}} \tag{1}$$

where $a_0, a_1, \ldots a_n$ and $b_0, b_1, \ldots b_n$ are filter coefficients. If the denominator in Eq. (1) is made equal to unity (no feedback), then the filter will act as an FIR filter [6]. The impulse response is a measurement of how a filter will respond to the delta function and is expressed by Eq. (2).

$$\delta_{ij} = \begin{cases} 1 & i = j \\ 0 & i \neq j \end{cases} \tag{2}$$

Window functions are a category of time-domain functions. Gibb's oscillations are decreased by using a suitable window function [1, 2]. Window functions $[w(nT_s)]$ are used to restrict the impulse response $[h(nT_s)]$ with certain value. $H(z)$ is the z transform of $[h(nT_s)]$ expressed by Eq. (3), $W(z)$ is the z transform of $w(nT_s)$ expressed by Eq. (4), and $H_{\mathrm{w}}(z)$ is the z transform of $[w(nT_{\mathrm{s}})h(nT_{\mathrm{s}})]$ expressed by Eq. (5).

$$H(z) = \sum_{n=-\infty}^{\infty} h(n\,T_s)\, z^{-n} \tag{3}$$

$$W(z) = \sum_{n=-\infty}^{\infty} w(n\,T_s)\, z^{-n} \tag{4}$$

$$H_w(z) = \sum_{n=-\infty}^{\infty} [w(n\,T_s).\, h(n\,T_s)]\, z^{-n} \tag{5}$$

Different filtering approaches are implemented for denoising of the different noises from biomedical signals. Initial step is the identification of noises present in the signal followed by the selection of the filter. Selection of optimal filter is a challenging task as in literature there are two types of filter IIR and FIR, and both have its benefits and downsides. In this paper, authors have stressed on FIR filter using windowing technique and IIR using approximate filter. When a digital FIR filter is designed using window techniques, it is essential to specify window function and the order of the filter as shown in Fig. 1. Gain (in dB) is calculated for different

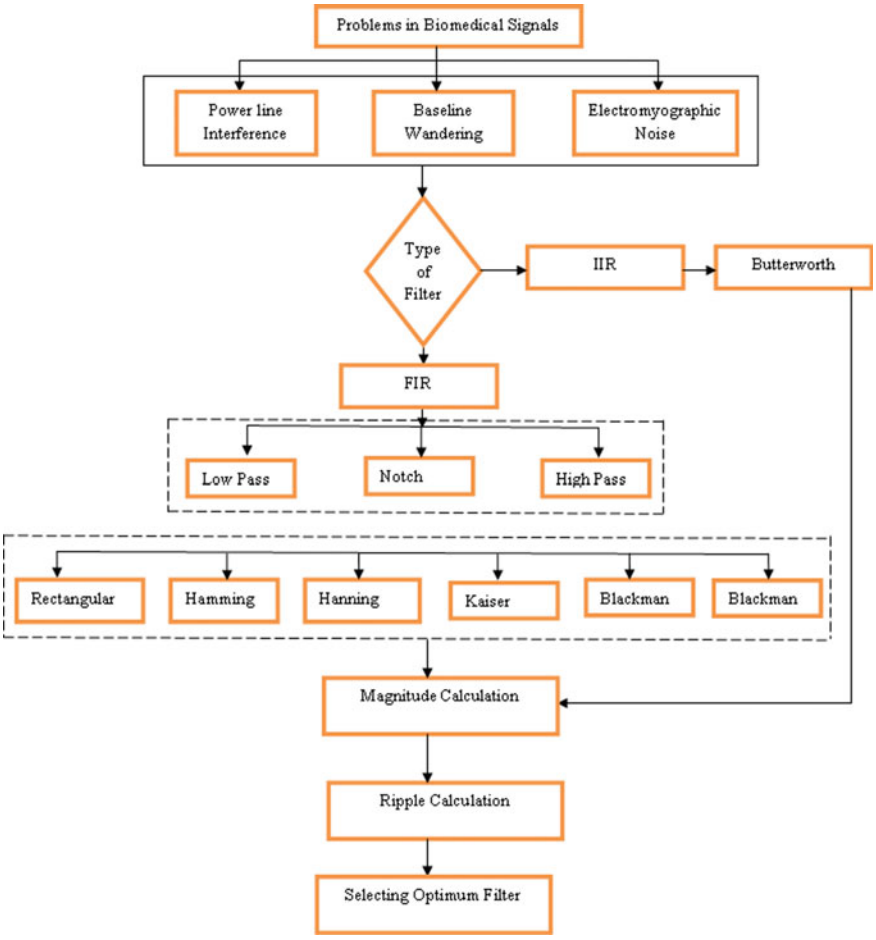

Fig. 1 Filter design steps

digital filters. The pole–zero plot and frequency responses of both filters were also analysed.

The fallacious electrodes placing, patient's motion and respiration (breathing) are the foremost reason of baseline wandering. The baseline signal is a low-frequency signal, with a cut-off frequency of 0.5 Hz FIR high-pass zero phase filters is used for the removal of the low-frequency noise from the biomedical signal [4–6]. Likewise for the removal of the high-frequency signal, low-pass filter with cut-off frequency of 100 Hz is designed.

3 Results and Discussion

There are some random noises such as high-frequency and low-frequency noises present in the biomedical signal. To remove these noises, optimum digital filters were designed using FIR and IIR filtering techniques. FIR and IIR filters are designed using different windowing techniques and approximate techniques, respectively. All the simulation was carried out in Intel 2.4 GHz, 64-bit operating system using LabVIEW and MATLAB software.

Removal of low-frequency noises: The high-pass FIR and IIR filter with cut-off frequency 0.5 Hz are designed (as shown in Fig. 2) to eliminate the low-frequency noises; this helps in removing the signal component of frequency beyond 0.5 Hz.

Table 1 tabulates the effect of order on gain using Butterworth approximate filtering (for IIR).

The gain of −36.53 dB is evaluated for the designed filter of order 2. It is observed that there is a sharp transition from stopband to passband. The pole–zero plot of the designed filter is also studied which is shown in Fig. 3.

The pole and zero both lie on the unit circle (as shown in Fig. 3) that signifies the filter is stable but the impulse response is infinite (as shown in Fig. 4) which is difficult to handle.

To overcome the problem of infinite response of IIR filter, FIR filters using different windows, namely Kaiser, Hamming, Hanning, Blackman, Rectangular and Gaussian are considered [6, 18]. Among various filters, Kaiser window shows the remarkable results. Kaiser window function is expressed by Eq. (6).

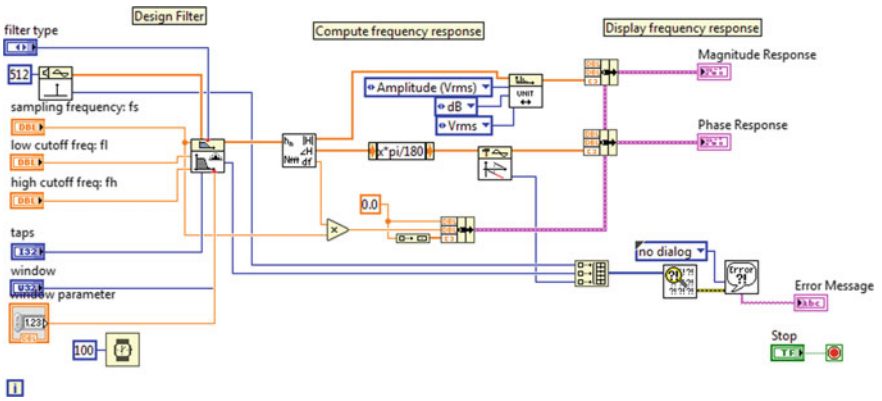

Fig. 2 Implementation of digital filter using LabVIEW

Table 1 Effect of order on gain for Butterworth HPF

Order	Gain (dB)
1	−18.33
2	−36.53

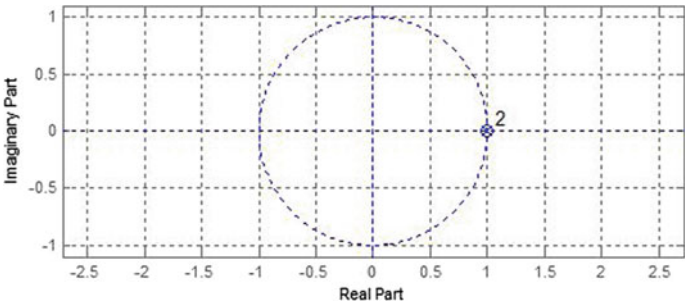

Fig. 3 Pole–zero plot of Butterworth high-pass filter of order 2

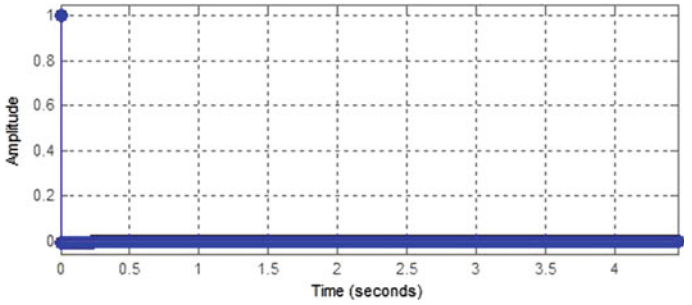

Fig. 4 Impulse response of Butterworth high-pass filter

$$W_k\left(n\,T_s\right) = \begin{cases} \dfrac{F_o\left(\beta\right)}{F_o\left(\alpha\right)} & -\left(\dfrac{N-1}{2}\right) \le n \le \left(\dfrac{N-1}{2}\right) \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

where $F_0(\beta)$ and $F_0(\alpha)$ are the zeroth-order Bessel function of the first kind which is expressed by Eqs. (7) and (8), respectively. In Eqs, $\angle k$ represents factorial of k.

$$F_o\left(\beta\right) = 1 + \sum_{k=1}^{\infty}\left[\frac{1}{\angle k}\left(\frac{\beta}{2}\right)^k\right]^2 \tag{7}$$

$$F_o\left(\alpha\right) = 1 + \sum_{k=1}^{\infty}\left[\frac{1}{\angle k}\left(\frac{\alpha}{2}\right)^k\right]^2 \tag{8}$$

α is an independent parameter, and β is a dependent parameter which depends upon α and is expressed by Eq. (9).

$$\beta = \alpha\sqrt{1 - \left(\frac{2n}{N-1}\right)} \tag{9}$$

The ripples found in the window can be removed by varying the shape parameter (β). The effect of β on Kaiser window is tabulated in Table 2.

The effect of odd and even order of filters using windowing technique (for FIR) on gain has been studied, and the results are tabulated in Tables 3 and 4, respectively. If the number of taps is odd, then the delay of the filter is an integer number of samples, which is desirable for some applications while if the number is even, then it leads to half-sample delay.

From Table 4, it is interpreted that for odd number order, the gain value decreases, but the transition is sharper for a higher-order filter which is desirable for some applications. From the results, it is interpreted that for linear phase FIR filter, the order of the filter should be odd. Figures 5 and 6 represent the impulse response and pole–zero plot of FIR high-pass filter, respectively, of order 11. It is interpreted that if the length of the impulse response is even, anti-symmetric and has zero at $z = 1$, it represents that the filter is of Type 4 and is best suited for the high-pass filtering.

From all the simulated results, it is analysed that Kaiser window (shown in Fig. 7) yields better results in comparison with other methods because of its sharp transition and better gain value.

The main reason for analysing any filter using windowing technique is its simplicity of design, and the design method is very well understood with basic DSP knowledge.

Removal of EMG/high-frequency noises: The low-pass IIR and FIR filter with cut-off frequency 100 Hz are designed and simulated. For the Butterworth IIR filter of

Table 2 Effect of β on Kaiser window HPF

β	Gain (dB)
0.5	−2.98
1	−2.79
2	−2.33
3	−1.97
4	−1.72
5	−1.539
6	−1.4

Table 3 Effect of even order on gain for HPF Kaiser window

Order	Gain (dB)
50	−0.45
100	−0.894
150	−1.39
200	−1.88
250	−2.409
300	−2.98

Table 4 Effect of odd order on gain for HPF Kaiser window

Order	Gain (dB)
11	−56.89
51	−44.13
101	−38.31
201	−32.48
251	−30.64
301	−29.16

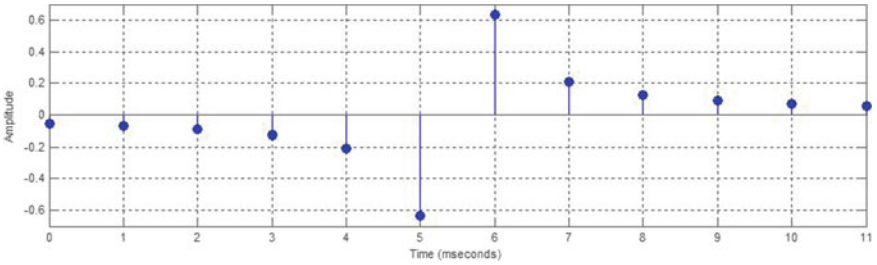

Fig. 5 Impulse response of FIR HPF of order 11

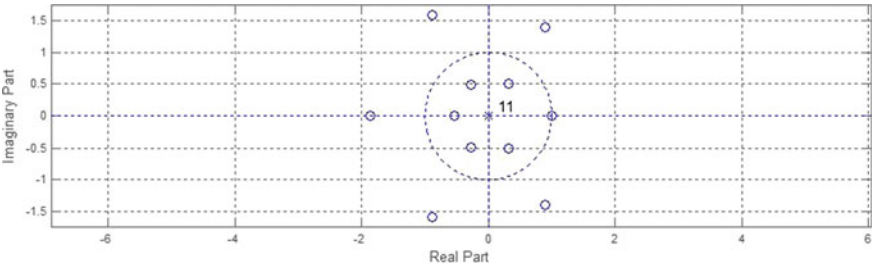

Fig. 6 Pole–zero plot of FIR HPF of order 11

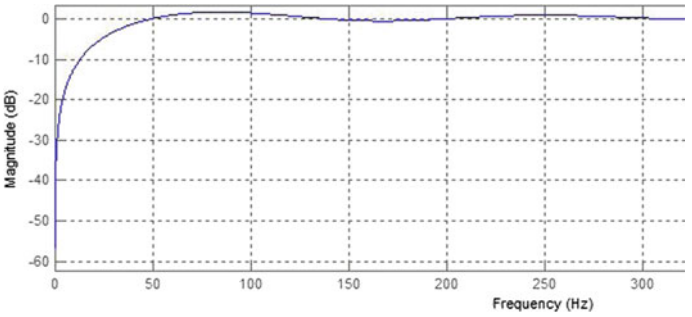

Fig. 7 FIR Filter design at 0.5 Hz using Kaiser window

order 2, it is interpreted that the frequency response is not good because the transition is very poor as shown in Fig. 8.

The pole–zero plot of the filter is also studied as shown in Fig. 9 which illustrates that the pole and zero both lie inside the unit circle that signifies the filter is stable but the impulse response is infinite which is difficult to handle. To overcome this problem, FIR filters using different window techniques are realized, and the results are tabulated in Table 5.

The choice of the window depends on the requirement like characteristics of noise, region of transition and the number of coefficients required. For the different windows, the Blackman windowing technique delivers significant results but have some limitations like large passband width (frequency of 135 Hz), while for the

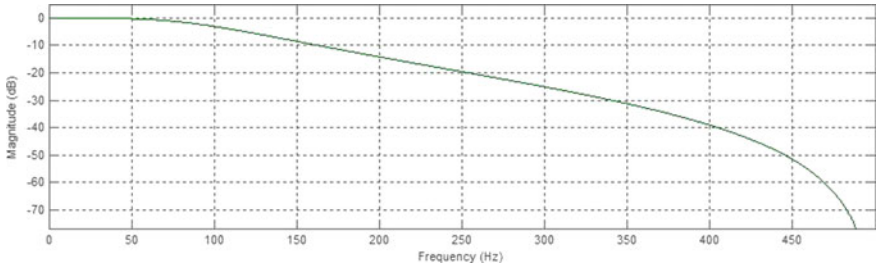

Fig. 8 Frequency response of Butterworth low-pass filter

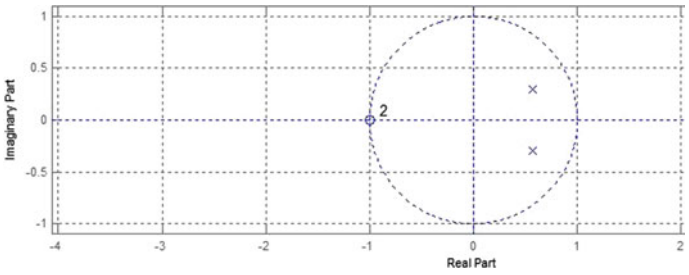

Fig. 9 Pole–zero plot of Butterworth low-pass filter of order 2

Table 5 Effect of gain on different window using LPF

Window	Gain (dB)
Hamming	−80
Hanning	−79.59
Kaiser	−61.75
Blackman	−108.21
Rectangular	−60.28

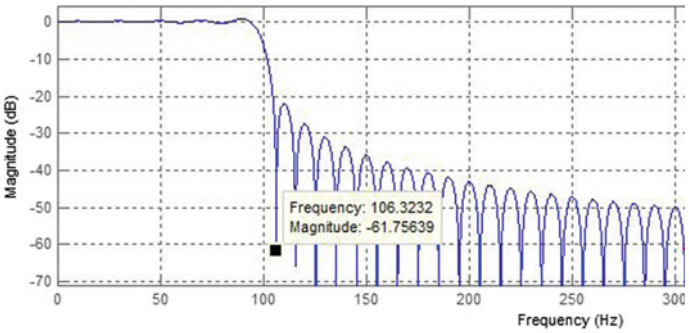

Fig. 10 Frequency response of low-pass FIR filter using Kaiser window

Kaiser window it is observed that the passband width possesses better gain as shown in Fig. 10.

From the frequency response of low-pass Kaiser window filter, it is observed that the gain is more in comparison with other window method as no ripples are found in the passband.

4 Conclusion

In this paper, optimum digital filtering techniques are designed to eliminate different noises that are propagating in the biomedical signal. This research paper carried out the analysis of various filtering methods and simulating in LabVIEW and MATLAB. For IIR Butterworth HPF of order 2, the gain of −36.53 dB is evaluated which shows a sharp transition but the main problem associated with the IIR filtering is its infinite impulse response nature. To overcome this problem, the FIR filter is designed. It is observed that on increasing the order of the filter from 50 to 300, the gain value changes from −0.45 to −2.98 dB. For order eleven, FIR high-pass filter, the value of gain is around −56.89 dB. The low-pass FIR filters are designed for the removal of high-frequency noises that results in −61.75 dB of gain. It is analysed that the FIR filters are best suited for the removal of noises from any biomedical signals because of its finite impulse response and no recursion which is mainly found in the IIR filtering. The Kaiser window is best suited with the appropriate value of β for the removal of different noises because of its better magnitude value and sharp transition from passband to stopband. In future, authors will try to filter the biomedical signals with the help of field-programmable gate array (FPGA).

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Chapter 7
Applications of Predictive Computing

7.1 Introduction

Predictive computing is used in a wide spectrum of real-world problems ranging from business, government, economics and also science. Some major fields reaping the advantages of predictive computing are financial services, insurance, telecommunications, retail, healthcare and government [1]. Predictive computing is now adopted by almost all major work sectors as its advantages are evident in every field. Predictive computing helps in knowing the customers and acts on the insights provided by the predictive analytics on future customer behaviour. This can help to identify the best actions to take for every customer or transaction [2] and help in guiding other strategic actions to be taken for the profit of business, such as collaborating with agencies that maximize the profit in the approved budget, or detecting frauds or abuse in insurance or healthcare claims. It can help in answering complex questions such as live transactions, with empirical precision at incredible speeds [2]. Decisions that earlier took hours or days, can now be taken in milliseconds. Insights given by analytics can be helpful as they can reduce the business losses by accurately measuring the risks and frauds. Predictive computing can detect the slightest abnormality in a pattern of usual business routine transaction or data, and hence can help reduce business losses. Predictive computing adds consistency and stability to business decisions and in turn improves customer service as it relies on mathematical models and techniques. Also, the decisions provided by predictive analytics are consistent and unbiased as compared to human experts. Predictive computing is a requirement of today's world as everyone needs consistent, faster, smarter decisions to meet the agile business standards, where market conditions change quickly and frequently. Also, it is required to improve the customer service and grow the profit of the business. Predictive computing improves every aspect of decision-making process, which includes: precision, consistency, agility, speed and cost [2]. There are uncountable applications of predictive computing in business intelligence, and this is because of the fact that predictive

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computing has reached the roots of various business sectors. Predictive computing allows us to anticipate the future and make an optimal decision by extracting information from the datasets, which in turn helps to discover complex relationships, recognize unknown patterns, forecasting actual trends, etc. [3].

7.2 Applications Based Features of Predictive Computing

Considering the various horizons for predictive computing as presented in Table 1.2 of Chap. 1, we have selected three application-based scenarios, i.e., smart mobility, e-Health and e-Logistics to be presented in this chapter. Each scenario consists of various applications, where predictive computing can be successfully implemented. Following sections discuss about these applications.

7.2.1 Smart Mobility

Urbanization of the cities of developing countries has led to a steady rise in the number of vehicle registrations, traffic congestion problems, heavy fuel demands and fuel consumption, and financial and economic challenges. In the past several years, smart mobility (e-mobility) has been a subject of intensive research and discussion revolving around ecological and economic arguments around the world [4]. Among the varied discussions, countries like Singapore, China, Japan, India and South Korea, have presented interesting approaches while promoting and implementing smart mobility. Key factors driving smart mobility among others are smart vehicle navigation, finding optimized shortest paths, smart technological capabilities of the vehicle to reduce fuel consumption. Smart mobility can be sought out as a solution to congestion, increasing air pollution, noise pollution in the cities of developing countries. Smart mobility can be considered for addressing these problems as well. In [5], Pattanaik et al. have proposed a *smart congestion avoidance technique* by estimating the scope of real-time traffic congestion on urban road networks which also *predicts an alternate shortest route to the destination* as shown in Algorithm 7.1. The proposed system uses *k-Means clustering algorithm* to estimate the magnitude of congestion on different roads, later it employs *minimum spanning tree algorithm; Dijkstra's algorithm* to predict the shortest route. Once the system receives the user's destination coordinates, it predicts the shortest route from the user's current location. This process is reiterated until the user reaches the desired destination. The proposed methodology can predict which road segments are congested or clear through the real-time GPS data and inform the user about real-time traffic conditions and adjusts the route so as to avoid congestions and reduce travelling time. The congestion avoidance algorithm is given below.

Algorithm 7.1: Congestion Avoidance Algorithm [5]

1. Fetch Driver's Current Location (Source)
2. Get Destination Coordinates
3. Retrieve Road Map of Area
4. **while** *Source* $\neq$ *Destination* **do**
5. Retrieve Real-Time Traffic Data from App
6. Plot Traffic Data onto 2D Problem Space
7. Apply *k-Means Clustering* on Traffic Data
8. Assign Weights to Traffic Clusters
9. Combine Traffic Cluster Data with Road Map
10. Convert Weighted Road Map into Neighborhood Matrix
11. Apply *Dijkstra's Algorithm*
12. Display Shortest Path
13. Fetch Driver's Current Location (Source) Again
14. **end while**

In another work, Milojevic and Rakocevic [6] have presented that vehicular traffic congestion is becoming a major economic and social problem which requires the government's utmost attention. It leads to significant financial and safety challenges, and also a major contributor to the increasing pollution in the cities. They have proposed a new vehicle-to-vehicle (V2V) congestion detection algorithm based on the IEEE 802.11p standard. This algorithm allows vehicles to be self-aware about road conditions and finds congestion detection based on the monitoring of speed and cooperation with the surrounding vehicles. Proposed algorithm comprises of five steps as shown in Algorithm 7.2, (1) *Speed Monitoring*, (2) *Congestion Detection*, (3) *Localization*, (4) *Aggregation* and (5) *Broadcasting*. They have also presented a performance evaluation using large-scale simulation in Veins framework based on the OMNet++ network simulator and SUMO vehicular mobility simulator. Results show that precise congestion detection and qualification can be achieved using a significantly decreased number of exchanged packets.

Algorithm 7.2: Congestion Control Algorithm [6]

1) Speed Monitoring
IF $V_c \neq V_t$ **GOTO** 2;
2) Congestion Detection
IF $V_c < V_t$ **THEN**
(Start Timer τ_c, WHEN $\tau_c = \eta.10s \Rightarrow C_p = \eta$);
ELSE (Start Timer τ_c, WHEN $\tau_c = 10s \Rightarrow C_p = 0$);
3) Localization
FIND A_{id} of the current location, **GOTO** 4;
4) Aggregation
GET $C_d(A_{id})$;
IF ($C_p \neq 0$) **THEN**
IF $C_p(A_{id}) > C_d(A_{id})$ **THEN** 5, $C_d(A_{id}) = C_p(A_{id})$;
ELSE skip 5;
ELSE IF $C_p(A_{id}) \neq C_d(A_{id})$ **THEN** 5, $C_d(A_{id}) = C_p(A_{id})$ **THEN** 5;
ELSE skip 5;
5) Broadcasting
Broadcast the (C_p, A_{id});

In [7], Abhishek et al. have presented a study to analyse and resolve the congestion of the complex traffic conditions in the cities. Proposed algorithm tries to control and optimise the duration of time for which the traffic light signal is green, and the number of vehicles passing through the junction during that time period. Wireless sensor network has been used to make the traffic signals adaptive to the dynamic traffic flow, so that the number of vehicles passing through the signal is maximized. Following parameters have been considered while the development of proposed algorithm: (1) *Waiting Time*, (2) *Clearance Time*, (3) *Rate of Arrival*, (4) *Proportionality Constant*, (5) *Clear Route* and (6) *Multiplication Factor*. In [8], a new smart traffic control design is presented which resolves traffic issues and utilizes available road infrastructure. Authors have also considered reducing the waiting time, fuel consumption, traffic congestion and levels of traffic obstruction. Intelligent Traffic Control System (ITSC) is based on a principle stated as 'a car can only move ahead if there is space for it to move ahead' and 'the signal remains green until the present cars have passed'. Here, sensors are placed at every entry and exit of a junction, and are responsible for monitoring the number of cars present at the junction to make traffic management smooth and efficient. Ye et al. [9] and Malekian et al. [10] have proposed driving route prediction methods based on the *Hidden Markov Model* (*HMM*). This method can accurately predict a vehicle's entire route as early in a trip's lifetime as possible without inputting origins and destinations beforehand. First, the driving route recommendation system architecture is proposed which highlights a method for route prediction based on the

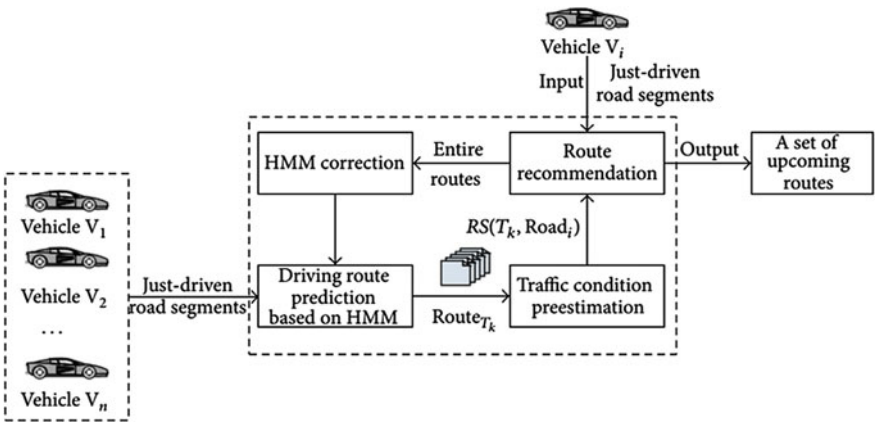

Fig. 7.1 Architecture of route recommendation system [9]

knowledge of HMM. The method can predict the congested road segments as well as smooth road segments through route prediction. The system also updates traffic information in real time and informs the driver to adjust the driving route as the trip progresses. Figure 7.1 shows the architecture of the proposed driving route recommendation system.

This architecture consists of four phases; (1) *Driving Route Predictions Based on HMM*, (2) *Traffic Congestion Pre-estimation*, (3) *Vehicle Route Recommendation* and (4) *HMM Correction* for route prediction and recommendation. Table 7.1 summarizes various applications designed and used for smart mobility of vehicles.

7.2.2 e-Health

Healthcare is another major sector that has witnessed the wide use of wireless sensor networks, IoT, and Cloud computing to perform various types of predictions related to patient's health, monitoring of blood pressure, heart beats, breast cancer, lung disease, etc. Diagnosing from early symptoms or patterns, predictive computing can be used at each level of e-Health-related applications. Health applications designed and used previously, have been shifted to e-Health [30]. Earlier, medical applications were based on the analog telephony that enables the individuals to call the healthcare professional, hospitals to take appointments, and to transmit electrocardiograms over telephone lines [30]. Tele-Health involves health services delivered from a distance and is an important constituent of e-Health [31], but these analog techniques could not be expanded due to the bandwidth limitations, low rate of data transfer over copper wires, the existence of inference and noise. Another constituent of e-Health is 'm-health' which can be defined as a medical and public health practice supported by mobile devices, such as mobile phones, patients monitoring devices and other wireless devices [32].

Table 7.1 Applications for smart mobility

S. no.	Application	Purpose
1	Smart real-time traffic congestion estimation [5]	An intelligent system that predicts congested road segments through real-time GPS data, and suggests shortest alternate route
2	Distributed vehicular traffic congestion detection algorithm [6]	A system that uses a new vehicle-to-vehicle (V2V) congestion detection algorithm which allows the vehicle to be smart. It allows vehicles to be self-aware of the traffic on the road based on the speed analysis and assistance with neighbouring vehicles
3	City traffic congestion control [7]	A wireless sensor network used to analyze and resolve the congestion of the complex traffic conditions in the cities
4	Smart navigation for visually impaired [11–14]	An intelligent, portable, and user-friendly system that enables the visually impaired people to navigate in an environment without any human intervention. It provides assistance for both indoor and outdoor navigation by voice input and output
5	Modelling urban traffic dynamics [15]	A smart system that proposes a way to capture the complexity based on generalization power of Markov chains in coexistence with continuous urban data streams
6	Remote monitoring of vehicle diagnostics [16]	A distributed system that is used for remote monitoring of vehicles and their geographical position using a smart box with GPS and GPRS
7	Intelligent traffic control system [8, 17]	A smart traffic control design that resolves traffic issues and utilizes 100% use of the road infrastructure
8	Route predictions based on hidden Markov model [9]	A system based on the HMM that can accurately predict a vehicle's entire route at the earliest in a trip's lifetime
9	Vehicle tracking system using IoT [18–20]	An intelligent system that makes use of built-in internet enabled GPS sensor to render a real-time and reliable vehicle tracking services to public
10	Intelligent ambulance using IoT [21]	An intelligent system that proposes to make way for ambulances in heavy traffic congestion traffic situations by manipulating the timer of the signal light board
11	Smart parking system using IoT [22–25]	A smart parking system that enables the user to identify the closest parking area and provides the availability of vacant parking slot in the current or neighbouring area
12	Improvement of traffic monitoring system using IoT [26]	An adaptive traffic congestion control system that provides time slot to each route based on the traffic density by fetching the location and

(continued)

Table 7.1 (continued)

S. no.	Application	Purpose
		speed of the vehicle using GPS, which in turns enables us to calculate the accurate time when the vehicle reaches the next intersection
13	IoT-RFID testbed for supporting traffic light control [27]	An IoT-based application for traffic management system that enables the traffic police officers in support decision making
14	Framework for agent-based traffic light control [28]	A smart agent-based framework that proposes a balanced, coordinated and optimal method for traffic light control
15	Real time traffic congestion detection system [29]	An intelligent system that detects real-time congestion without any human intervention or human supervision without any prior knowledge about the condition

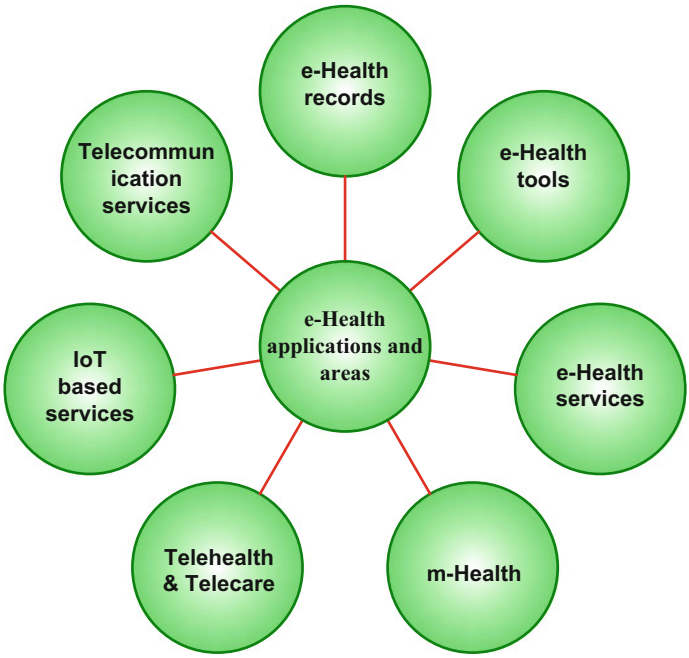

Fig. 7.2 e-Health applications and its target areas

e-Health has become part of every citizen's everyday lives and impacts them in one way or other, and this has led to the development of various e-Health related applications. e-Health applications use the information and communication technologies (ICT) for handling various health-related services. It deals with the broad spectrum of e-Health policies, legal and ethical frameworks, adequate funding and

training [33]. The target areas of e-Health are depicted in Fig. 7.2. It has seen a tremendous growth over the past 30 years, enabling the exchange of healthcare and administrative data and transfer of medical images and laboratory results [30].

In [34], Gupta et al. have discussed an IoT-based cloud-centric healthcare architecture predictive analysis of physical activities of the users in sustainable health centers. The prerequisite of this framework is that health centres should be well equipped with sensors for capturing the patient's basic health parameters while exercising, such as heart rate, distance, speed, and calories burned daily by a user. These parameter values are stored at the end of the session using either a public or private cloud. Next, the healthcare personnel can access this stored information when required. An alert is sent automatically to the healthcare personnel, if any irregularity is predicted in the user's activity or basic parameters, and an action is initiated by the healthcare personnel. In [35], Baccar and Bouallegue have proposed a novel website architecture for an e-Health program based on a wireless sensor network. Designed website offers an ergonomic and multifunctional platform for an intelligent hospital. Features of this website include management of patient's records, real-time monitoring of patient's condition and geo localization for patients as well as professionals involved with the hospital. The system shown in Fig. 7.3, uses remote sensing of biometrics signals for patient's monitoring. The main three functionalities of the proposed website are; (1) *Manage patients records*: Add/Delete and Modify diagnostics for the health file, (2) *Follow the vital signals progress of patients:* Temperature, Blood Pressure, Cardiograph Pulses, etc. and (3) *Localize patients and professionals; mapping service for out-patients.*

In [36], Ahmed and Abdullah have presented an e-Health model from ubiquitous perspective. This model provides data acquisition, archiving, and presentation in the cloud. The proposed model makes use of cloud service architecture (CSA) for

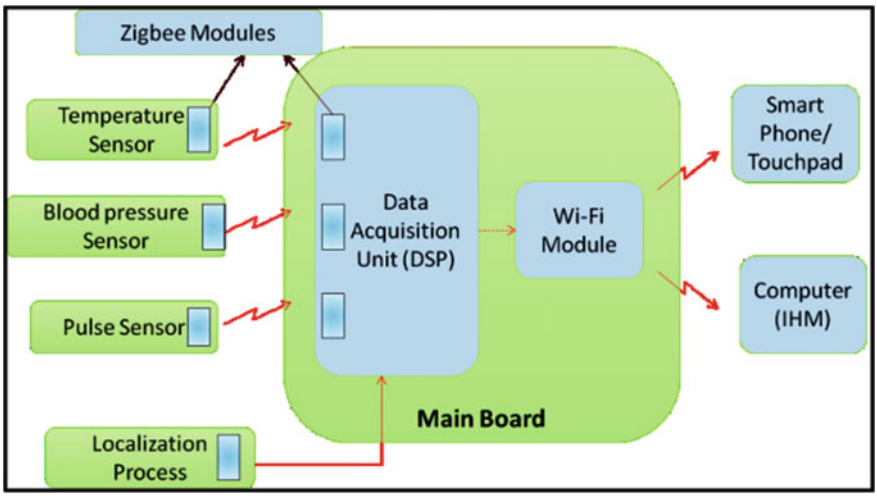

Fig. 7.3 Main board for e-Health platform [35]

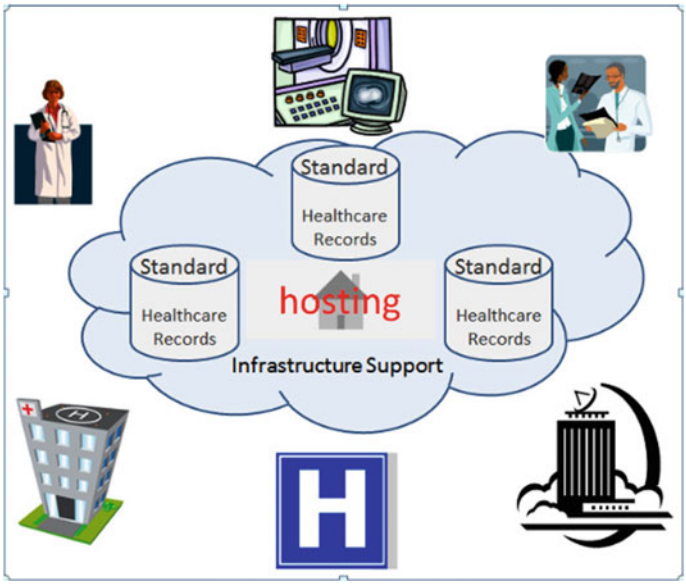

Fig. 7.4 e-Healthcare cloud [37]

processing of medical information of a patient. In another work [37], Liu and Park have focused on the e-Healthcare application cloud-enabling characteristics. The authors of this research work found close proximity of the proposed e-healthcare architecture and the cloud environment. The e-healthcare cloud is shown in Fig. 7.4.

Authors have also discussed the challenges in the adaptation of a pure cloud solution for smart e-healthcare. In [38], Aruna et al. have designed a patient health monitoring system (PHMS) which includes three phases; (1) *collection phase*, (2) *transmission phase* and (3) *utilization phase*. A Body Area Network (BAN) is constructed and used to collect the required data from the patient. PHMS notifies the registered patient with the possible precautionary measures to be carried. It suggests the patient with medical care and further steps to be followed in case of critical conditions. A typical architecture of PHMS is shown in Fig. 7.5.

In [39], Piliouras et al. implemented the Electronic Health Records (EHR) technologies. They have listed various challenges that were experienced while integrating EHR technology within the workflow of an already existing healthcare setting. Authors have also listed the various lessons learned from its implementation: (1) *Identify System Champions*, (2) *Give users a lot of Training*, (3) *Perform Root Cause Analysis* and (4) *Quality Management Principles*. Table 7.2 summarizes various applications designed and implemented for e-Health of user or patient.

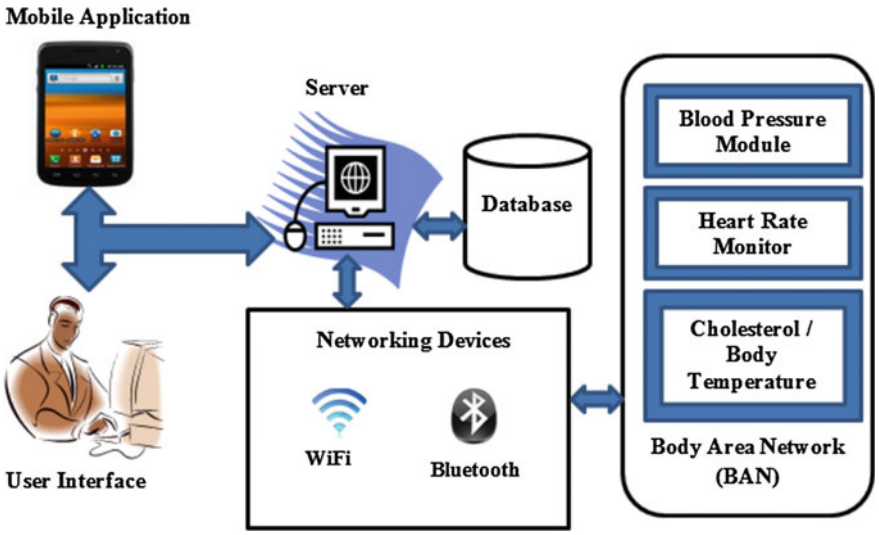

Fig. 7.5 Architecture of PHMS [38]

Table 7.2 Applications for e-Health

S. no.	Application	Purpose
1	IoT-based cloud-centric architecture to perform predictive analysis of user activities in sustainable health centres [34]	A cloud-centric architecture using IoT that uses predictive analysis of the physical activities of the users in maintainable health centres
2	Web-based e-Health platform [35]	A web-based architecture for an e-Health program using a wireless sensor network that offers an ergonomic and multifunctional platform for a smart hospital
3	e-Healthcare management system-based on the cloud-and service-oriented architecture [40]	A smart, and flexible e-Health management system based on cloud computing and SOA and using RIA that overcomes various shortcomings in existing healthcare management systems
4	e-Health monitoring architecture [41]	An intelligent e-Health management system that supports real-time analysis of various parameters of patients using smart devices and wireless sensor networks
5	e-healthcare and data management services in a cloud [36]	An e-Health model that addresses the issues regarding management and security concerns in cloud domain. It includes wireless sensor networks, communication, and storage systems for any hospital using CSA

(continued)

Table 7.2 (continued)

S. no.	Application	Purpose
6	Healthcare cloud computing application solutions [37]	An intelligent cloud-based system that focuses on the cloud-enabling characteristics of e-Healthcare applications
7	Health monitoring and management using internet-of-things (IoT) [42, 43]	An IoT-cloud-based remote patient monitoring system that is used for health monitoring and management
8	Smart real-time healthcare monitoring and tracking System [44]	A smart real-time healthcare monitoring and tracking system that aims to bridge the gap between patients and healthcare professionals
9	IoT-based smart healthcare kit [45]	An intelligent and robust health monitoring system that is capable of monitoring the patient automatically using IoT
10	Remote mobile health monitoring system [46]	A remote mobile health monitoring system that uses mobile and web service capabilities to delivers an end-to-end solution to health-related queries
11	IoT-based remote health monitoring system [47]	An IoT-based health monitoring system that addresses a key challenge to efficiently transmitting healthcare data within the limits of the existing network infrastructure
12	Patient health monitoring system (PHMS) using IoT [38, 48, 49]	An intelligent PHMS that collects patient's sample values and suggests the patient with medical care and further steps to be followed in case of critical conditions
13	Smart cards in healthcare information systems [50–52]	A smart card in healthcare that enables access to a patient's health record stored on network
14	Electronic health record systems [39]	An electronic health record system that uses EHR technologies
15	e-Health tele-media application for patient management [53]	An intelligent e-Health system that provides patients with real-time management of illness, reaction/side effects to prescribed medication, prescription reminders, provides survey data, etc.

7.2.3 e-Logistics

The logistics business has changed dramatically over last few years. Today, the differentiators are more strategic: benchmarking, innovation, network modelling,

etc. Employing suitable logistics strategies is a necessity. However, logistic strategy planning is becoming more and more challenging due to dynamically changing scenarios and difficulties in integrating information from different partners. Information from various sources could be combined to generate integrated knowledge that could support the planning process. Integrated knowledge can better describe the potentials of synergy between the available sources of information, and accordingly better exploit logistics strategy planning. In the following proposal, a machine learning-based adaptive framework for logistics planning is proposed. The proposed system will evolve, adapt and improve as its knowledge grows providing a generalized solution to all kinds of logistics activities.

In [54], Khayyat and Awasthi have conducted a study that investigates the problem of collaboration planning in logistics and proposed an agent-based approach for better management of collaborative logistics. Based on the approach, they have designed a support system which utilizes RFID technology for ensuring inventory accuracy. The proposed approach involves three steps: (1) a conceptual agent-based model is designed, (2) the game theory method is utilized to intensively study and analyse suppliers' collaboration and carriers' collaboration that represent major objectives proposed in the preceding model, (3) correctness of the games is verified by formulating them mathematically. Figure 7.6 shows the design of the conceptual multi-agent-based model.

In [55], Wrighton and Reiter have discussed the problem faced in urban cities of Europe, i.e. the transport of goods contributes to the adverse condition of

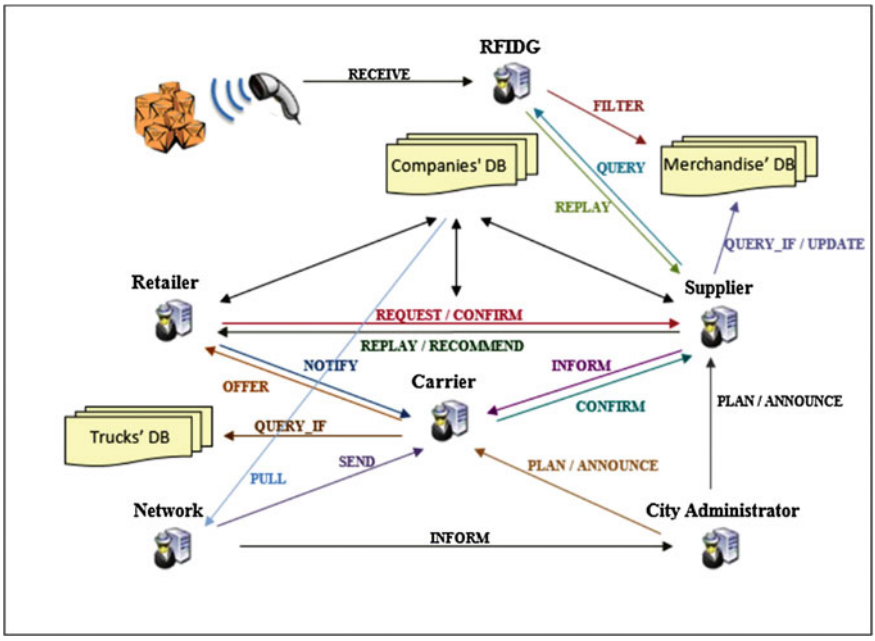

Fig. 7.6 Design of conceptual multi-agent-based model [54]

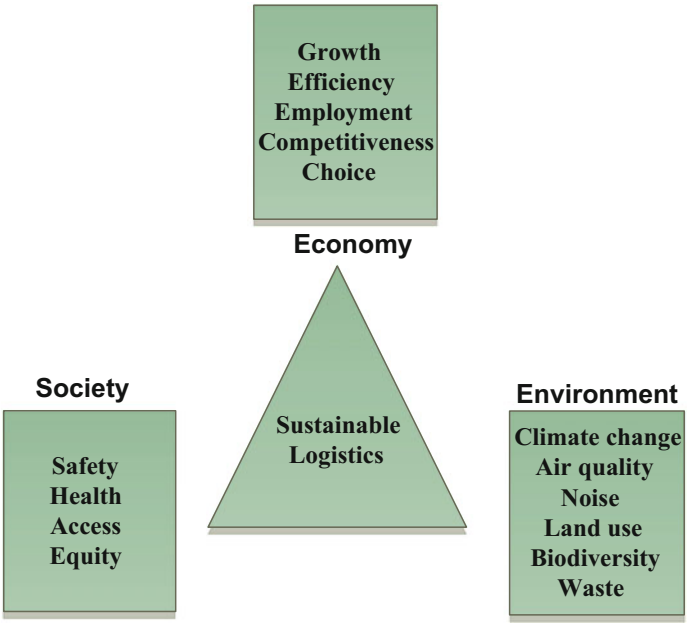

Fig. 7.7 Sustainable logistics dimensions [56]

overcrowding by motorized traffic. City administrators of Europe are aware of the fact that if early measures are not taken to improve this scenario then this will result into a problematic situation. The Cyclelogistics (2011–2014) and Cyclelogistics (2014–2017) projects offer a possible solution to the stated problem. Authors have demonstrated the great potential for the reduction in energy consumption and pollutants caused by urban goods transport by shifting intra-urban final delivery of goods from the car to the bicycle. In [56], the main objective of proposed work is to suggest Smart City logistics on the cloud computing model. Authors have discussed the smart city logistics in terms of sustainable logistics dimensions: Economy, Society and Environment, as shown in Fig. 7.7.

Due to many beneficial characteristics of cloud, the smart logistics has been shifted to cloud computing. Cloud implies a broad range of benefits to the enterprise and other organizations. In [57], the authors have proposed a smart logistics vehicle management system based on Internet of Vehicle (IoV). IoV for smart logistics vehicle management provides various services such as; (1) fleet management, (2) smart driving and (3) transport management. The proposed smart logistics vehicle management consists of following modules based upon the functionality: (1) data collection module, (2) communication module and (3) computational module. In [58], Jianyu and Runtong have represented the model to resolve physical distribution and its effects on E-commerce. Physical distribution is a bottleneck in E-commerce. Authors have constructed the distribution system in

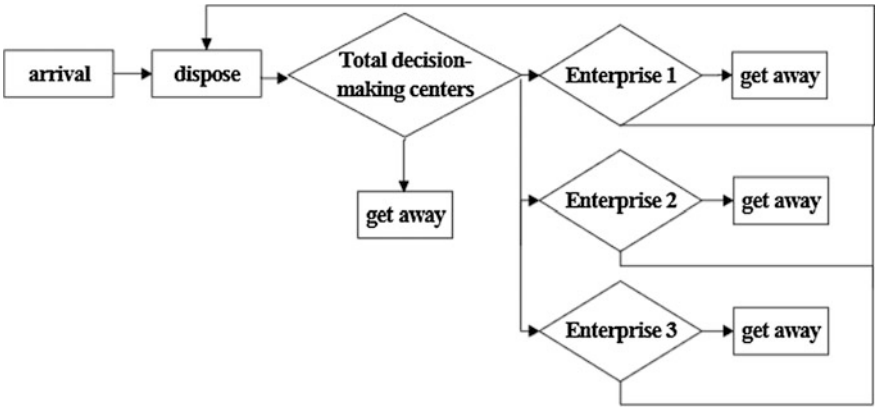

Fig. 7.8 Non-grid simulation logic model diagram about ELS [58]

Table 7.3 Applications for e-Logistics

S. no.	Application	Purpose
1	A comprehensive framework for measuring performance in a third-party logistics provider [59]	A smart framework that provides comprehensive and innovative performance measurement framework for a third-party logistics provider
2	An intelligent multi-agent-based model for collaborative logistics systems [54]	An intelligent multi-agent-based model that has proposed and agent-based approach for better management of collaborative logistics
3	Automobile logistics service supply chain based on reliability [60]	A smart system that deals with building a two-stage automobile LSSC, where the dominant LSI integrates FLSP
4	Cyber-physical logistic systems [61]	An intelligent cyber-physical logistic system that proposes a model for application of innovative techniques for data acquisition and analytics in cyber-physical logistic systems
5	Cyber-physical logistics system-based vehicle routing optimization [62, 63]	A smart routing adjustment model that considers the existing road congestion and minimizes the total distribution in cost. Here, static and dynamic models are proposed for traffic information transmission network
6	Quality of logistics services [64]	A research that deals with the customer satisfaction with services and discusses the importance of relation between the logistic companies and customer satisfaction with logistics services

(continued)

Table 7.3 (continued)

S. no.	Application	Purpose
7	CycleLogistics [55]	A research that demonstrates the great potential for the reduction in energy consumption and pollutants caused by urban goods transport, and discusses how to shift from motorized vehicle to bicycles to change the condition of traffic congestion and over pollution
8	Cyber-physical production systems combined with logistic models [65]	A research that discusses the advantages of cyber-physical systems by considering the production planning, controlling and monitoring
9	Hierarchical integrated intelligent logistics system platform [66]	An intelligent system that proposes HIILS platform for the wide spectrum of the city logistics problems
10	Smart city logistics on cloud computing model [56]	An IoT cloud-based smart city logistics model that deals the smart city logistics in terms of sustainable logistics dimensions
11	Parcel industry in the spatial organization of logistics activities [67]	A research that aims to study the location of parcel industry, and its orientation in the spatial organization of logistics activities in the Paris region
12	Smart logistics [57, 68]	A smart logistics system that proposed a smart logistics vehicle management system based on the IoV
13	e-Commerce logistics in supply chain management [69]	A research that presents the state-of-the-art e-Commerce logistics in supply chain management from practice perspective
14	RFID-based data mining for e-Logistics [70]	An intelligent system that combines RFID for data acquisition, data mining for knowledge discovery and enterprise applications in the field of e-Logistics
15	e-Commerce logistics based on the gridding management [58, 71]	An intelligent e-Commerce logistics-based gridding management system that deals with physical distribution and its effect on e-Commerce

E-commerce logistics based on the gridding management, via the comparison analysis between the grid and non-grid distribution system in E-commerce logistics.

The structure and level of E-commerce logistics system (ELS) consist of (1) function entity, and (2) management level. The proposed framework is shown in Fig. 7.8. Table 7.3 summarizes various applications designed and implemented for e-Logistics.

7.3 Summary

This chapter discusses the applications of predictive computing in real life. It deals with the concept of how and where we can explore predictive computing and deploy the applications. The discussion is concentrated on three case studies where predictive computing can be applied to various applications, namely; smart mobility, e-Health and e-Logistics.

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About this book

This book describes various methods and recent advances in predictive computing and information security. It highlights various predictive application scenarios to discuss these breakthroughs in real-world settings. Further, it addresses state-of-art techniques and the design, development and innovative use of technologies for enhancing predictive computing and information security. Coverage also includes the frameworks for eTransportation and eHealth, security techniques, and algorithms for predictive computing and information security based on Internet-of-Things and Cloud computing. As such, the book offers a valuable resource for graduate students and researchers interested in exploring predictive modeling techniques and architectures to solve information security, privacy and protection issues in future communication.

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Chapter 6
Cloud-Based Information Security

6.1 Introduction

Cloud computing facilitates on-demand service model and provides resources, information and software on sharable basis to their users. It supports heterogeneous connectivity of systems and can interact with each other at same time. The cloud computing provides various dynamically scalable resources as a service over the Internet. There are several economic benefits of using cloud computing as it reduces the overall expenditure and provides better performance and data storage capacity. However, there are still some potential challenges left to focus such as security, privacy and trust. The data that is being communicated between users, and cloud systems need to be secured from different threats and attackers. In [1], Shaikh and Haider have stated that one of the reasons why the cloud computing is not fully accepted by the users is the security. The users are always in fear of losing their data as well as privacy. They have identified various thrust area of cloud security and categorized them. Alassafi et al. [2] have emphasized on secure use of information technology (IT) to reduce risks and for further possible improvement of confidence and trust among the customers. They have stated that IT governance and information security governance (ISG) are two major factors for an organization to promote and use of cloud successfully. While implementing cloud security, security risks are associated with various infrastructure layers like application layer, virtualization layer, trust layer, authentication layer, access control layer, etc., the cloud computing can introduce the variety of risks and threats related to these layers. In [3], Tianfield has discussed about the various issues of security in cloud computing. They have analysed the cloud security requirements in terms of fundamental issues like trust, availability, audit, integrity and confidentiality. As the security is a major issue, it should be applied at different levels to ensure right implementation of cloud computing such as: security of host server, security of data storage, network security and security of application. In [4], Gugnani et al. have focused on cloud-based web services and proposed an approach for selective encryption of

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XML elements. They have used deoxyribonucleic acid (DNA) encryption technique for selective XML elements.

The cloud architecture is classified into four different layers [5] as shown in Fig. 6.1:

(a) Physical layer—The hardware level resources like network resources, computing resources and storage resources are all contained in this layer.
(b) Resource layer—All the resources that have been virtualized lie in this layer. These resources can be used by upper layers and end users further.
(c) Service layer—It supports various services, and software tool, middleware and provides development and deployment of platform.
(d) Application layer—It consists of all the executable applications in the clouds.

The cloud computing models are generally classified into three service models and four deployment models. The service models, as shown in Fig. 6.2 which can be categorized into further three categories: (i) Software as a Service (SaaS), (ii) Infrastructure as a Service (IaaS) and (iii) Platform as a Service (PaaS). On the other hand, the deployment models typically consist of (i) private cloud, (ii) public cloud, (iii) hybrid cloud and (iv) community cloud.

6.2 Related Work

Though the cloud computing architecture and its models are widely adopted by the industries, it still has certain drawbacks. The foremost issue in cloud computing is of security and privacy related to the data of the users. The cloud computing model leaves the clients vulnerable to different types of attacks and threats. Due to this, the client may suffer from a heavy loss of any confidential data or may lose any confidential information. An attacker may eavesdrop the conversation between two clients on cloud or between client and cloud. The users who move their data onto

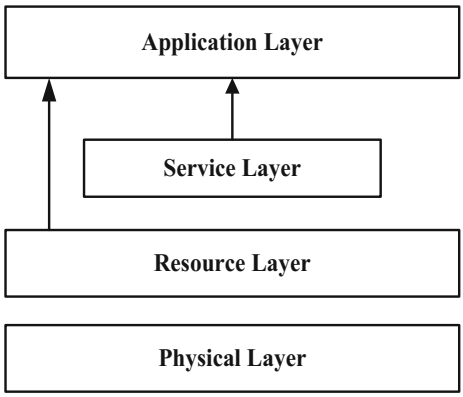

Fig. 6.1 The cloud architecture [5]

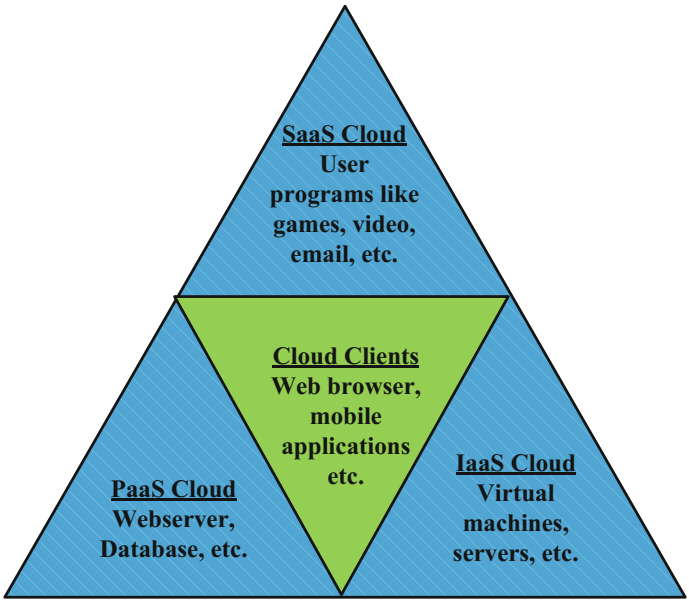

Fig. 6.2 The cloud computing service models

the cloud are unaware of the integrity of their data. They do not know as to where their data is getting stored. Due to these reasons, some users are still adamant of making use of this technology. So, there is a great need to protect the clients from such type of attacks.

The cloud security refers to a broad variety of technologies, policies, mechanisms, frameworks and controls deployed to protect data, applications and the associated infrastructure of cloud computing model. The potential areas that require focus to embed security features are:

- To safeguard all end cloud—user activities, actions regardless of device,
- To protect cloud, database and data centres, and
- To facilitate superior cyber security against various attacks.

The cloud security mechanism must ensure the implementation of correct defensive implementations. The well-organized cloud security mechanism should recognize and address the various security-related issues. Implementation of effective security mechanism and controls defend the system from flaws and decrease the possibility of an attack. These security controls can be categorized under the following category [1]:

- **Deterrent controls**—are anticipated to decrease attacks on a cloud. These deterrent controls typically diminish the effect of threat by notifying the attackers that there will be poor consequences for them if they continue further or move forward in that particular direction.

- **Preventive controls**—toughen the system against threats and attacks, and vulnerabilities. However, the well-built authentication of cloud customer stops unauthorized cloud access by the customers.
- **Detective controls**—are proposed to sense and respond to any accidents that occur. When an attack occurs, this control will sign the anticipatory or remedial controls to tackle the issue. The system and network sanctuary monitoring, intrusion detection and prevention arrangements, are typically engaged to sense attacks on cloud systems.
- **Corrective controls**—these controls decrease the result of a threat, usually by restricting the harm. These controls generally come into effect during or after an attack has occurred. Re-establishing system backup so as to reconstruct a cooperated system can be seen as a paradigm of a corrective control.

Since accessing of information in heterogeneous environment at a time, the integrity and privacy can be breached and always at risk. The cloud computing provides distribution of data over computers. When data is sent by the user to be processed in the cloud; the control of the data is given to a remote party that may not address security concerns of the user. As a user has no physical access to the data, he/she is unaware about the location of his/her data and is not sure whether the integrity of his/her data is maintained or compromised in the cloud. It is important to ensure that the information being processed on cloud is secure and no tampering of information is done when previously unknown parties may be present [6].

6.2.1 Security Issues

Security is termed as the prevention of any unauthorized access, unauthorized deletion or amendment of the information. ISO 27001 defines the security as: '*Preservation of confidentiality, integrity and availability of information; in addition, other properties such as authenticity, accountability, non-repudiation, and reliability can also be involved*'. Cloud computing may introduce many risks to cloud service and cloud deployment model. In [7], Aluvalu and Mundane have presented various access control techniques and models and stated that privacy, trust and access control are important factor to maintain the security in cloud. Rashdi et al. [8] have defined the term cloud computing security as, '*The set of control-based technologies and policies designed to follow to regulatory compliance rules and protect information, data applications and infrastructure associated with cloud computing use*'. The main dimensions of security that should be kept in mind for providing user satisfaction are confidentiality, integrity and availability, (CIA) [9]. CIA provides the basis for implementing security principles, as shown in Fig. 6.3, to known set of threats and can be known as follows:

- Confidentiality—stands to keep the user's data secret. According to Xiao and Xiao [10], confidentiality is one of the major issues in cloud because the information that is outsourced by users on cloud servers is managed and

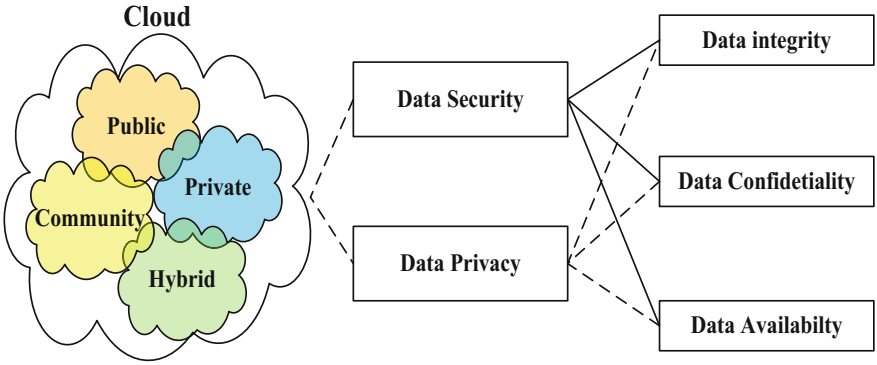

Fig. 6.3 Organizing security and privacy for various cloud deployment models

controlled by untrustworthy cloud providers. In [3], Tianfield also mentioned that threat to data increases because of increased number of applications, parties and devices which leads to increase in number of point of access. One way to achieve confidentiality is to encrypt the information sent by user before placing it in cloud.

- Integrity—stands to preserve the integrity of the information. It should be checked that the information is not lost or modified by unauthorized user. One technique to maintain the integrity is usage of digital signature. In [3], the authors have stated that by using service level agreement (SLA), information is protected while it is on cloud, preventing intrusion or attack on data and responding swiftly to attacks such that damage is limited.
- Availability—The users can access the resources, information from any place and at any time. Denial of service attacks, equipment outages and natural disasters are all threats to availability of information in clouds. According to Zissis and Lekkas [12], the availability should not only be in terms of information, software but also hardware being available to authorized users upon demand.

The risks associated to stored information in clouds can vary according to cloud service models deployed by the organization. Some risks can affect all the cloud service models including SaaS, PaaS and IaaS, whereas some are limited to one or two models only. Table 6.1 represents some of the major risks of cloud computing associated to CIA security principles.

6.2.2 Privacy Issues

The cloud computing uses different ways to manage the information and user-related personal data. The privacy refers to the right to self-determination, i.e. the ability of individual or group to seclude them from access of information and

Table 6.1 Various risks associated to CIA security principles and cloud service models

CIA security principles	Associated risks	Cloud service models		
		SaaS	PaaS	IaaS
Confidentiality	Users from organization	•	•	•
	Attacker(s)	•	•	
	Data leakage	•	•	
Integrity	User access	•	•	•
	Data segregation	•	•	
	Quality of data	•	•	
Availability	Change of policies or management	•	•	•
	Denial of service	•	•	•
	Physical disruption			•
	Lack of recovery methods	•	•	•

then selectively reveal them. Privacy issues are becoming more important while using Internet-based transactions. Lack of effective security mechanism and loss of control could result in serious threat to data integrity, confidentiality and privacy principles [13]. In terms of organization, personally identifiable information is managed by providing privacy which involves the application of processes, standards, laws and mechanisms. Xiao and Xiao [10] have considered the emerging cloud platform and used an attribute-driven methodology to design security and privacy paradigm. They have used attributes like confidentiality, availability, integrity, accountability and privacy-preservability. In [14], Chen and Zhao have analysed the data security and privacy-related issues using various algorithms. They have stated that because of these issues, many large organizations still do not share their data on cloud. In [15], Sun et al. have identified the various elements related to privacy and categorized them in three groups known as (i) *When*—a user is more cautious about the use of information which is either being accessed or will be accessed, (ii) *How*—user must ensure the way for accessing this information manually or automatically, (iii) *Extent*—user can define the several points as an ambiguous region and can only be used by group of users those who have the precise access to that region. Privacy issues vary according to different cloud scenario. In [16], Pearson has mentioned that existing cloud services impose a lot of challenges to privacy of data while handling sensitive data, and data leakage related issues and suggested that this type of data cannot be stored in public clouds of various cloud service providers in an unencrypted form. Pearson [16] and Guilloteau et al. [13] have identified the key potential privacy issues as follows:

- Lack of user control—As the user stores their data over public cloud, then cloud service providers become responsible for further handling and managing of data. Users have limited control over the stored data in public clouds. There is always an issue of transparency in between the cloud user and service providers as the stored data over clouds can be analysed by security agencies or law enforcement

agencies. A trust is required between both of the parties while transferring data rights and providers must ensure the data integrity throughout its lifecycle.

- Lack of training and expertise—Developers are focusing more on easy to design and deployment models of clouds rather the handling of privacy concerns to their models. They need to be trained with existing information security laws and practices to maintain the privacy of data. By ensuring privacy of users data, one can build the trust over the period of time.
- Unauthorized use of data by third party—There is always a risk associated with the stored data in the clouds that it can be used by the third party for their own purpose. Nowadays, it is getting more common as users may get annoying advertisements while accessing or using of stored information. Currently, there is no such arrangement to stop this unauthorized use of data by third party.
- Achieving regulatory compliance—Global use of cloud computing makes it complex as user never knows about the exact location of data that is being stored in clouds. These cloud servers can be in the same country or may be located globally. Things become complex if cloud is located in different country as many legislations in place around the world. It is always difficult to ensure compliance with all the legislations. The cloud computing may exacerbate the transborder data flow issue that may restrict the flow of information.

6.2.3 Trust Issues

Trust is a measureable belief that is used to make trustworthy decisions based on experience and it is a major issue with cloud computing irrespective of the cloud model being deployed. The security and privacy challenges discussed above are also relevant to the general requirement upon cloud suppliers to provide trustworthy services. Trust relationships are very much at the centre of certain security and privacy solution. To build trust, one need to ensure security and privacy of data is intact and foolproof. This situation is also depicted in the Fig. 6.4, where trust lies in between security and privacy. Trust has several different attributes like reliability, confidence, dependability, honesty, etc., to obtain various cloud services. Sun et al. [9] and Pearson [16] have identified various issues of trust in cloud computing:

- The attributes of cloud computing environment are unique, so the definition and evaluation of trust become difficult.
- Based on the degree of trust, how to provide different security level of services.
- The trust relationship in cloud computing is temporary and dynamic, so handling of malicious information is a tough task.
- Lack of consumer trust is another major reason for avoiding the cloud adoption. Various critical challenges like vendor's lock-in, cloud availability, cloud performance, cloud data security, etc., need to be addressed to encourage cloud adoption. In clouds, customers have limited control of resources that is why they cannot protect their data against unauthorized access or its misuse.

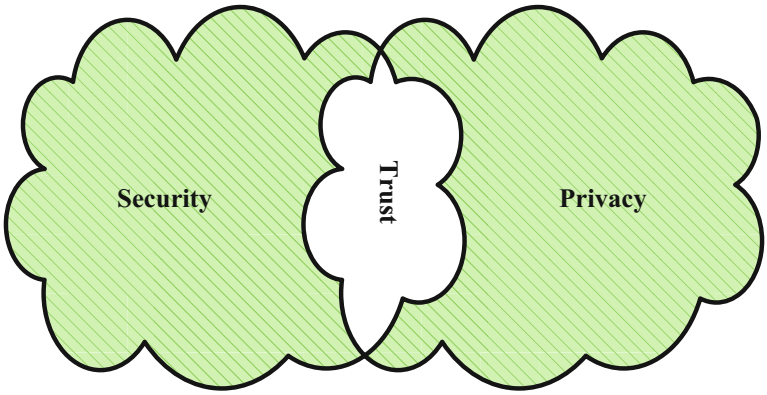

Fig. 6.4 Obtaining trust from security and privacy of data

- Weak trust relationships and lack of transparency between cloud user and service provider may lead to failure of cloud service delivery chain.
- Lack of knowledge and consensus for using standardized trust models and approaches for cloud environment [17].

6.2.4 Issues with Cloud Service Models

Apart from the issues as stated in the preceding sections, there are many other issues of cloud computing pertaining to its different service models known as IaaS, PaaS and SaaS. In [18], Rana et al. have proposed a combined and improved IaaS and PaaS architecture to remove their drawbacks.

- **IaaS issues**—It provides only basic level of security like load balancing, firewall, etc. The applications moving to the cloud require high degree of security. One company may be hosting many other companies' workloads and data in a shared environment. In such cases, it may expose all parties to a higher risk of security- or privacy-related incidents [19]. In [20], Joshi et al. have listed the component wise security issues in IaaS like SLA issue for monitoring of quality of services to cloud users and enforces trust between cloud service provider and user, and cloud software related issues which coins the cloud component together to make them act as a single component so that attackers cannot easily target the SOAP envelop or XML signature. The different issues in IaaS are summarized as follows in Table 6.2 [21]:
- **PaaS issues**—The hacker can use the advantages of PaaS to influence the PaaS cloud infrastructure for malware command and control. One major challenge is the interoperability of PaaS as most of the applications, APIs, database are vendor specific. The various issues in PaaS are summarized in Table 6.3 [21].

Table 6.2 Issues in IaaS

Area	Security	Privacy	Trust
DOS (denial of service)	Misconfiguration, vulnerabilities in system or OS	Access control compromised	Service not available
Robustness of virtual machine-level Isolation	Vulnerabilities in hypervisor	Internal network probing may occur	Compromised virtual machines/hypervisors permit the loss of trust
EDOS (economic denial of service)	Authentication, authorization, and accounting (AAA) vulnerabilities	User provisioning, de-provisioning vulnerabilities	Access control compromised

Table 6.3 Issues in PaaS

Area	Security	Privacy	Trust
Technical immaturity	Compliance challenges	Storage of data in multiple jurisdiction and lack of transparency about this	Lack of information on jurisdictions
Lack of portability	Non availability of common authentication interface	'Data hostage' clause in supplier outsourcing contracts	Liquidate damage for lost business
Protecting API keys	Bad key management procedures	Service information leakage	Lack of sensitivity

- **SaaS issues**—The main focus is not only on application's portability but also on migration of data and enhancement of security functionalities. For development and deployment of SaaS application, the order of following security elements must be ensured. The following should be kept in mind:
  - *Data security*—In SaaS model, the data is stored at the vendor's end. The SaaS vendor should acquire additional security checks so as to ensure security of data and prevent data breach through unauthorized users. The strong encryption techniques should be involved for data security. Due to loophole in data security model, malicious users can gain access to the data.
  - *Network security*—The sensitive data that is obtained from the users/organizations are stored at SaaS vendor end. All the data over the network must be protected to prevent leakage of data. This is achieved by using strong encryption techniques to manage network traffic like SSL and TLS.
  - *Data locality*—The applications provided by SaaS are used by consumers and then data processing is done. The consumers are unaware of the fact as to where their data is getting stored. Example: In many European countries, certain type of data cannot leave the country because of the information being sensitive. The SaaS model should provide reliability to the customer in terms of location of data
  - *Data integrity*—It is easier to achieve data integrity in a single system with single database by making use of database constraints and transactions. Transactions follow ACID properties. The problem of data integrity gets magnified in case of cloud computing. The SaaS vendors unveil their web service APIs without any support for transactions. There are different levels of availability and SLA in each SaaS application which makes it difficult to manage the transactions and provide data integrity
  - *Data segregation*—Due to multi-tenancy feature in cloud computing, multiple users can store their data on cloud. The data of various users will reside at same location. Intrusion in user's data by another user becomes easy in such environment. Intrusion can be done by hacking or by injecting client's code into SaaS system. Therefore, SaaS model should ensure boundary for each user's data not only at physical level but also at application level

Table 6.4 Issues in SaaS

Area	Security	Privacy	Trust
Unauthorized access	Data integrity and confidentiality loss	Compromised communications secrecy	Loss of trust in service
Physical risks	Physically destroyed data	–	–
Browser-based risks	Loss of data integrity, and confidentiality	Loss of user secret credentials	Loss of confidence upon channel
Network dependence	Loss of availability	–	Trust on service reduces

- *Data access*—Various security policies are provided by the organization to the users when accessing the data. Based on these policies, each employee can access limited information. Cloud must stick to these security policies in order to avoid intrusion of data.
- *Authentication and authorization*—The authentication is assurance that the communicating entity is the one that it claims to be that is 'who are you?' and authorization is a kind of access control 'what you can do'. This means that no unknown or harmful entity should able to pretend that he or she is the authenticated one and even authenticated persons should have a limited access to the data.

The various issues in SaaS are summarized in Table 6.4 [22].

6.2.5 Threats in Cloud Computing

The cloud security alliance has presented a primary draft for threats relevant to the security architecture of cloud services. In this section, we have given few potential threats related to the cloud [23, 24].

(a) **Malicious insiders**—Majority of the companies conceal their strategies about the height of access to their staff. Though, via superior level of access, a member of staff can grow access to top secret data and services. As there is deficiency in transparency of cloud provider's policies, processes and procedures, some insiders can frequently have the privilege to access the client's data. Malicious insiders (employee) actions are often evaded by a firewall or infringement discovery system considering it to be an authorized action. Though, a trusted member of staff may also convert into an opponent. In these kinds of scenarios, insiders can source a significant effect on cloud services. Let us take an instance —here malicious insiders can access top secret data and put on control over the cloud services without any jeopardy of revealing his identity. These kinds of threats may be applicable to any cloud service SaaS, PaaS and IaaS. So as to avoid these kinds of risks, there is the need of more transparency in security and management process together with compliance reporting and breach

notification. This is amplified in the cloud via the meeting of IT services and client over a single management domain which is united within a general transparency deficiency into the service supplier process and procedure [25].

(b) **Shared technology issues/multi-tenancy nature**—Virtualization in multi-tenant architecture is used to provide shared on-demand services. Different users who have access to the virtual machine may use the same shared application. Though, as mentioned above, via some attacks and threats, some malicious entities can gain access and control of the lawful users' virtual machine. In multi-tenant architecture through shared resources, IaaS services are delivered which sometimes are not designed to give sufficiently strong isolation. Giving permission to one tenant to interfere in the other can cause serious affect on the cloud architecture which can affect its regular operations. Generally, these types of threats have an effect on IaaS. Transparency in SLA for patching, well-formed authentication system and access control mechanisms to administrative tasks are some of the solutions to resolve this issue.

(c) **Insecure Interfaces and APIs**—Cloud providers offer their services by using the various types of APIs, available for different cloud service models like SaaS, PaaS and IaaS. These weak set of APIs and interfaces can result in many security-related issues in cloud which includes unauthorized access of security key and data, insufficient input data validation, weak credentials that lead to loss of data integrity and CIA [26, 27].

(d) **Data threats**—In [27], Kazim and Zhu have stated that in cloud computing, data is the valuable resource for any organization, and security of the data is the biggest challenge for cloud service providers. Major data security threats that may arise over the period of time are data breaches, data loss, unauthorized access and integrity violations.

- **Data breaches**—are also commonly known as data leakage of stored information in cloud via unauthorized access. The major reasons of data breaches are poor application designing, flaws in operational and infrastructure setup, insufficiency of authentication, authorization and audit controls [27].
- **Data loss**—Information can be exchanged in many ways. This can incorporate data insertion, data compromise, deletion or modification. Data loss occurs because of many reasons like malicious attackers, data deletion, data corruption, etc. [27]. As the cloud is shared and dynamic in nature, so these threats could prove to be of a foremost concern leading to data theft.

(e) **Service hijacking**—is a very serious threat. In this, the hijacker may forward the cloud customer to an illegal website. For attackers, service instances and user accounts can serve as a new base for attack. This threat can have great impact on IaaS, PaaS and SaaS. There are some of the solutions to resolve this threat which include safety policies, strong authentication and activity monitoring.

(f) **Identity theft**—The identity theft is a kind of scam in which one acts as if to be someone else so as to access resources or obtain credit and other benefits. The casualty (of identity theft) can undergo undesirable consequences and losses and held responsible for the criminal's activity. Some of the security perils are phishing attacks, weak password, recovery workflows, key loggers, etc. This threat can have significant impact on SaaS, PaaS and IaaS and some of the solution includes the use of powerful encryption, authentication and authorization mechanisms.

(g) **Denial of Service (DOS)/Distributed Denial of Service (DDOS)**—DOS attacks prevent users from accessing of cloud services, network and other services whereas in DDOS, attackers use the multiple network sources to send a large number of requests to the cloud for consuming its resources [27, 28].

(h) **Online Cyber theft**—In [29], Chou has stated that as the cloud-based services are becoming popular among the customers and organizations for storage of information, stored sensitive data is becoming an attractive target to online cyber theft. Online cyber thieves can make the use of stolen password and user IDs or can take the advantage of computing power offered by cloud service providers to launch attacks or to access user accounts.

6.2.6 *Attacks on Cloud*

There is number of security risks and issues as shown in Fig. 6.5, associated with cloud computing but they are grouped in two categories: (i) security issues faced by cloud provider and (ii) security issues faced by their customers. Various types of attacks in cloud are listed as follows:

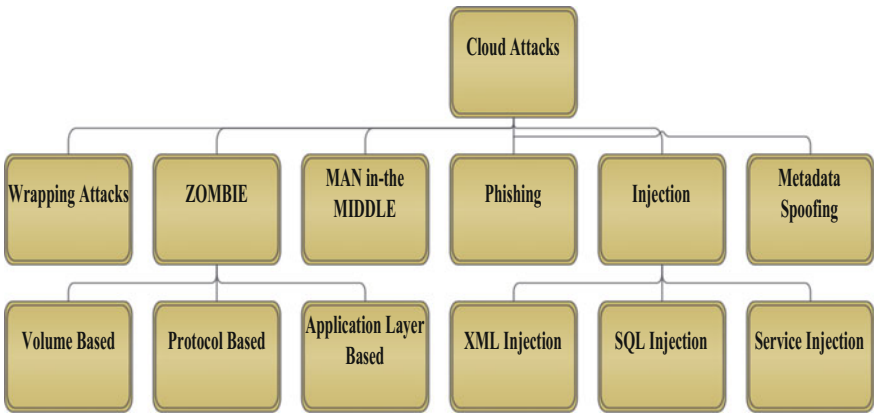

Fig. 6.5 Various types of cloud attacks

(a) **Zombie Attack**—An attacker can overflow the huge number of requests via *zombies*. This kind of attack disrupts the normal performance of cloud, disturbing the availability of cloud services. This cause cloud to be overloaded to serve a huge number of requests and therefore all its resources get exhausted, which can further originate DoS (Denial of Service). In DoS, in cloud due to the presence of invader's overflow of requests, cloud becomes unavailable to serve legitimate user's requests. Nevertheless, strong authentication and authorization and IDS/IPS can offer defense in opposition to such type of attack.

(b) **Injection attack**—Injection attacks are such attacks where intentionally malicious data is included as the input to disrupt the normal functioning of the cloud. A few of the injection attacks are:

- *XPath Injection:* When user and the cloud communicate, they communicate through XML files. XPath is a kind of query language for XML document as for relational databases we have SQL. Dissimilarity among SQL and XPath is that XPath is implementation independent [30]. XPath injection can occur by querying the XML database or when a service is invoked.
- *SQL injection:* In such kind of attacks, user injects malicious SQL statements into an entry field for execution. SQL injection is generally recognized as an attack vector for websites but can be used to attack any type of SQL database.
- *Service Injection:* An opponent attempts to insert a suspicious service or new illegal virtual machine into the cloud system and could supply malicious service to users. Cloud malware deforms the cloud services by changing (or blocking) cloud functionalities. Let us take an example in which an opponent makes its own malicious services like SaaS, PaaS or IaaS and attach it to the cloud system. In case, an opponent becomes successful to perform this, then legitimate requests are readdressed to the malicious services automatically. To protect against such an attack, there is a need to implement the service modules.

(c) **Man-in-the-Middle attack**—An attacker is capable of accessing the data exchange between two parties, if SSL is not configured properly. In case of cloud, an attacker is capable of accessing the data communication between data centres. To reduce or to prevent cloud from man-in-the-middle attack, proper configuration of SSL and data communication tests between cloud and its client are required.

(d) **Metadata spoofing attack**—In such kind of attack, an opponent amends or changes the service's Web Services Description Language (WSDL) file where descriptions about service instances are stored. In case, if the opponent succeeds to suspend service invocation code from WSDL file at delivering time, then metadata spoofing attack can be feasible. So as to triumph over such an attack, information about services and applications should be kept in ciphered form. Currently, WS-Security Service is broadly used in cloud to endow with security for the system [31].

(e) **Phishing attack**—is famous for manipulating a hyperlink and sends false link to obtain confidential information from the user. In cloud, sometimes it might be possible that an adversary uses the cloud service to host a phishing attack site to hack accounts and services of other cloud users.
(f) **Wrapping attack**—In [29], Chou has mentioned that web service security mechanism is used to ensure the confidentiality and integrity of SOAP messages communicated between user and cloud service providers. Wrapping attacks use XML signature wrapping to exploit a weakness when web servers validate signed requests [32]. These attacks generally take place during the translation of SOAP message between users and web servers. Since cloud users normally request services from cloud computing service providers through a web browser, wrapping attacks can cause damage to cloud systems as well. In [33], a group of researchers have demonstrated the use of XML signature wrapping technique for hijacking of an account that exploited vulnerability in the Amazon web service.

6.2.7 Cloud-Based Information Security Models

To ensure cloud security at various levels from information retrieval to its storage, security models are implemented. These security models must ensure the support for cloud security issues related to security issues, privacy issues, and trust issues as discussed in previous section. These security models also build the user's confidence by deploying various techniques for handling the various cloud-related threats. In [34], Mushtaq et al. have proposed the quad-layered framework for data security, data privacy, data breaches and process associated aspects. This proposed layered framework prevents the confidential information and try to build user's trust on cloud computing. In [35], Kritikos and Massonet have proposed a security meta-model for clouds. This model captures the high-level and low-level security requirements and capabilities to derive application deployment. Nafi et al. [36] have proposed a security model for cloud and implemented various security algorithms like RSA, AES and MD5 for secure communication of information between users and servers. To resolve the problem of privacy in the clouds, Metri and Sarote [37] have introduced a threat model known as STRIDE which helps in analysing a problem, designing appropriate strategies and evaluating the solutions. They have listed the following steps to ensure the privacy:

(a) Identify—attacks, and threats
(b) Prioritize threats—according to the impact using STRIDE model.

- Spoofing identity—means an attacker poses as another user or a machine poses as a valid machine.
- Tampering with data—means to maliciously modify the data.
- Repudiation.
- Information disclosure—means to expose the information to the unauthorized users.

- Denial of Service (DoS)—means to deny any service to valid users. Example: web browser made temporarily unavailable.
- Elevation of privilege—means the privileged access is gained by unprivileged users to destroy entire system.

(c) Select appropriate strategies for threats

In [38], Mathew has presented a model to help the cloud users and cloud providers to ensure the safety of data. He has used the secured virtual private network (VPN) for accessing clients and providers. In [39], a privacy protection framework was proposed by Gajanayake et al. based on information accountability (IA) components. They have used IA agent for accessing of information by the users. In case of any misuse of information, IA agent implements various methods to stop this. In [40], Chidambaram et al. have proposed a secure storage system to handle sensitive data in clouds. They have introduced a user authentication mechanism to prevent unauthorized access to data. RSA algorithm has been used for encryption of files in cloud and MD5 has been used to generate the digital fingerprint. Hamlen et al. [41] have proposed a framework consisting of layers for cloud security and focused on two of the layers known as the storage layer and the data layer. A bottom-up approach to security was also proposed, where work is done on small problems in the cloud to solve the larger problem of cloud security. First, the various methods have been discussed for securing of documents. Second, how security can be enhanced by using secure coprocessors is discussed. Juels et al. [42] described a formal 'Proof of Retrievability' (POR) model as shown in Fig. 7.6 for ensuring the remote data integrity. This model utilizes the error correction code approach to verify the validity of data. In POR protocol, the verifier stores only a single key for each file. This scheme requires that only a small portion of file F is accessed by the prover in course of a POR. POR encrypts file F and randomly valued check blocks called *sentinels* are embedded. The prover is challenged by the verifier by specifying position of collection of sentinels and asking the prover to return associated sentinel values. If any modifications are made on file F by the prover, then large number of sentinels is likely to be compressed. To protect corruption of file F by the prover, error correcting codes are employed.

In Fig. 6.6, by using encoding algorithm, raw file F is transformed into file F' and is stored with the prover/archive. A key K is produced by using the key generation algorithm and it is stored by the verifier. The key K is used in encoding mechanism. A challenge–response protocol is performed by the verifier with the prover to check that file F can be retrieved by the verifier. The drawback of the approach is that there is computational overhead. In [21], Mohta et al. have discussed about the implementation of TPA for verifying the cloud service provider (CSP). A protocol was proposed that is used for supporting various operations which also maintains privacy and integrity. The architecture is shown in Fig. 6.7

In [43], Chalse et al. provide a detailed analysis of the cloud security problem. The different problems in a cloud computing system and their effect upon the different cloud users are also analysed. This architecture is shown in Fig. 6.8 and consider the following:

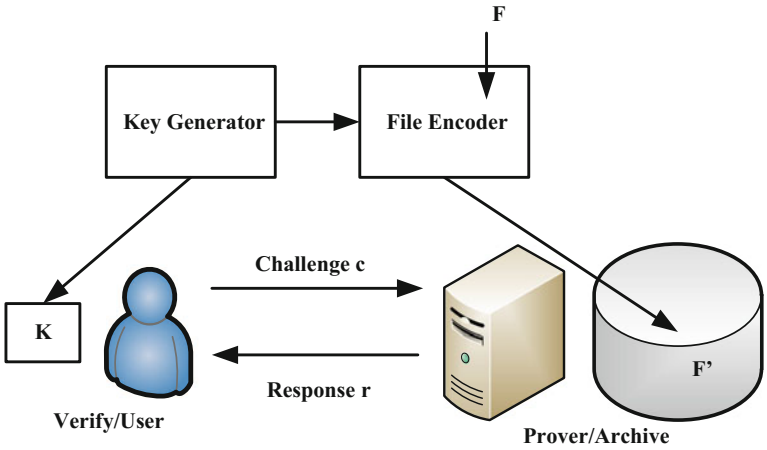

Fig. 6.6 Schematic of a POR system

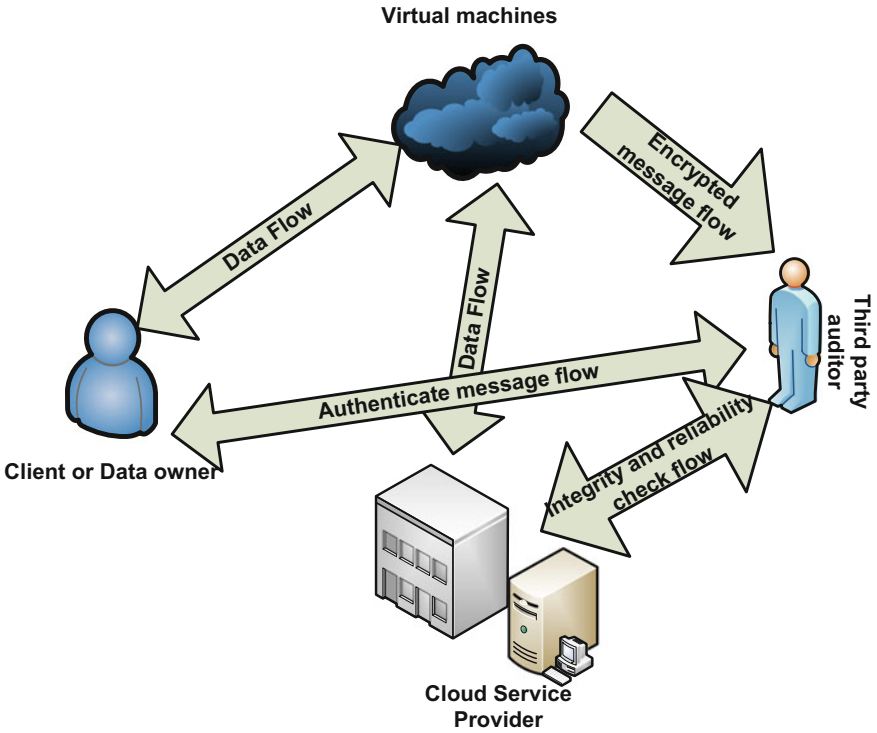

Fig. 6.7 Architecture for client, third party auditor and cloud service provider

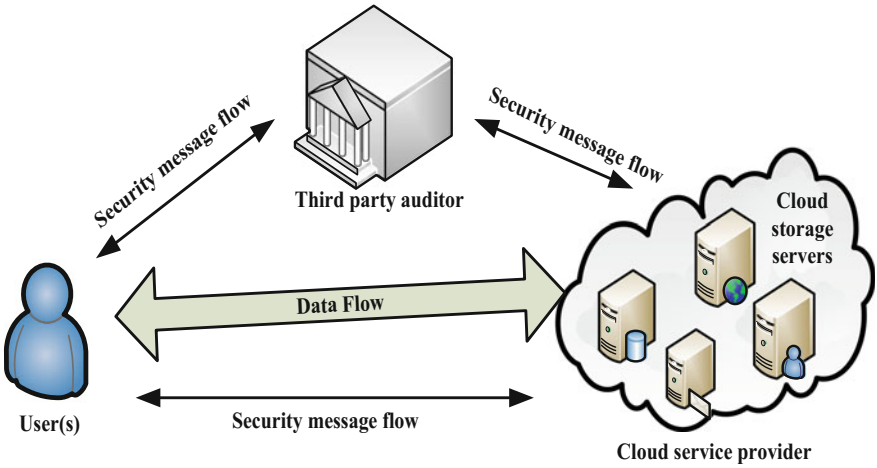

Fig. 6.8 Cloud data storage architecture

- A client who wants to store large amount of data in multiple clouds and has the permissions to access and manipulate stored data.
- Cloud service providers (CSP) support various services related to data storage and its usage and have sufficient resources available for computation.
- Trusted third party (TTP) ensures various parameters related to storage and use of data and provides appropriate public query services available to these parameters.

6.3 Framework to Maintain Data Integrity

This section defines the proposed framework to provide data integrity in multi-cloud system. Proposed framework shown in Fig. 6.9 has three main roles [11]:

- *Users*—who will store the data by selecting appropriate layer depending on the level of security needed for the data stored on cloud.
- *Cloud service provider (CSP)*—provides the storage of data service with flexible resources to keep the user data. The CSP manages cloud server (CS) which informs the user about the intrusion of data on cloud.
- *Third party auditor (TPA)*—verifies the cloud server and checks whether there is any manipulation of user data by the cloud server. It then sends a report to the user stating that the cloud server (CS) was trusted or not.

There are many cloud service providers and each of them provides different storage plan along with different QoS parameters so it becomes a tough task for users to keep moving their data from one cloud to another based on QoS and cost optimization [14]. In the proposed model, concept of multi-cloud is used to provide best cost optimization for various requirements of user.

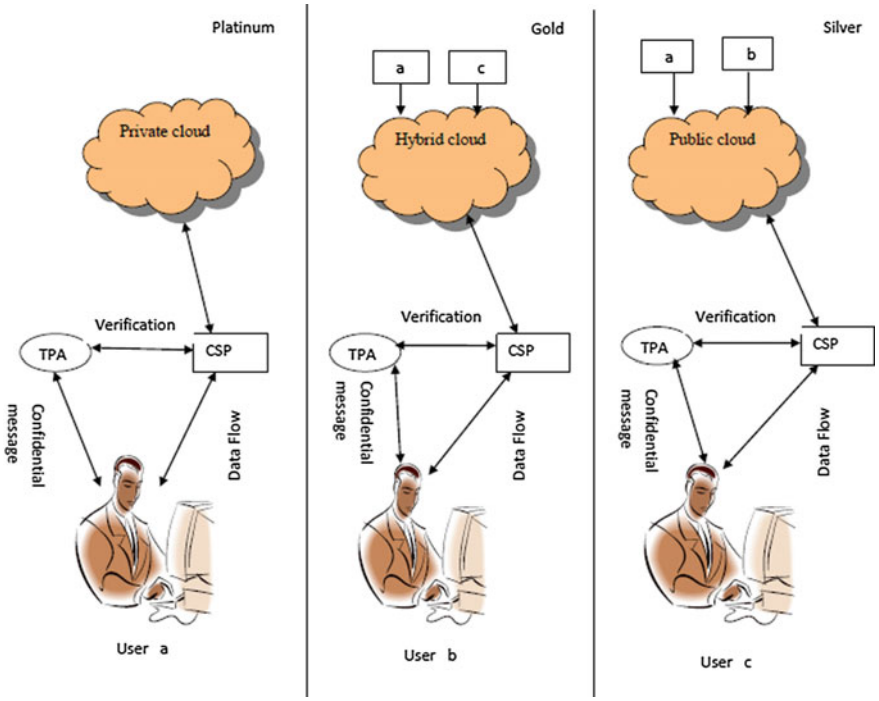

Fig. 6.9 Data integrity framework

It can clearly be seen that depending on type of data, the user can move from one service provider to another, e.g. the user 'a' can put his data over hybrid or public cloud depending on the security needed for the data stored. The same thing can be applied by other two users. Depending on the type of data to be stored on various clouds, there are three main platforms in the model namely:

- *Platinum*—To store sensitive data like data related to transactions of ATMs, bank account information along with high level of security on the data. The data will be stored on a private cloud.
- *Gold*—To store data related to simple login on any page like Facebook, ebooking and email login is stored. The level of security needed is not that high. Security only on password is required.
- *Silver*—To store data related to only simple browsing of sites, uploading of images, downloading of files like downloading of music files or images are stored. The level of security needed is the least.

Based on these levels, the user will decide the platform to store the data.

6.3.1 Data Integrity Algorithms

In this section, we have discussed various algorithms which are used to implement the proposed framework.

Algorithm 6.1: SaaS cloud integrity

```
/* Variables used for:
        User => u,
        Platinum => p,
        Gold => g
        Silver => s
 */
 Begin
        If u chooses p
          Then call module m1;
        If u chooses g
          Then call module m2;
        If u chooses s
          Then call module m3;
 End

Module m1:
  Begin
     User's data is encrypted using RSA and sent to CSP;
     Data is verified by CSP;
     If data is valid
           success message;
      Go To Module T
  End

Module m2:
  Begin
     Data stored is encrypted using Bcrypt algorithm;
     Data is verified by CSP;
     If data is valid
           success message;
     Go to module T
  End

Module m3:
   Begin
     Data is encrypted using AES algorithm;
     Verification of data is done by CSP;
     If data is valid
       success message;
     Go To Module T
    End

Module T:
  Begin
     Check the data stored.
     If  user's data == cloud data then
       data valid;
     Else
       corrupted data;
  End
```

In module m1, RSA algorithm [44] is used to provide integrity of data because for storing sensitive information on cloud, hashing algorithms are used. RSA is based on the difficulty of factoring large numbers. There are various advantages of RSA due to which it is preferred over DSA.

- DSA can only be used for authentication while RSA can be used for both authentication and to encrypt a message.
- A bad random number generator will leak DSA key bits.
- Faster at encrypting than DSA.

In module m2, Bcrypt algorithm is used for hashing the passwords over algorithms like MD-5, SHA-1, SHA-2 and SHA-3. A password hashing algorithm should preferably be slow in order to prevent brute force attacks; it should have features which actually decrease the feasibility of a distributed brute force attack on the hashes. Bcrypt algorithm is derived from the Blowfish block cipher which uses lookup tables that are initiated in memory to generate the hash.

In module m3, AES algorithm is used to provide security on the stored data. AES is asymmetric encryption algorithm which is used to encrypt the message. Here, sender uses the public key of receiver and receiver uses its private key to decrypt the message. The following features of AES over DES describe its usability for the framework presented in Fig. 6.10.

- AES is more secure in comparison to DES algorithm.
- AES data encryption is mathematically more efficient and elegant cryptographic algorithm. Key length option is the main strength of the algorithm. Time required to crack an encryption algorithm is directly related to the length of the key used to secure the communication. AES gives an option to choose a 128-bit, 192-bit or 256-bit key, making it exponentially stronger as compared to the 56-bit key of DES.
- Block size of DES is small compared to AES algorithm.
- A balanced Feistel structure is used by DES while substitution-permutation is used by AES.

6.3.2 Performance Analysis of Security Techniques

In order to provide assurance of characteristics in cloud systems like reliability, security, fault tolerance, sustainability and scalability, computational services timely, repeatable and controllable methodologies are required for evaluation of new cloud applications and policies before actual development of cloud products. In [45], Thakur et al. have presented the simulations of above mentioned algorithm using CloudSim. Algorithmic analysis and obtained results using RSA, AES and Bcrypt for the presented framework in Fig. 6.9.

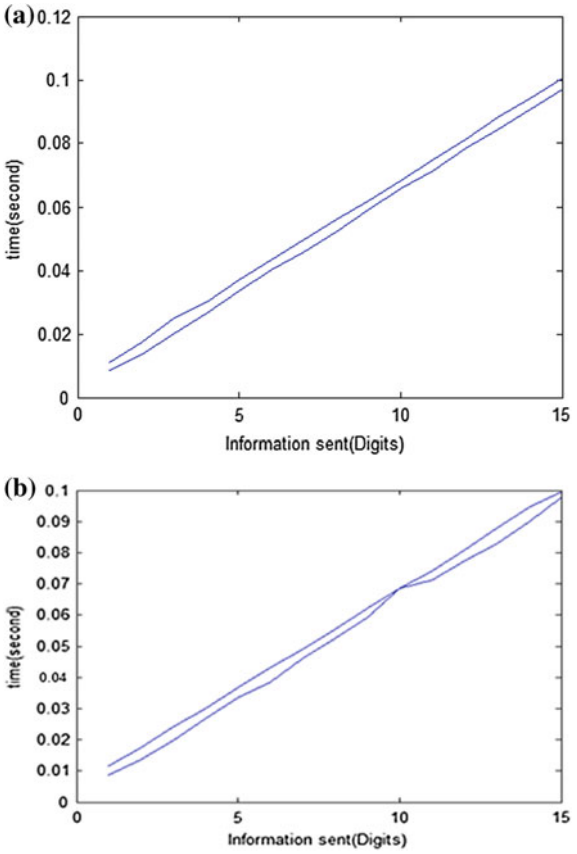

Fig. 6.10 Message length versus time. **a** $p = 3$ and $q = 7$, **b** $p = 23$ and $q = 17$

- *RSA Algorithm Analysis*

RSA algorithm is tested for integer numbers ranging from a single digit message length to 16-digit message length. The execution time t is in seconds. The execution time depends on the values of p and q which are prime numbers. Different values of p and q have been considered and depending on these values, graph between message length and time is plotted (Fig. 6.10a, b).

- *AES Algorithm Analysis*

AES is used here to provide data integrity while simple browsing of webpages over Internet. Plain text is encrypted to hexadecimal format. The change in graph depends on the value of plain text. The time taken increases if there is a use of combination of text and digits. A graph between information sent and time is plotted (Fig. 6.11).

Now by using the discussed framework and the type of information that has to be stored, multilevel security can be provided on different files. Tables 6.5, 6.6 and 6.7 summarize the execution time of four different files using RSA algorithm, Bcrypt algorithm, AES algorithm, respectively.

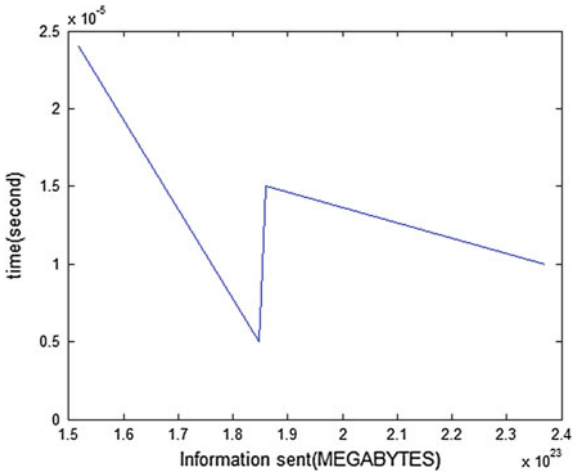

Fig. 6.11 AES algorithm

Table 6.5 File execution time using RSA algorithm

File size (MB)	RSA encryption (ms)	RSA decryption (ms)
1	66,787	720
2.9	2206	385
3.98	17,325	1081
4.65	40,441	1064

Table 6.6 File execution time using Bcrypt algorithm

File size (MB)	BCRYPT encryption (ms)	BCRYPT decryption (ms)
1	1306	447
2.9	1218	454
3.98	1225	510
4.65	1225	445

Table 6.7 File execution time using AES algorithm

File size (MB)	AES encryption (ms)	AES decryption (ms)
1	2129	234,229
2.9	3132	21,663
3.98	3276	71,129
4.65	2613	152,405

Table 6.8 Performance analysis of previous scheme versus proposed framework when number of requests is 8

No. of requests	Previous scheme [21] (time in ms)	Proposed scheme (time in ms)
1	3074	3074
2	3074	2917
3	3075	796
4	3009	1108
5	2995	1108
6	2905	796
7	3079	921
8	3420	827

Table 6.9 Performance analysis of previous scheme versus proposed scheme when number of requests increased to 16

No. of requests	Previous scheme [21] (time in ms)	Proposed scheme (time in ms)
1	3248	3006
2	3291	3110
3	3106	900
4	3341	1249
5	3570	1289
6	3320	1160
7	3334	1276
8	3456	900
9	3418	1000
10	3534	958
11	4018	2987
12	3987	3540
13	3765	3491
14	4211	4010
15	4300	2667
16	4696	3800

To analyse the performance of discussed algorithm, a comparative analysis is also done with previous algorithms using the presented framework. In [21], all files were provided same level of security irrespective of the type of data which is in contrast to the current framework that provides different levels of security on files with varying sizes. Tables 6.8, 6.9 and 6.10 present the comparison between the encryption time of previous scheme and the proposed scheme when the number of requests keeps on increasing. Figure 6.12a–c, represent this process.

Table 6.10 Performance analysis of previous scheme versus proposed scheme when number of requests increased to 32

No. of requests	Previous scheme [21] (time in ms)	Proposed scheme (time in ms)
1	3896	3694
2	3424	3341
3	3308	3208
4	3410	3400
5	3540	3459
6	3691	3576
7	3330	3200
8	3120	3110
9	3600	3567
10	3498	1000
11	3900	3741
12	4009	4003
13	3774	3669
14	4219	4198
15	4166	4047
16	4333	4216
17	3681	3538
18	3908	3497
19	3724	3623
20	3805	3551
21	3500	3348
22	4460	4234
23	4000	3811
24	4790	4626
25	4546	4377
26	3980	3694
27	2196	987
28	2897	1248
29	3071	2381
30	4298	3106
31	4571	3963
32	5168	4685

Tables 6.8, 6.9 and 6.10 show the average time taken for all three cases for proposed framework and performance is evaluated as shown in Table 6.11.

The average time taken by the schemes in both the cases is shown in Fig. 6.13. It can be predicted easily that the time taken by proposed scheme is less than the time taken by previous scheme.

In case, if the file is modified then the data in file will get encrypted using RSA algorithm but it will not be decrypted as shown in Table 6.12.

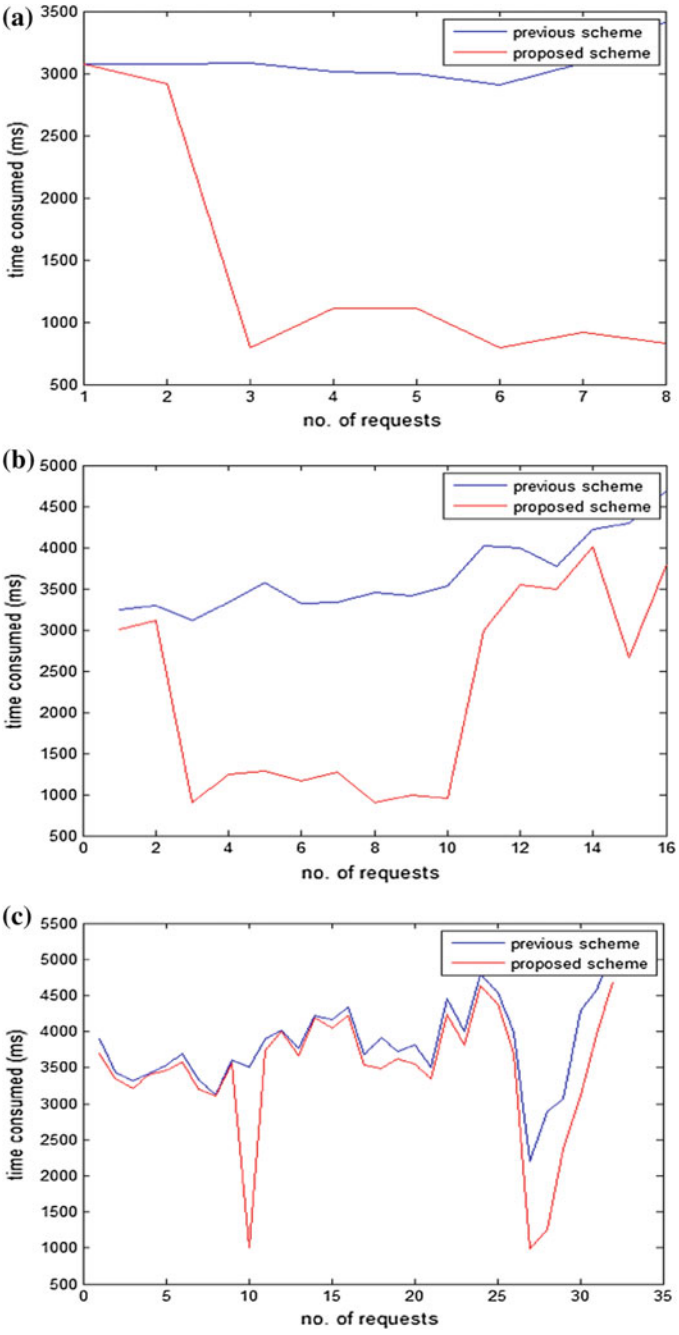

Fig. 6.12 Encryption time for previous scheme and proposed scheme: **a** number of requests = 8, **b** number of requests = 16, **c** number of requests = 32

Table 6.11 Average time taken by previous schemes and proposed scheme when requests vary from 8 to 32

No. of requests	Previous scheme [21] Avg. time (ms)	Proposed scheme Avg. time (ms)
8	3105.91	1086.3
16	3870.19	2519.88
32	3899.72	3149.19

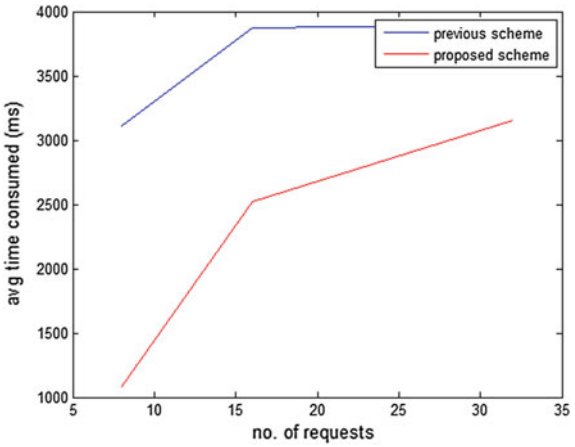

Fig. 6.13 Average time taken by both the schemes

Table 6.12 Encryption and decryption time when file is modified

File size (MB)	Algorithm	Encryption (ms)	Decryption (ms)
1	AES	1037	3184
2.90	Bcrypt	698	1786
3.98	RSA	1123	–
4.65	Bcrypt	695	1781

6.4 Summary

Cloud computing is becoming one of the crucial technologies and considered as a boon for the IT sector. It follows multi-tenancy where several users can share the resources at a given time over the Internet. Along with the benefits of cloud computing there are some drawbacks, in which security is major concern which causes hinderance in full acceptance of this technology. In this chapter, we have summarized various security issues and security threats related to each level of cloud. We have proposed a framework to maintain data integrity in SaaS. This framework also implements the various security algorithms at three different levels. The performance analysis of this framework represents that the proposed framework is easy to implement and can effectively maintain the information security in clouds.

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About this book

This book describes various methods and recent advances in predictive computing and information security. It highlights various predictive application scenarios to discuss these breakthroughs in real-world settings. Further, it addresses state-of-art techniques and the design, development and innovative use of technologies for enhancing predictive computing and information security. Coverage also includes the frameworks for eTransportation and eHealth, security techniques, and algorithms for predictive computing and information security based on Internet-of-Things and Cloud computing. As such, the book offers a valuable resource for graduate students and researchers interested in exploring predictive modeling techniques and architectures to solve information security, privacy and protection issues in future communication.

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Chapter 4
Cloud-Based Predictive Computing

4.1 Introduction

Recent advancements in the field of wireless and multimedia technology as well as computing, hold out promise to perform real-time communication in the various user-based sectors of health, transportation, media and education. The vision of the IoT and cloud computing is one such and provides real-time information to the connected users in the network. This advancement in technologies has led to the issue of data proliferation which in turn is responsible for data explosion and high cost of data processing. This exponential increase in data includes human data on the social media in the form of emails, photos, messages, blogs, tweets, digital data generated by sensors, such as GPS, the business data, the classified data to name a few. It is becoming difficult to store, query, analyze and share the data as the available data are huge in volume and highly complex due to the number of data sources and their interrelationships. The scope of the IoT-based cloud computing is significantly broad and includes the living and non-living entities connected to each other in the network. Making use of predictive computing over this large volume of data collected from various sensors nodes and stored in a cloud environment can be made more scalable, pervasive and easier to deploy using these advanced technologies. The cloud enables the business analytics to scale out the data easily and quickly, which in turn enables them to analyze data archive to identify the developing trends and leads to better customer satisfaction and profitability. Using cloud for predictive computing will make the computing resources delivered as a service and will provide multi-tenancy and shared resources this will also help in managing the issue of data proliferation. Various areas of opportunities can be achieved by using the cloud for predictive computing. Some of which are pre-packed cloud-based solutions, predictive modelling with the data in the cloud, and flexible compute power among many more. The advantages are scalability, pervasiveness, deployment agility, moving analytics to data, whereas the cons are complexity, privacy and security, regulatory issues and moving data to the cloud.

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Knowledge discovery and decision making are one of the major objectives of predictive computing. Big data computing poses a severe challenge in terms of the necessary hardware and software resources required for decision making. Hence, we look upon cloud technology as it offers a promising solution to this challenge by enabling ubiquitous and scalable provisioning of the computing resources [1]. In this chapter, we have explored the hybrid measure of IoT and cloud computing to predict the health status of a user by analyzing his/her physical activities at sustainable health centre of the smart city. It is considered that equipment in these sustainable health centres are equipped with sensors and continuously store the data related to the user's session in the cloud. This stored data is further utilized by the concerned healthcare professional for predicting the health status and in case, if any severe measures are required then alert is sent accordingly.

4.2 Related Work

Use of predictive computing from healthcare perspective is also increasing with the advancement of technologies. Various healthcare professionals and users are using a variety of ways and techniques for analyzing and predicting the health status. To perform prediction, data is collected from a variety of sensors like embedded sensors, wearable sensors and stored in the cloud for its further analysis and finding of patterns. Zhang et al. [2] also explained the use of the wireless sensor networks in healthcare in the future from a ubiquitous perspective and proposed a 3-tier system architecture for healthcare applications. They have also stated that with the technological advancements, the field of medical informatics has focused more on as well as emphasized the use of the Smartphones over wearable devices. Chen et al. [3] have presented the vision of IoT from the perspective of China and specified that in 'Remote medical monitoring' data can be collected from various sensor-like devices placed on an individual's body and once the data is processed advice can accordingly be given. In [4], Islam et al., have presented various aspects of the IoT-based healthcare technologies and stated that IoT can help any age group and address any disease in an innovative manner. In [5], Yang et al., have designed the home mobile healthcare system for wheelchair users. The proposed architecture utilizes the Smartphone for sending and receiving instructions from the source and sink nodes. In [6], Amendola et al., have used the RFID-based wearable tags to identify the movement of the body parts like arms, legs etc.; in fact, they have used the IoT for monitoring the information collected related to human lifestyles.

4.2.1 Cloud-Based Healthcare Frameworks

With the advancement in technologies, a number of cloud-based healthcare frameworks are being designed. Further, integration of clouds with IoT-and big

data-based frameworks could provide several benefits of easy to deploy mechanism over traditional networks, enhanced information security during communication, quick access of records and energy savings over traditional existing healthcare frameworks [7]. In [8], Ghulam et al. have also focused on integration of cloud and IoT to have smart health solution. They have stated that convergence of the IoT and the cloud can render a wide application in daily and social life. It is because, IoT is a set of real-world small devices with limited processing power and storage capacity whereas the cloud can have huge storage capacity and processing power. Integration of IoT and cloud depicted by them is presented in Fig. 4.1. They have also identified various attributes like storage, accessibility, processing, distance, big data and security, where cloud computing can provide milestones achievements over IoT.

In [8], Ghulam et al. have also presented a health monitoring framework that captures voice, temperature, humidity, electrocardiogram of a patient using IoT technologies and at cloud side, main components are authentication manager, data manager, feature extraction server, classification server and storage. For authenticity, authors have embedded watermark into the signal. In [9], Tyagi et al. have proposed a cloud-based conceptual framework for implementing a cloud-centric IoT-based healthcare framework. Authors have built a network of various healthcare entities like patients, doctors, hospitals, etc. and used this network for safe transfer of medical information. In [10], Hossain and Muhammad have focused on real-time health monitoring infrastructure for analyzing patients. They have designed and presented a cloud-based healthIIoT framework to monitor ECG and other healthcare-related data using smart phones. Authors have also implemented the used the watermarking techniques for the security of data. In [11], Kashfia et al. have presented a healthcare framework known as 'Cloud-based MEDical system' (CMED) for developing countries. This CMED system consists of a portable health kit, WSN connection and tablet/Smartphone. CMED framework is shown in Fig. 4.2.

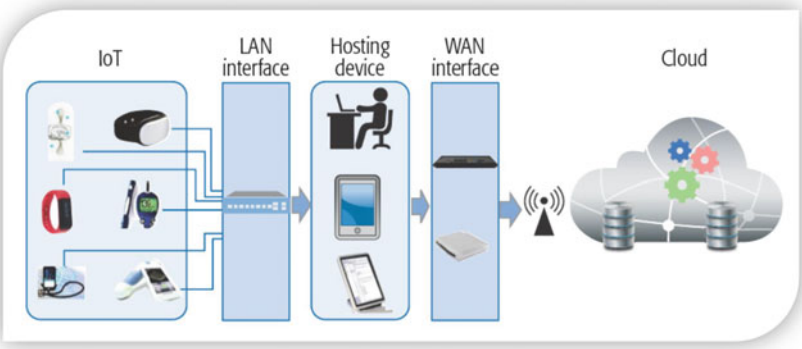

Fig. 4.1 Integration of IoT and cloud [8]

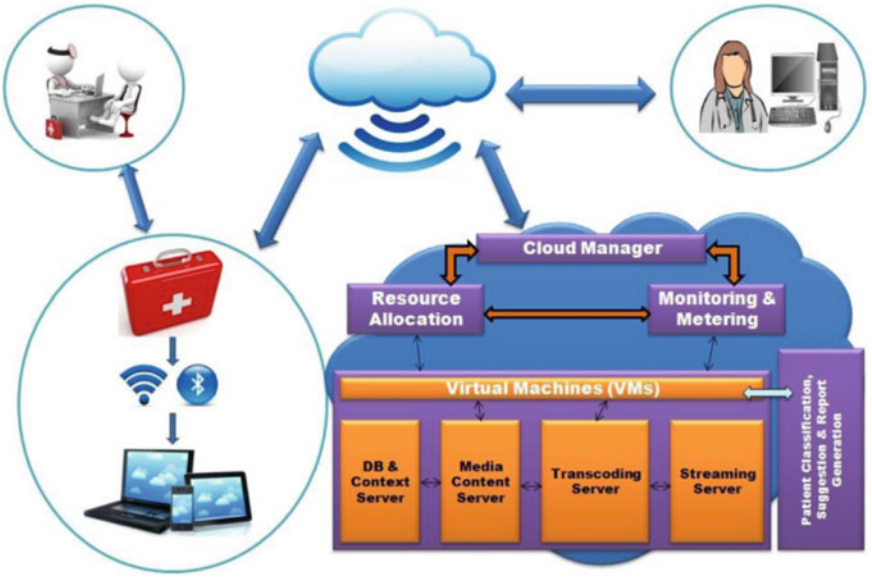

Fig. 4.2 CMED healthcare framework [11]

In [12], Nandyala and Kim have proposed an IoT-based architecture for u-Healthcare monitoring. They have also mentioned that traditional cloud computing architecture faces a lot of challenges and presented an extension of cloud as Fog. They have proposed a Cloud to Fog computing model for implementing the proposed architecture of healthcare monitoring. In [13], Kumar et al., have proposed a RFID-based intelligent authentication scheme in the healthcare using vehicular cloud computing. The authors have placed various tags and readers from users to road side units. Communication between these tags and readers are secured by elliptical curve cryptography-based key generation algorithm. In [14], Hassanalieragh et al., have presented the integration guidelines for remote health monitoring into medicinal practice. They have used smartphones as concentrator in IoT infrastructure and for aggregation of data, cloudlet's or clouds have been used. It is also realized that data processing could be done more efficiently using cloud rather that cloudlet's and wearable sensors have been used to collect the information. Authors have performed 2-3 days of continuous physiological monitoring using these sensors and collected related physiological parameters to update the relevant health database. In [15], Seales et al., have proposed an architecture for content centric networking for Health-IoT. This networking has several benefits and integrates health services and sensors, and clouds in Health-IoT. Proposed PHINet architecture automatically records the body data from user body sensors and further updates the database accordingly. Use of clouds in this architecture makes data easy to handle for analysis of both user and healthcare personnel. Wan et al. [16] have implemented the platform production services using IoT and inter cloud computing

architectures. Proposed framework was used by vehicular networking applications. Authors have evaluated the performance of proposed system using probabilistic theory.

4.2.2 Predictive Healthcare Applications

Advances in sensor devices also lead to the development of predictive healthcare applications to be used by e-Health frameworks. Mobile healthcare which is also known as mHealth has only become possible because of this advancement in sensor technology and represents the new opportunities for mHealth-based predictive applications. A wide range of mHealth applications can be found for monitoring of Diabetes [17], Blood Pressure [18], Heart rate [19], Physical activity [20] and Anti-Obesity [21] like areas. There are varieties of healthcare applications available for various types of Smartphone, Tablets and iPad like devices and are known as BlueBox [19], WIHMD [18], AppPoint [22], Heart-To-Go [23], Instant heart rate [24]. Though various types of applications can be find over the internet but somewhere these applications lack in security and privacy, reliability, efficiency and acceptability.

Moreover, these applications are designed for Smartphone like devices where battery life is another issue. Figure 4.3a represents the healthcare application to monitor ECG using Smartphone, Fig. 4.3b shows the mobile application for monitoring of blood Pressure, heart rate, SPO2, Fig. 4.3c represents the capturing of blood pressure monitoring device data using smart phone and Fig. 4.3d represents the information of Glucometer using smartphone. These applications continuously check for the incoming data obtained by sensor for activities like heart rate, ECG, pulse, blood pressure and blood sugar levels of user and keep informing to the healthcare personnel in case of any emergency.

4.3 IoT-Based Cloud-Centric Design Architecture

From the previous discussion, we can observe that most of the proposed healthcare frameworks are over-optimized as they generate large amounts of data, and continuously send alerts to the users and healthcare personnel, which are of no use. Some of these frameworks and applications are designed to use the Smartphone for monitoring and capturing of data. In such a scenario, the continuous connectivity of the Smartphone devices is questionable. Keeping these shortcomings a priority, we have proposed the IoT-based predictive framework as shown in Fig. 4.4 which consists of the evaluation, implementation, feedback and security layers in the IoT environment for a cloud-centric communication between the user and healthcare personnel. IoT-based cloud computing framework architecture is applied for predictive analysis of physical activities of the users in sustainable health centres.



Fig. 4.3 Healthcare applications using Smartphones to monitor **a** ECG, **b** blood pressure, heart rate, SPO2 and body temperature, **c** blood pressure and pulse, **d** blood sugar level

The cloud computing framework provided a system which is embedded with intelligent sensors and devices rather than using smartphone sensors and wearable sensors to sense and retrieve data to store the information (value) of the general health-related parameters for individuals [25]. In this framework, IoT system includes a cloud centre for storing different data, public cloud centre, private cloud data centre and uses the intelligent services for providing the mechanism to secure the stored data and fast communication through intelligent devices. Finally, IoT-based cloud architecture is applied to perform the evaluation for its adoption, prediction analysis of physical activities, efficiency and related security. In the current work, the concept of IoT has been used with the proposed cloud-centric architecture to predict the user's physical activities at sustainable health centre of the smart city. Most healthcare personnel purport that if individual exercises

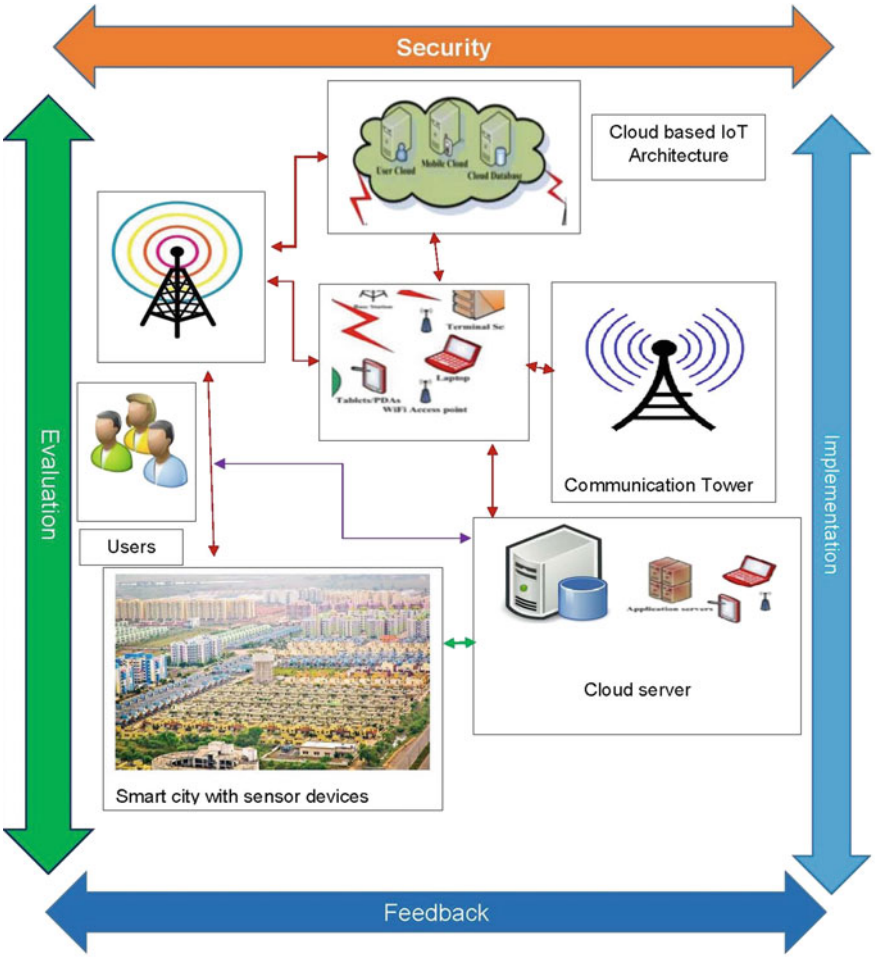

Fig. 4.4 IoT-based predictive healthcare framework for cloud-centric communication

regularly, then the complications and increase in the dosages of medications for diseases like diabetes, blood pressure and heart issues, can get postponed accordingly [26].

In Fig. 4.4, IoT-based cloud computing framework has been developed for providing the solution to individual users using smart devices. The system includes major phases for development of cloud systems. The system consists of the evaluation of sensing data and retrieving information, implementation paradigm, feedback phase and security phase in IoT-based intelligent sensors environment for a cloud-centric communication between the user and healthcare personnel. The basic methodology is applied to implement the IoT-based computing models or framework for the cloud-centric system for providing the efficient solution in the health sectors. The IoT-based cloud framework includes four different phases in the

cloud system-based model. These phases are applied to cater the faster data processing and data communication between the individual and IoT-based systems (e.g. health assessment systems) [27]. The IoT-based computing models and methodology also can be applied to mitigate the redundancy and sparsity of massive amount of data which are necessary to be stored for analysis purposes. The four phases in this process are given as follows [26]:

(i) **Implementation phase**
The implementation phase depicts the overall framework architecture of IoT-based computing systems from the data acquisition, extraction of information, to data storage and analysis of data. It also uses the embedded intelligent sensors or devices in compression of any wearable devices or intelligent sensors by the individual.

(ii) **Security phase**
Security phase mainly emphasizes on IoT-related security issues and challenges on data storage and transfer extracted knowledge from data between source and destination intelligent sensors [28]. It also caters the better services for implementation of distributed system and cloud computing framework for various types of cloud servers (cloud database servers, data-centric server, database servers). The main objective of this phase is to implement the better security to user privacy preservation and security to user information.

(iii) **Feedback phase**
In IoT-based cloud computing framework, feedback phase uses the results of the evaluation phase which are applied to revise the different applications. After each cycle of the performed application, the reported component or modalities are improved by doing rectification which assists to improve the overall performance of the IoT-based framework.

(iv) **Evaluation phase**
Evaluation phase is a phase which performs the functions of IoT-based computing and modelling systems by utilization of the different applications and to ensure a mitigation in the design complexity and its adoption to improve different services (e.g., healthcare services, agriculture monitoring services, traffic signal monitoring, transportation services, smart village-based services, medical services and information services between remote systems, etc.) [29].

4.3.1 Application Architecture

Application architecture for the IoT-based system proposed above reduces the complexity of the information storage, communication and enhances the performance of the overall healthcare system. The proposed application architecture is modified form of traditional 3-Tier architecture that represents the client-tier, business logic at middle tier and database at server-side. In the proposed application

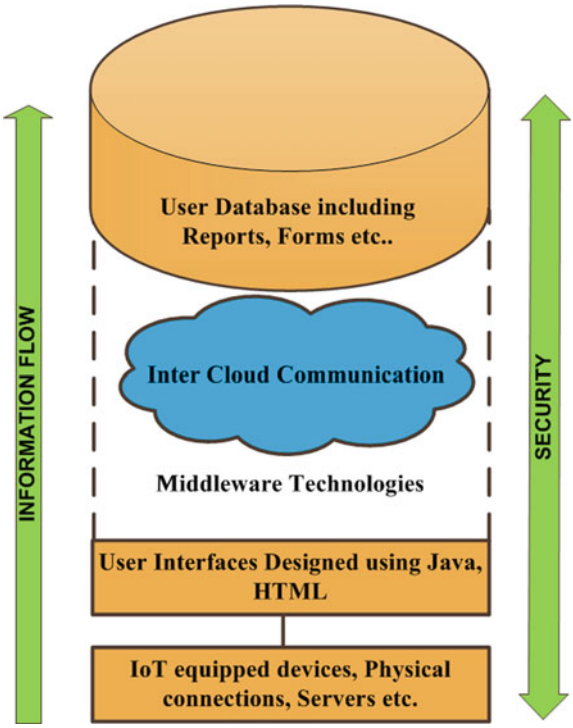

Fig. 4.5 Application architecture

architecture [26], various web services and security services reside inside the cloud which are further implemented as a part of middleware technologies Fig. 4.5 introduces the multilayer application architecture which includes the IoT sensor devices, Treadmill equipment, application servers, base stations and handheld devices like PDAs, Tablets, notebooks, etc. at the bottom. These interconnected devices communicate with the user interfaces designed with JAVA. These user interfaces are responsible for capturing the information from the connected sensors of the treadmill equipment at the end of the user session and any further update of this information with the cloud servers. These user interfaces are further connected via the middleware with many Cloud Servers and support the inter cloud communication with cloud database. In middleware technologies, XML web services can be used to carry secure information from these interfaces to the cloud and can also communicate with the required database for reporting to the user's request.

4.3.2 Predictive Framework for User Activity

Presented predictive user activity framework keeps both the users and healthcare personnel updated [26]. Here, user of the system has been considered as a smart

user and performs health-related activities in sustainable health centres. These sustainable health centres have equipment fitted with sensors which are sufficient to capture the basic parameters related to the users' health activities, such as average heart rate, total calories burned, total distance and average speed. This framework captures the information required once the user completes the exercise. Regular activities in these health centres are believed to be able to keep a user fit rather than on the heavy dependence on medicines. Healthcare personnel also suggest the same, and encourage regular physical activity to keep healthy for a longer time and avoid an overdose of the prescribed medicines. The proposed activity framework monitors the user's activity on a regular basis and updates the captured information to the required cloud. In case the user does not perform an activity for a specific time period then this information will also be updated in the cloud database and an alert will be sent to the respective healthcare personnel, who can further communicate with the user regarding understanding the status of his health.

Figure 4.6 represents the user activity framework from the beginning and until the end of the physical activity in a sustainable health center. As the biometric identification and authentication are completed for the user, a secure session gets established with the local database server to monitor the user's activity on that equipment. Here, it is considered that the equipment has embedded sensors which can monitor and transfer the details of the basic parameters like heart rate, total calories burned, total distance and average speed to the connected local database servers. As soon as the physical activity session is over, the equipment stops and the respective values of the basic parameters are stored in the local database server of the sustainable health center. In case the user terminates the session in the middle of the physical activity then that session will be marked INCOMPLETE and the

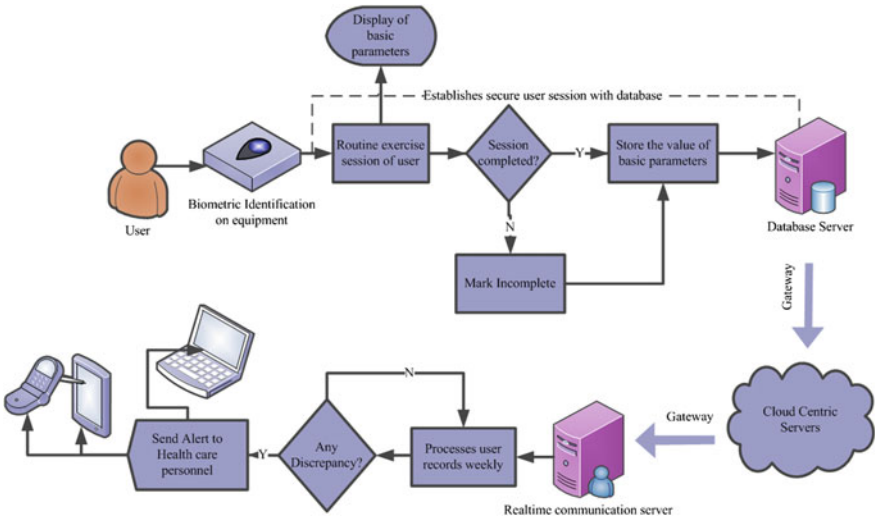

Fig. 4.6 Predictive user activity framework

respective values of the basic parameters are stored in the database. In the next step of this framework, the information stored at the local level is transferred via the gateway to the various cloud servers. These cloud servers keep the information up-to-date and secure. Later on, this stored information is picked up by the real-time communication servers located geographically with the different healthcare personnel. These real-time communication servers process the record thus obtained and relate them to the user on a weekly basis to produce the reports accordingly. If the user regularly terminates the physical activity sessions, before the prescribed activity time for particular equipment or is absent from the sustainable health center then an ALERT message is sent to the user's healthcare personnel either in the form text message or an Email alert.

4.4 Cloud-Based Predictive Computing Design

The proposed cloud-centric architecture reduces the overall complexity of the implementation of the system [26]. It implements various security measures at each step of the communication of the information. As shown in Fig. 4.7, the initial level collects and stores the information for each user from the sustainable health centres into their database server at the local level. The information collected represents the daily values of the basic parameters the specific user has worked out. To communicate this information thus gathered over the cloud the XML web services have

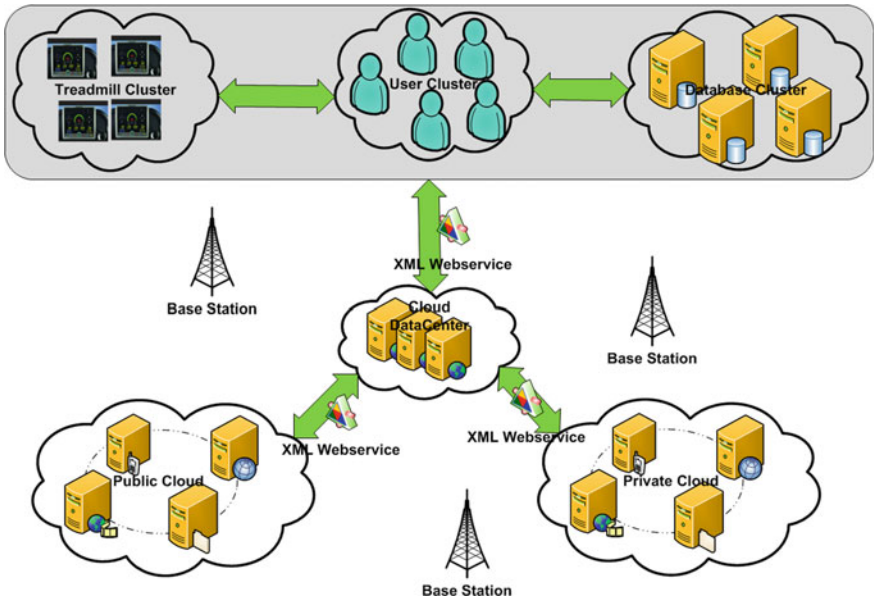

Fig. 4.7 Cloud-based predictive computing design

been used as these are considered secure and faster. From the initial level, the information is collected from the various database clusters distributed to the cloud-centric data center. These data centres also ensure the security of the stored information and further disseminate the information to the public and private clouds.

Both private and public clouds are equipped with a mobile information server, content management server, file server and streaming media servers. These servers continuously exchange information whenever required with their respective clouds. While implementing this architecture, different algorithms are used with different types of clouds to maintain the integrity, consistency and security of the user's information.

4.4.1 Predictive Analysis of Physical Activities

The proposed framework presents the ease of interface to both the healthcare personnel and users. While performing a physical activity in a sustainable health centre, it represents no interface to the user except for identification, authentication and establishing the session with the local database server which is responsible for storing the values of the basic parameters as the user completes the session. We have performed the analysis on average data collected in real time from five different nodes up-to duration of 30 days for time interval 20 min every day. To vary the considered data for experimental purpose requires more nodes and time so that the data could be collected in real time. However, this will not affect the overall performance of proposed architecture as from collected data our main objective is to test the alert mechanism of proposed user activity framework. Figure 4.8 represents the values of the basic parameters stored after 20 min of each physical activity session by the users. It shows the various scatter plots for the distance, calories burned, heart rate and speed with respect to the age of the users. Healthcare personnel can thus define the daily maximum threshold value of these parameters for their users individually and further predictive analysis can be performed accordingly. Here, Fig. 4.8a represents the threshold value for distance ≥ 4.5 km, Fig. 4.8b represents the threshold value for the calories burned ≥ 340, Fig. 4.8c represents the threshold value for the heart rate ≥ 170 bpm, and Fig. 4.8d represents the threshold value for speed ≥ 13 km/h. While performing prediction analysis, the defined threshold values of these basic parameters are checked and if any of value exceeds the limit then an alert is sent to respective healthcare personnel to initiate the necessary action. Also, if a user misses the physical activity session for a whole day or terminates the session in between, then also a message 'INCOMPLETE/ABSENT' gets stored into the database.

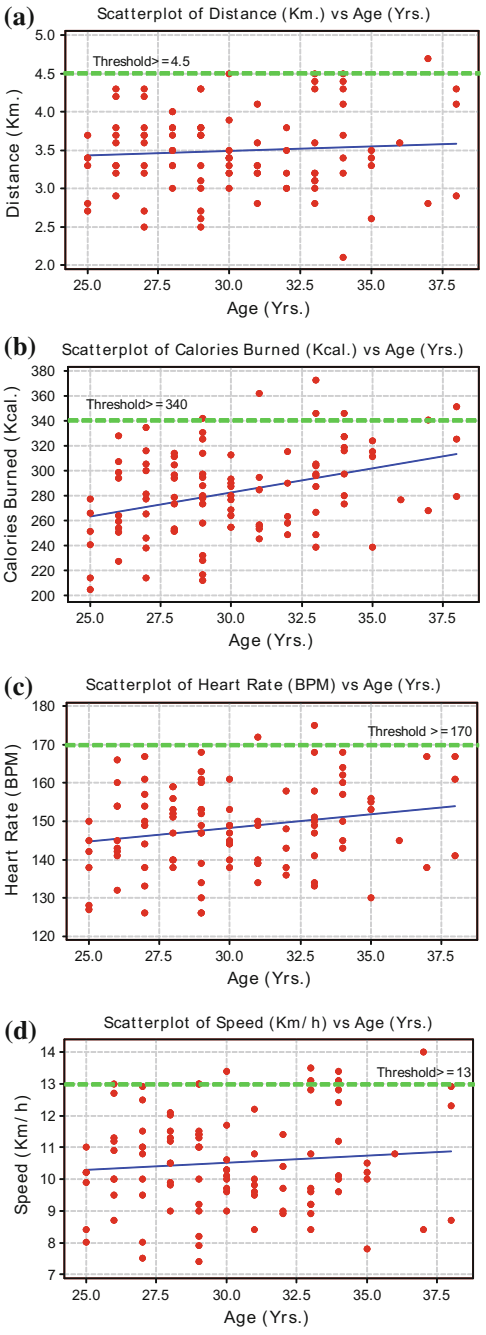

Fig. 4.8 Scatter analysis of users on treadmill **a** distance (km) versus age (years), **b** calories burned (Kcal) versus age (years), **c** heart rate (bpm) versus age (years), **d** speed (km) versus age (years)

4.4.2 Predictive Efficiency of Framework

The efficiency of the proposed framework is evaluated using the total communication time, and end-to-end delay.

– *Total communication time* represents the total time taken for the storage of information from the local database server to the cloud data centre and further to the public or private cloud. This time can exceed if there is any alert sent from the public or private cloud to the healthcare personnel. Here, Eqs. 4.1 and 4.2 show the computation of the total transmission time where n represents the number of clusters, t is the time, and w the total offloading iterations and x total number of alerts.

$$T_{\text{TIME}} = \sum_{i=1}^{n} (t(w) + t(x)) \tag{4.1}$$

If there is no alert then the value of $t(x) = 0$ and Eq. 4.1 will become:

$$T_{\text{TIME}} = \sum_{i=1}^{n} (t(w)) \tag{4.2}$$

– *End-to-end delay* represents the information delay time between the nodes. This can be computed by subtracting the minimum time of communication from the total time of communication. Its minimum value shows the early arrival of information at the destination node (Eqs. 4.3 and 4.4).

$$T_{\text{delay}} = T_{\text{TIME}} - T_{\text{minimum}} \tag{4.3}$$

$$T_{\text{minimum}} = f(T_{\text{TIME}}, \text{minimum}) \tag{4.4}$$

Figure 4.9 represents the total transmission time for both the public cloud and private cloud. Here, the value of T_{TIME} reaches up to 12 s for the public cloud and

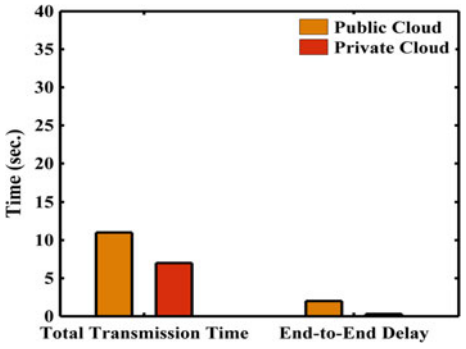

Fig. 4.9 Efficiency of cloud-centric framework

7 s in case of the private cloud. The higher value of T_{TIME} for the public cloud shows that more users are connected with it, as the services are not payable to this cloud.

4.5 Summary

In this chapter, we have presented an integrated view of IoT and cloud computing and proposed a predictive healthcare framework for monitoring of physical activity of user. The proposed framework simplifies several of these issues and stops the proliferation of information. This framework can be used by user of any age group. The proposed framework, has been evaluated on the basis of predictive analysis of physical activities, and its efficiency. There was also an understanding that to minimize the overall cost there should be a minimum time delay between the advice time and issue reported time. This can be observed from the analysis performed for the end-to-end delay for the proposed framework. Predictive analysis of the physical activities represents the results collected in real time using the sensors for the various users on the treadmill for a 20 min time duration. These results also present the common threshold value for all the users, although the healthcare personnel can define it separately for the individual users. Overall, the architecture presented and discussed is more robust and secure in nature, although a lot of work could still be done in the future for its improvement. The issue of load balancing and information distribution throughout the cloud servers can be considered, and proposed framework can be extended to include more health parameters and activities.

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This book describes various methods and recent advances in predictive computing and information security. It highlights various predictive application scenarios to discuss these breakthroughs in real-world settings. Further, it addresses state-of-art techniques and the design, development and innovative use of technologies for enhancing predictive computing and information security. Coverage also includes the frameworks for eTransportation and eHealth, security techniques, and algorithms for predictive computing and information security based on Internet-of-Things and Cloud computing. As such, the book offers a valuable resource for graduate students and researchers interested in exploring predictive modeling techniques and architectures to solve information security, privacy and protection issues in future communication.

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Chapter 5
Internet of Things Based Predictive Computing

5.1 Introduction

The IoT is an emerging research area which is gaining more proliferations due to wide range of applications and uses in different intelligent devices. The connected intelligent devices and extensively interconnected objects are identifiable and equipped with sensing, computing and communication capabilities [1–3]. Therefore, IoT-based computing paradigms provide fast computations and transferring the sensed data onto connected intelligent devices [2, 3]. Atzori et al. [3] defined the '*IoT*' and illustrated those various paradigms for effective computation and transferring of the relevant information between smart devices. Generally, the computing paradigms in the IoT-based frameworks include (1) Internet-oriented computing and communication-based paradigm known as middleware. In the Internet, objects (devices) are connected by various protocols and networking topologies (e.g. star topology, ring topology, mesh topology and other networking topologies) using Internet services, (2) things-oriented based computing paradigms known as intelligent smart sensing devices such as intelligent sensors and actuators. In this paradigm, the intelligent sensing devices are connected to other devices and these devices are capable of receiving and transferring the sensed data. After computation of sensed data, these devices extract relevant information from the captured data and transfer the retrieved information to the other devices, and (3) Semantic-oriented based computing paradigms, known as sharing knowledge-based computation models [4, 5]. In semantic-oriented computing based paradigm, the retrieved information of captured data is computed by predictive computation techniques and relevant information is transferred among connected smart devices and sensors by means of semantic structures of connected devices and its standard. This needs appropriate techniques for retrieving information from the data. The advantages of IoT-based computing paradigms can be unleashed only in the application domain where the three models intersect as mentioned above. IoT is a computing paradigm for smart sensors and devices. The propagation of these

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smart devices builds the IoT in the communication-based network, wherein sensors and other physical devices combine seamlessly with the environment around us, and the information is shared and distributed across different computing platforms in order to develop a common IoT-based framework.

In the IoT scenario, computing framework allows several intelligence sensors and connected devices to cater quick services and fast sharing of knowledge across different platforms [6, 7]. During sharing of knowledge, first, it considers the pervasive presence in the environment of different things or objects that are connected through Internet communication (e.g. wireless and wired communication network). For connection and addressing for devices, distributions of unique addressing schemes are used to provide the standard paradigms to interact the intelligent devices with other devices. These computing platforms cooperate with other things/objects to achieve the common objective by creating new applications and efficient services [8]. The common objectives of IoT-based computing framework can be obtained by integrating sensor–actuator–Internet frameworks and technological aspects. This platform enables things or objects to be connected anytime, anyplace, with anything and anyone using any connected or non-connected path or any networking protocols and any service. The deployment of various sensor based devices in the IoT-framework can be used to provide the various facilities to the different consumers. For enabling the privacy protection and security concern for the individual, IoT-based frameworks are also used in the health care. In the health care, the wearable sensor devices with smart sensors, IoT-based computing system has been envisioned for the past few decades. IoT provides a computing platform to accomplish this vision using body area network, smart devices and sensors. The IoT-based frameworks back end to upload the sensed data by connected devices to servers. In the transportation field, the traffic management and infrastructure monitoring, intelligent transportation and path optimization are also deployed based on real-time traffic information using IoT-based system. The deployed intelligent sensors and physical devices are connected to build an IoT-based infrastructure for monitoring the structural fatigue and other maintenance issues. It also provides a good platform for monitoring of accidents.

5.2 IoT Applications

In this section, various application domains are discussed in detail which gained more proliferation due to IoT. These diverse applications are categorized based on various types of resources availability. The resources include network availability, coverage, scale up and down, heterogeneity of data, repeatability of the different processes, the involvement of customer and their impact [9]. The applications of IOT are shown in Fig. 5.1. Figure 5.2 shows an overview of services by Internet of Things.

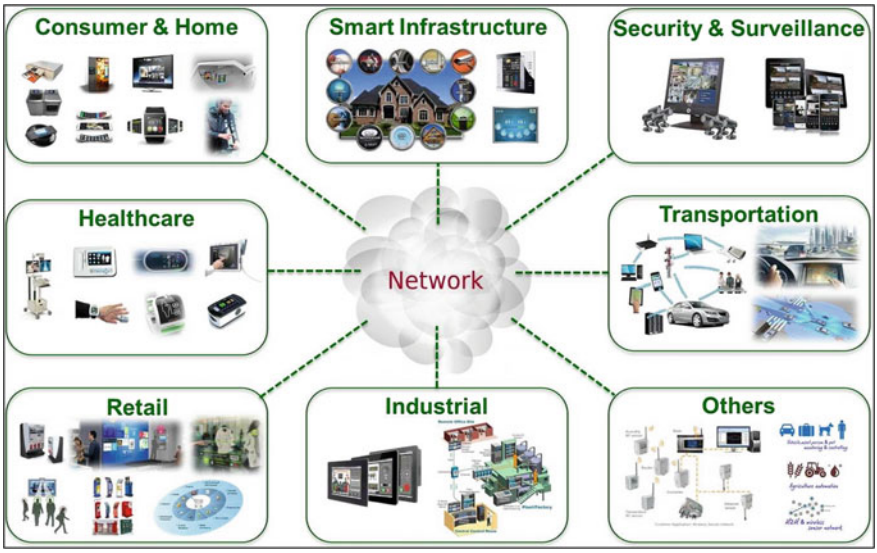

Fig. 5.1 Overview of Internet of Things based applications

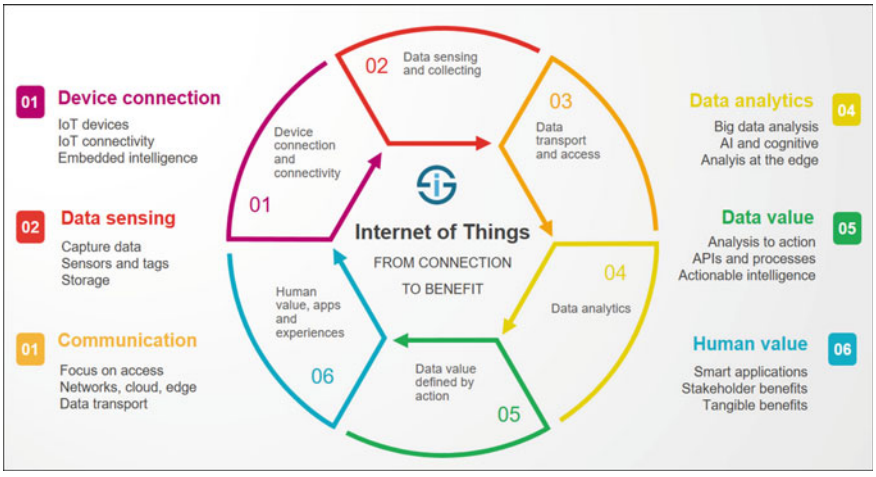

Fig. 5.2 Overview of Internet of Things services

5.2.1 Personal and Home Services

The collected information of sensors such as room temperature by temperature sensors, humidity data, etc., is used for various applications. This information is used by an individual person who directly owns the network. Generally, Internetworking is deployed as the backbone enabling higher bandwidth data

(video) transfer as well as to get the higher sampling rates. In the field of health monitoring, ubiquitous sensors have been used for the last two decades. IoT-based framework provides a good platform to realize the home services using different sensors and to upload the captured or sensed data to servers. For instance, smart devices such as smart phones, smart tablets and intelligent sensors can be used for sensing data and transfer the sensed data using communication protocol along with several communication interfaces. The communication interface includes Bluetooth, WiFi and other for interfacing sensors to measure the data based on physiological parameters. The personal body area network is also gaining importance to monitor elder's care at home. The system provides services to an individual at home. It allows the doctor to monitor patients and the elderly in their homes. Therefore, home monitoring system plays a vital role to provide efficient services to the individual by reducing hospitalization costs through early intervention and better treatment to individuals [9, 10]. The air conditioners, washing machines, automatic ovens, refrigerators and other electronic equipments can be joined with intelligent sensors to control home and allow better home facility and energy management. The consumers and individual become fully involved and connected in the IoT revolution in the same manner as the Internet revolution itself [11–13].

5.2.2 *Industries and Enterprises*

In the industries and enterprises sector, there is a growing interest in using IoT technologies in different industries and businesses [4]. Many industrial IoT-based research-based projects have been done in various areas such as health, agriculture, food processing-based industry, monitoring of environmental effects, security surveillance and others. A wide range of industrial IoT applications has been developed and deployed in recent years.

5.2.3 *IoT-Based Utility Services*

The captured information using sensors from the networks is usually for service utility and optimization of services rather than consumer consumption in the application domains. It is used by different utility companies. These consist of wide range of networks for regional and national scales. These networks are used for critical utilities monitoring and efficient resource management. The wide range of networks used between cellular communication, WiFi communication and satellite communication. In the current scenario, smart grid-based communication frameworks and smart metering-based communication frameworks are also used for potential applications of the IoT. These are being implemented throughout the world [14]. Efficient consumption of energy is also achieved by proper monitoring of electricity point within the house and using this information to modify the way

electricity is consumed. This information at the city scale is used for maintaining the load balance within the grid ensuring high quality of service.

5.2.4 *Internet of Things in Healthcare*

IoT has received much attention in the healthcare sector. The healthcare services using IoT raises a powerful research domain where the embedded intelligent sensors and physical devices are connected and these sensors and devices are capable of exchanging the information over the network. In these systems, the remote health monitoring of individual includes complete functionalities for long-term diagnosis and recording of health parameters, and detection of critical diseases and health monitoring based on recorded physiological information of the patient [4]. Based on available literature, the healthcare monitoring and diagnosis-based IoT frameworks consist of architecture of three levels: (1) body sensor network that includes body-wearable intelligent sensors for the recording of data from the different part of the body. It works as a unit for data acquisition from an individual body. The acquisition of data includes blood pressure, heart status and body temperature, ECG signals, (2) the second tier consists of complete set-up of communication, networking and the services-based framework. The integrated framework is capable of collecting the sensed data from equipped intelligent sensors from the human body. The collected information is forwarded to the next level [5, 6]. (3) The final third level generally includes the processing, normalization of collected data and analysing the data for retrieving the information for monitoring of health. Figure 5.3 depicts the working architecture of healthcare system using IoT [7, 8].

The IoT-based cloud-centric architectures are also applied for deployment of e-Health based predictive analysis of physical activities of the users in sustainable health centres.

Figure 5.4 depicts a framework for monitoring of individual health. In IoT-based computing paradigm, the predictive model uses the mathematical approaches and computational techniques to predict an event or outcome in the connected or shared smart objects. In this context, the multidisciplinary researchers, data scientists and engineers have begun to design and develop models, and IoT-based computing



Fig. 5.3 Healthcare monitoring system architecture

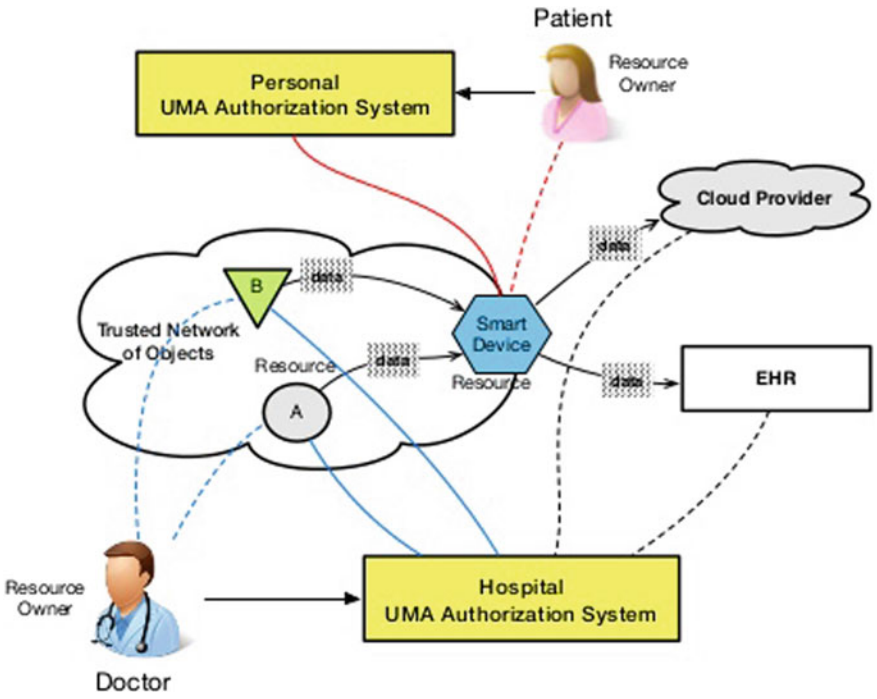

Fig. 5.4 Block diagram of IoT-based framework for health centre

systems to solve the major challenges in using the predictive analytics techniques and computing approaches [8, 15]. These techniques provide the better platform to create an intelligent and smart world, which is equipped with smart sensors and other devices. These connected devices and smart sensors makes possible to convert the real, digital and the virtual platforms into energy efficient smart environment, and provides faster means of communication and transportation, for developing smart cities and other areas [16].

The different devices are currently available commercially for different application-oriented uses and purposes including personal healthcare, activity awareness and fitness.

5.3 Major Issues and Challenges

5.3.1 Technical Challenges

The technical challenges of the IoT-based intelligent devices are numerous and subject of intense research. A set of technical features is also required especially for industrial applications, depending on different applications [17]. These applications

include comprehensive capabilities for sensing, and communications in terms of types of intelligent sensors and high sampling rate of received data, fast communication through wireless communication and Internet protocols, data transferring mechanism between intelligent sensors and receivers and computation of precise time for the synchronous collection of data both in one-hop and more hop Internet networks. Moreover, device packaging and defined protocols of intelligent sensors also play a vital role in the proper utilization of the extracted features, and transferring of the massive amount of the data. It is also required for the industrial application, medical science applications, prediction of unknown data based on discriminatory information of extracted features [18, 19]. These intelligent sensors, physically connected devices and their computation capability need the predictive computation based modelling system for forecasting the results based on learned system and salient features of given data which is indispensable for reliable operation.

5.3.2 *Device Lifetime and Energy Challenge*

In IoT research field, IoT-based intelligent devices and objects are related to the lifetime of the IoT device. This is a big challenge of computation of lifetime of devices. The lifetime mismatch of intelligent devices requires being deliberated in the full design and management of the different organization, configurations and installations involving IoT devices [9, 20, 21]. Moreover, management of energy and complete utilization of energy for intelligent devices are also the major challenging problem. It is especially for active IoT intelligent sensor devices [9]. Based on overall operations and computation, the energy harvesting can be a better solution for intelligent devices. The harvesting of energy can be done based on good predictive computation model or system [10].

5.3.3 *Representation of Massive Data and Information Challenge*

Representation of the massive amount of data and extraction of meaningful information is the important aspect of the current state-of-the-art-based IoT-based approaches. The IoT-based intelligent devices are significant to receive data from various sources (devices) [11, 12]. The received data are the source of richness and spatial distributed data, historical and sensor data. For example, taking a simple industry sensing and supervision as example, with 1000 intelligent devices or sensors connected to Internet and collecting sensing data by using these devices such as temperature, three-axis acceleration data with 10 K samples per s, and multimedia audio and video channel with 100 K samples per s, also considering

that data is collected only 12% of daytime, 100 min per day, the total amount of received raw data for one year will be up 1000.4 PB/year [11, 12, 22]. This is a huge data. It is very difficult to store the data with different kinds of formats in the database. The predictive computation models are also unable to perform any computation and prediction on such amounts of raw data. It is needed to be processed and condensed and analysed in order to be functional at all so not data, but information behind it needs to be extracted for basic use [13, 23].

In the similar direction, the massive amount of data (volume and data heterogeneity) is also an important problem in the field of the IoT and data storage [13, 24, 25]. From the huge data, what data are required to perform the prediction and compute the performance of predictive modelling based computational devices? Which main factors and parameters contribute to the failure of predictive models? Based on observations, optimum maintenance schedule is also a significant problem in the IoT-based research field [26].

To solve these problems, new predictive model-based computation systems and efficient algorithms to visualize and represent data in the feature space [27, 28] are required. All this huge data and information also need special algorithms, mathematical models and meta-heuristics computational models, machine learning approaches regarding representation of data, extraction of features, handling and management in terms of data security, integrity and access mechanisms in the intelligent devices.

5.3.4 Incomplete Data Representation

Sparse, uncertain, complex and incomplete huge data are the discriminatory features for wide applications in big data prediction. Being data sparse, the number of feature points in given data is too less for making analysis and drawing reliable complete conclusions [9, 29, 30]. The feature space does not present complete patterns or data trends and distributions of data for different applications and predictive analysis. In the fields of pattern recognition and machine learning, models and data mining based representational systems, set of algorithms are also unable to represent the data in high-dimensional space, because sparse data representation significantly deteriorates the reliability of different predictive models and computation systems [29, 30]. General data mining and emerging machine learning, deep learning and computational intelligent methods can be applied for dimension reduction of the massive amount of data. After the dimensional reduction, the predictive model extracts features from reduced data sets. The extracted features are stored in the database. After that, feature selection algorithms are applied to choose the salient set of feature data from the stored information or data [30]. Data dimension reduction techniques perform the reduction of data and include additional set of feature points or sample data to improve the data scarcity using generic unsupervised machine learning methods and pattern recognition approaches [31]. In the similar direction, uncertain data is a special kind of sparse data sets. Each data

field has longer deterministic value, however, it is subjected to few random/error distributions [32]. It is mainly linked to different domain-specific applications with inaccurate data readings and collections [9, 14, 33–35].

Learning capability is another major challenging problem in big data analytics. The existing data mining and the machine learning algorithms fail to perform the computation and prediction of outcomes using the massive amount of data. The learning models are bound to take the input data with respective memory space [29]. With the rising demands, the great proliferation of applications and wide uses and the future possibility of the implementation of the IoT in different fields, IoT-based predictive modelling and computation intelligent algorithms play significant roles in several disciplines such as medical sciences, e-health services, agriculture and weather forecasting with learning and prediction capability. The IoT-based models and frameworks have been proposed for monitoring of the users in real-time scenario and to cater better support if required [31].

IoT-based computation models and frameworks provide numerous benefits of easy to deploy mechanism over classical and standard networks with existing learning capability, enhanced information security during communication, quick access to records and proper utilizations of energy and harvesting of energy over existing Internet of Things based computing paradigm and frameworks [36].

5.4 IoT-Based Predictive Modelling

According to Gartner [1], the massive number of intelligent sensors is equipped with devices, coupled with the volume, velocity. Different kinds of structural design for IoT data present major challenges in the areas of data storage, security, data integrity, storage management, transferring of massive amount of data from source to destination server and the distributed data centre network in real-time scenario. Therefore, IoT can affect the computation and information sharing among intelligent objects on a different kind of computational paradigm. IoT-based predictive computation based models are required to design to solve these major challenges.

5.4.1 Predictive Model

The predictive modelling is defined as the process of applying a statistical model or data mining algorithm to data for the purpose of predicting the outcome of new or future observations or data sets. Moreover, in non-stochastic based predictive computation on data sets, the main objective is to predict the output Y for unknown observations $X1$, $X2$, $X3$, …, Xn. In given observations, it also includes temporal forecasting, where each observation is collected with respect to given time T. The inputs are used to forecast the result using future values at time $T + t$, where $t > 0$. In IoT-based predictive computation, the predictive model performs the predictions

of future observations. The prediction of data includes point-wise or interval-wise predictions, prediction regions or prediction analysis based on the distribution of data, and ranking method for new observations. Predictive models select any method that produces predictions, regardless of its underlying approach. Moreover, predictive computing based models perform the process of information extraction using mathematical methods and the set of computational tools from existing data sets to identify patterns. The identification of patterns helps to predict future outcomes from given unknown data sets and trends in real-time scenarios.

5.4.2 Descriptive Modelling

Descriptive modelling is a type of modelling which is aimed at summarizing or representing the massive amount of the data structure in a compact representational manner. Unlike explanatory data computation modelling based frameworks, in descriptive modelling, the reliance is on an underlying causal theory which is absent or incorporated in a less formal way. Also, the focus is at the measurable level. Fitting a regression model for the given data can be descriptive if it is used for capturing the association between the dependent and independent variables rather than for causal inference or for prediction.

5.5 IoT-Based Predictive Techniques

In this section, IoT-based predictive methods are discussed. These methods use the coherent set of fundamental aspects of probability and statistics theory to solve major problems in big data.

5.5.1 Probabilistic Learning Model and Statistical Analysis

For uncertain data, the major challenge is that each data item is represented as sample distribution, not as a single value, so most existing data mining algorithms cannot be directly applied. Common solutions are to take the data distributions into consideration to estimate model parameters. For example, error-aware data mining [14] utilizes the mean and the variance values with respect to each single data item to build a Naive Bayes-based predictive model for classification. Comparable approaches have also been applied for decision trees or database queries. Incomplete data is defined as the missing of data field values for given samples or data [35]. The missing data values can be caused by different realities, such as the malfunction of a sensor node, or some systematic strategies to deliberately skip some data values (e.g. dropping some sensor node readings to save power for transmission) [37]. Most

modern data mining approaches have in-built solutions to handle missing data values (such as ignoring data fields with missing values), data imputation (imputation of missing values to produce improved models) [21, 35, 37].

5.5.2 *Predictive Analytics and Data Mining Algorithms*

The predictive analytics and models apply the classification techniques for classifying the data. Classification is a machine learning technique to classify the data into different classes. The primary objective of a classification model is to predict a target variable (the unknown variable) using the similarity score based matching techniques. The classification method generates the outputs in binary forms (e.g. a loan decision for the bank customer) or particular (e.g. a client type) when a set of input variables are provided (e.g. credit score, customer name, income level, etc.). The process in data mining includes prediction of customer demands based on collected data in businesses. The classification model performs prediction of the massive data by applying the learning technique to find the generalized relationship between the predicted target variable with all the stored attributes of input data in the stored data set.

5.5.3 *Data Fusion Approach*

Data fusion is a computing paradigm to provide a technique to fuse multiple data received from different sensors or objects. In IoT, various sensors or intelligent devices are equipped with primary source model or framework; received data is unstructured and unorganized. The received data has to be fused. In the predictive computing models and maintenance cases, fusion approaches are applied to business data, telematics and original sensory data. In the fusion mechanisms, few data is obtained from the external sensors data sources, such as weather databases. These external databases are received by the Internet of Things based intelligent devices. After that, predictive computing machine takes the collected data and maps to feature space and generates similarity matching scores. Data fusion based predictive models and frameworks perform prediction and analysis of data using supervised and unsupervised machine learning techniques. Depending on the availability of explicit and implicit sensors links between diverse data sources, many machine learning methods and big data analytics techniques of connecting data are needed in IoT-based predictive computing models and framework to evaluate the experimental results [38, 39].

5.5.4 *Failure Prediction Using a Tree Ensemble Classifier*

For prediction of failures, records of sensor data are also validated using machine learning-based ensemble classifier techniques in the big data [40]. Tree ensemble classifier models are applied to learn sensory data to predict failures of the future system from past failures. The ensemble classification models use the gradient boosting classification approach to representing the data using regression trees. The regression tree is used to represent the classified data in the form of the tree. It builds an ensemble of classification trees one by one. After that, the predictions of the individual trees are added for the evaluation of final prediction score of given data. In the final regression tree, the consequent tree tries to build a model to generate the differences between the unknown data item and training data and the current ensemble prediction value by reconstructing the residual [40, 41]. The ensemble classification model trains a boosted regression tree framework. The framework consists of a series of trees that encodes characteristics of data records about failure. Based on the values of features of a given data record, the model is trained in such a way that each tree can decide which set of record groups a particular item belongs to. An appropriate weight is then assigned to each record, indicating evidence for or against the record belonging to a failing system. The model aggregates the evidence weights of all trees and outputs a probability of failure. Thus, the model reflects the likelihood that the given data record is an indication of a failing system [41, 42]. Figure 5.5 depicts a tree ensemble

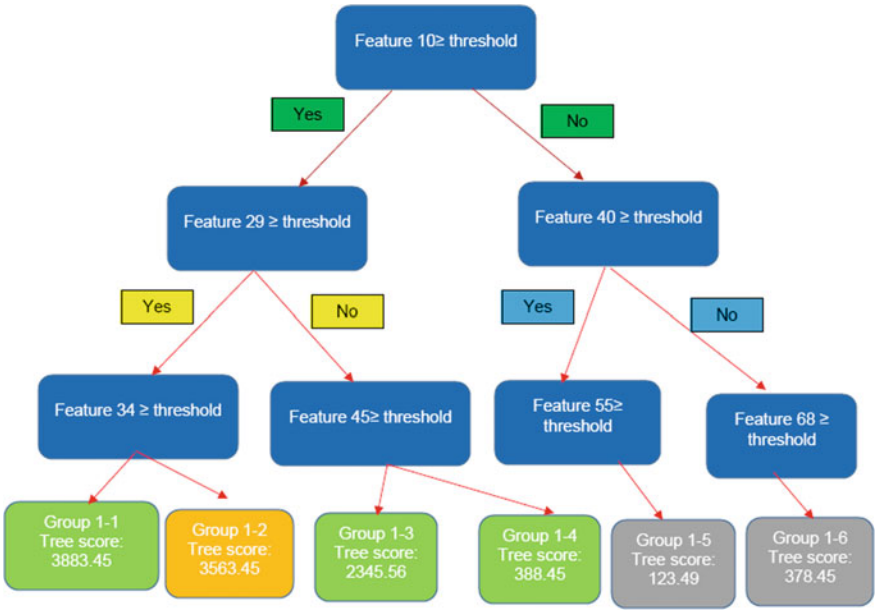

Fig. 5.5 Example for ensemble tree classification model for sensor data classification

classification model which is created by the regression-based classification algorithm. The regression tree based classification algorithm is a supervised learning method. It indicates for each record whether a record belongs to a regular or a failing system.

5.6 Summary

In this chapter, IoT-based predictive computing and modelling techniques are discussed. Due to advances in data storage, data computations, data capacity, machine learning, statistical modelling, etc., techniques based on predictive computing and modelling techniques have gained lot of popularity. A variety of applications based on these techniques are proliferating in the market. The predictive modelling and computation techniques are applicable to modelling credit card fraud detection, e-Health, e-Transportation, e-Logistics, e-horticulture, etc. These techniques collect the data in real time and provide the predictive information accordingly. However, IoT-based techniques face a lot of challenges which need to be handled carefully.

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About this book

This book describes various methods and recent advances in predictive computing and information security. It highlights various predictive application scenarios to discuss these breakthroughs in real-world settings. Further, it addresses state-of-art techniques and the design, development and innovative use of technologies for enhancing predictive computing and information security. Coverage also includes the frameworks for eTransportation and eHealth, security techniques, and algorithms for predictive computing and information security based on Internet-of-Things and Cloud computing. As such, the book offers a valuable resource for graduate students and researchers interested in exploring predictive modeling techniques and architectures to solve information security, privacy and protection issues in future communication.

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Predictive Computing **Internet-of-Things**

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Chapter 2
Predictive Computing and Information Security: A Technical Review

2.1 Introduction

Future of computing depends upon the effective integration of existing technologies and computing techniques. Integration of cloud computing and IoT provides a new dimension to computing known as 'Predictive Computing' and opens the new possibilities to researchers and developers. Predictive computing utilizes the data to make real-time or near real-time predictions for making life easier and comfortable. The predictive computing consists of various smart objects connected via wireless sensor network for collection of the data which gets stored in clouds for further its processing. The possibilities of predictive computing spans over healthcare, transport, travel, sales, smart home like other many sectors. With the rising demand of sensor-based products and applications for making predictions in many sectors also include the security risks and privacy issues related to data collection and data storage.

Use of predictive computing is getting popular as it is possible to design a smart environment, capable of monitoring air and water pollution, prediction of weather, earthquakes, detecting forest fires, tsunamis and various types of disasters so that early measures could be taken to reduce their devastating effects. Further, to make tourism sector attractive, the travel industries have come out from existing practice of making prediction based on travellers surveys and expert views to real-time collection of information of travellers location and updates about location in terms of photos, nearby spots and many more. Moreover, the big data analysts can capture the information from various photos posted on Facebook and other social networks [1–3]. With the increased use of IoT, a number of smart home appliances have been released into the market that include smart TV, smart refrigerator, smart lights, smart cooling and heating devices that can be controlled by mobile devices or desktops from remote location using internet [4]. Similarly, the use of sensor-based IoT devices is rapidly increasing in predicting the shortest path for vehicle navigation and avoiding of traffic congestion. Vehicle route is predicted in real-time by

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using the existing driving habits in the database and GPS to find the traffic congestion or road block like scenarios [5, 6]. A variety of devices is available in the market to monitor the health of a person. Monitoring of health, using smart blood pressure monitor, glucose monitor, pulse monitoring device, tracking of user activity running, walking, heartbeat, etc., can be done using various sensors and storing of this information over cloud for its further monitoring by healthcare personnel [7]. The healthcare personnel can make the prediction on the basis of received data and can provide suggestion or medications accordingly. In this chapter, we have discussed various such predictive frameworks and computing techniques based on IoT and cloud computing to perform various predictions. As the dependency on these smart devices is increasing and these smart objects are becoming the soft target of attackers to breach the user's privacy. Managing data confidentiality, integrity is becoming a major task it is because a number of restrictions associated with these smart devices in terms limited battery power, lack of complex encryption algorithm, poor access control at user level and lack of secure communication methods, etc. This chapter discusses various information security techniques and frameworks to maintain the confidentiality, integrity, availability and trustworthiness of data. We have listed various available security threats and their countermeasures with respect to two major technologies cloud computing and IoT.

2.2 Google Trend Analysis

With the growing shift towards the use of IoT, cloud computing and predictive computing, we have tried to find and analyze the Google search trends for computing terms like 'Cloud Computing', Internet-of-Things, 'Predictive analytics' and 'Information Security' from year 2008 to 2017 (up to May 2017).

The Google search trend results are shown in Fig. 2.1 and it can be observed that cloud computing and information security are two major areas which lead the global market whereas significant advancements are taking place with IoT and predictive analytics. The authors have also tried to find the trend results for 'Predictive computing' but no results are returned for the same. Market role of predictive computing is gearing up and one can expect a big demand and growth in future with the increased use of IoT 2.0 [8]. We have also analyzed the search trends at region level which are represented in Fig. 2.2 for all the previously mentioned computing techniques. From these results, it is clear that the regions like Singapore, India, Kenya and Uganda are the major regions, related to use of mentioned buzzing words.

Here, Fig. 2.2a represents the top five regions for cloud computing where India lead the search trend, Fig. 2.2b represents the top five regions for information security where Uganda lead the search trend, Fig. 2.2c represents the top five regions for Internet-of-Things and Fig. 2.2d represents the top five regions for predictive analytics, in both the cases Singapore leads the search trends.

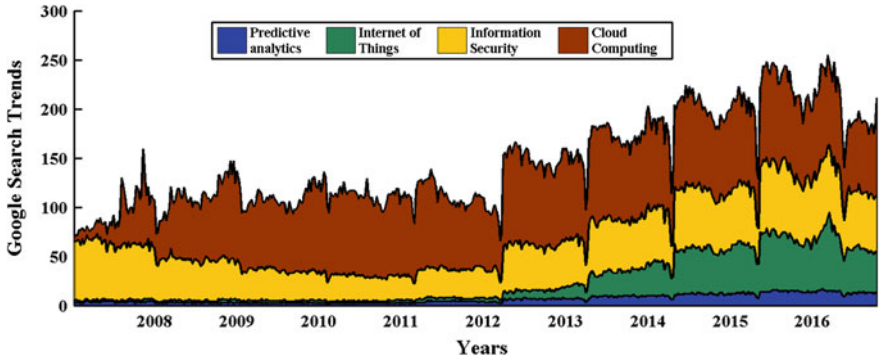

Fig. 2.1 Google search trends for buzzing words cloud computing, information security, Internet-of-Things, and predictive analytics

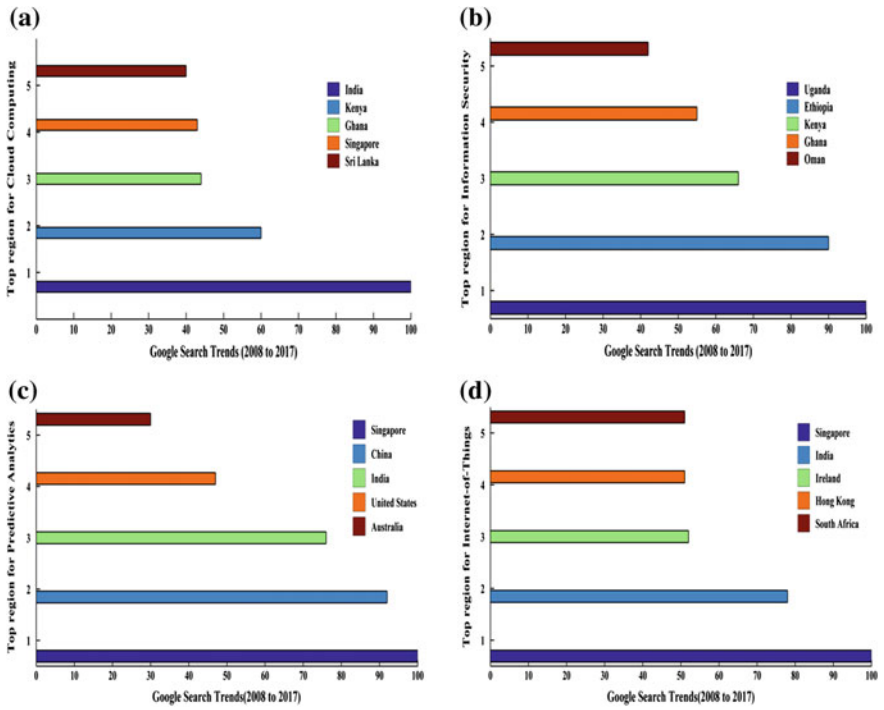

Fig. 2.2 Google search trends versus top 5 regions **a** cloud computing **b** information security **c** Internet-of-Things **d** predictive analytics

2.3 Predictive Computing Techniques

On the basis of performed operations and actions, the predictive computing techniques can be categorized into various categories. In this technical survey, we have tried to incorporate all the recent techniques which are mostly used by the developers to build their predictive solutions.

2.3.1 Data Handling Techniques

With the advancement in technology and computing techniques task of data generation and data processing has become easier. Various technologies like cloud computing, mobile computing, voice recognition, artificial intelligence and advanced application software are making prediction modelling possible. The predictive models are created whenever data is used to train a predictive modelling technique [9]. Table 2.1 summarizes various data handling techniques proposed by various researchers to find patterns in obtained data to perform smart computation.

2.3.2 Sustainable Techniques

Sustainable techniques are used to handle the issue of power consumption of computer systems and its devices. Majority of computer systems and devices are left unattended while they are active where they consume less amount of power. Similarly, if we discuss the same scenario from data centre's point of view then the power by such standalone device becomes disastrous. By using various predictive models and sustainable techniques, we can make predictions about the future of the device and computer system or device can be switched to energy saving state. In [10], Zhu et al. have presented an energy efficient reliable data gathering scheme in wireless sensor network environment. The proposed scheme is based on *Reed–Solomon code* and its enhanced version has been presented with intra-segment and inter-segment coding schemes. The authors have initially defined the optimization problem to derive the proposed energy efficient and reliable packet delivery scheme. In their obtained results, authors have claimed that proposed scheme is applicable in collecting data from sensor nodes at low-rate and low-power. In [11], Khan et al. have proposed a localization scheme *StreetLoc* for energy efficient smart phones using participatory sensing and have focused on the issue of data collection by these participatory nodes from urban streets. Authors have introduced the coverage metrics for the proposed full coverage, partial coverage and k-coverage schemes for the collected data from a street segment of the city. In their obtained results, authors have shown that proposed schemes can save a significant amount of energy. In [12], Abdullah and Yang have considered the issue of energy

Table 2.1 Data handling techniques for predictive analysis

S. No.	Author(s)	Proposed/Applied technique	Technical description	Parameters observed	Limitations and challenges
1	Wang et al. [119]	TVAS	Solved the issue of selection of destination sink node in the sub regions of sensor nodes and switching of aggregation scheme between TVAS and NS	– Time interval – Nearest neighbouring node, and – Data pressure	– Data pressure of sink node depends on threshold value – Metrics used for comparison average hop count, and network life time, and – Complicated concentration model
2	Villari et al. [120]	AllJoyn system	Proposed scalable solution to integrate system with lambda architecture [120] and processing is done using MongoDB	– Uses D-Bus to develop object oriented software independently – Patterns like regular, event based, and automated	– Difficult to handle complex scenarios – No connectivity support for inter domain – Large-scale smart environments management, and – Big data storage
3	Zhu et al. [121]	Permission-based RFID data collection algorithm (PRDC)	Proposed specification language can describe the complex tasks and algorithm is scalable during RFID data collection	– RFID collision – Temporal relations	– Communication overhead – Resource access in large-scale RFID systems
4	Wang et al. [122]	Data collection based on trajectory prediction (DCTP)	– DCTP designed for smart environments – Focused on reduction of incoming data and distributed prediction in real time	– Hidden Markov model – Message (ME) – Prediction of distance (PWD) – Prediction of trigger time (PTT)	– Churning of people is not considered, and – Walking speed is considered as constant

(continued)

Table 2.1 (continued)

S. No.	Author(s)	Proposed/Applied technique	Technical description	Parameters observed	Limitations and challenges
5	Zhu et al. [10]	Enhanced Reed–Solomon (E-RS) code	– Presented inter and intra-segment coding scheme	– Overall energy consumption	– Communication overhead – Lack of security
6	Sharma and Singh [123]	Seed block algorithm (SBA)	– Smart connectivity with remote client in absence of network and remote data backup	– Exclusive OR operation – Seed blocks	– More memory requirement for remote server – Huge difference in processing time
7	Xu et al. [45]	– Semantic data model – Data accessing method (UDA-IoT)	– IoT-based emergency medical services system is designed – Metadata model for ubiquitous data accessing, and – Building real-time system	– Value, annotation, and ontology, and – Entity oriented resource	– Processing cost of data – Coordination of multiple resources, and – Data security issue is not addressed

conservation in IoT and proposed a *message scheduling algorithm* to improve the efficiency of the system. The authors have also handled the faulty and failed node with the proposed algorithm. They have considered two main issues for energy conservation known as saving energy in battery powered objects and quick response to the query and the obtained results show the efficiency and effectiveness in service response and energy consumption. In [13], Brienza et al. have proposed the energy management system E-Net-Manager for various networked computers. They have proposed unique methods to reduce the energy consumption by using the soft sensors of computer systems like keyboard, mouse, bluetooth, Google calendar and PC activity soft sensors. In their results, significant energy saving has been achieved for short idle period. In [14, 15], Gupta and Singh have proposed a novel sustainable algorithm for prediction of CPU workload for minimizing the power consumption by personal computers. They have proposed a prediction model [16, 17] and algorithms for switching the current state of running computer system into power saving state.

2.3.3 Navigation Techniques

One major use of predictive computing is in navigation of vehicles or e-Transportaion. With the growth of technology, it has become possible to predict the shortest route for vehicle navigation. One can predict the navigation paths with lesser traffic rather than considering the busiest road networks in the city. These algorithms usually require a constraint to be placed on the system for effective prediction to take place. A Markov process is a stochastic process in which one can make predictions about the future state of the process based only its current state. Vehicle navigation paths are usually repetitive in nature due to natural constraints that limit the freedom of the driver. One of the most common natural constraints is time where most drivers just attempt to reduce the amount of time spent travelling between their origin and destination. The number of methods has been suggested for the prediction of vehicle navigation paths. Barth and Karbassi [18] have used a hierarchical tree data structure to perform real-time prediction of the navigation path that a vehicle may take for direct trips (source to destination). Their algorithm is recomputed as new data from the vehicle arrives while the vehicle is already in transit. Froehlich and Krumm [19] have discussed an alternative method where details of vehicle navigation path are collected and grouped by similarity. Each specific navigation path is assigned an index and stored. As the vehicle begins journey, the navigation path progresses and the algorithm attempts to match the current navigation path with an existing one. Although this allows for an initial prediction of the navigation path, the prediction is continuously updated as the journey advances. Kansal et al. [20] have discussed a sensor network for tracking using mobile phone devices. They have mentioned the fact that the prevalence of mobile devices and the increased availably of GPS technology makes them ideal nodes in a sensory network that focuses on the same GSM signals used for voice

communication. Trials for autonomous vehicle navigations are on the way and soon one can expect the market release of such cars [21, 22]. Technologies like GPS, RFID [23], sensor networks and IoT have made predictive navigation approaches easier and implementable in all the sectors like automobile, aviation [24] and marine. Cao et al. [25] have used the GPS technology for constructing the minimum dominating set of navigation paths and used this data for selecting the best possible navigation path to drive. The authors have implemented the algorithms like marking process to find the dominating vehicle, Updating process to keep the data updated of neighbour's node, and cutting process to cut down the redundant vehicle information from the database. In [26], Davidson has presented three different algorithms that can be integrated into personal navigation systems. First, algorithm computes positioning for a map aided navigation system designed for land vehicles travelling on road network; second, algorithm is aimed at map aided vehicle navigation indoors and the third algorithm computes solution for the pedestrian navigation system. In [6], Pattanaik et al. have presented a smart congestion avoidance technique by estimating the scope of real-time traffic congestion on urban road networks and predicts an alternate shortest route to the destination. This technique utilizes the k-means clustering approach to estimate the magnitude of congestion and applies Dijkstra's algorithm to predict the shortest route. In [27], Su et al. have designed a shortest path computing algorithm for navigation of large commercial vehicles. They have integrated spatial data with the proposed algorithm. Authors have listed various characteristics of commercial vehicles types like bus, truck, trailer and passenger car, etc. Mitton and Rivano [28] have deployed sensors on bicycles to analyze the various road conditions for medical purpose and have gathered the data in real time from the deployed bicycles. The proposed system is in its preliminary stage and a lot of work is still remaining to obtain the results. In [29], Kranz et al. have discussed the concept of embedded interactions of objects in the day-to-day utilities. They have monitored these interactions using IoT. They have also listed various challenges for embedded IoT like Invisibility dilemma, implicit versus explicit interactions, context dependence, etc. They have presented the vision beyond ubiquitous computing for day-to-day computing using IoT. Similarly, in [30–35], the authors have presented the architecture and smart navigation techniques for vehicles and the presented techniques utilize the IoT and sensor networks for navigation of vehicle. Some of the major predictive navigational techniques are shown in Table 2.2.

2.3.4 Intelligent Agents

The vision of smart environment is possible because of growth in computing techniques and use of predictive models. The smart environments utilize the concept of prediction and communication among the various existing objects. This communication involves various intelligent agents at middleware level for remote access and control of information in smart environment. Chen et al. [23] have

Table 2.2 Predictive navigation techniques and their advantages and challenges

S. No.	Navigation algorithm	Purpose	Advantages	Challenges
1	Dijkstra's [124, 125]	To find shortest path with minimum cost	Can find the shortest routes or the routes with the shortest travel times between the origin and the destination	– Considering large number of nodes, and – Achieving better run time
2	Restricted search algorithm [124, 126]		Unlike search the entire circle as in Dijkstra, restricted search with the small area of the remaining part of rectangle	– Considering large number of nodes
3	*k*-top [127, 128]		Algorithm not only finds the shortest path, but also $k-1$ other paths in non-decreasing order of cost. k is the number of shortest paths to find	– Without considering the loops
4	A* search [124, 129]		Instead of finding the next node with the least cost, the selection of node is based on the cost from the start node plus an estimate of proximity to the destination	– Without improving worst case time complexity
5	Bellman-Ford [130]	To find shortest paths from a single source vertex to all of the other vertices	– Provides more efficiency in terms of nodes covered or path travelled – Edge weights in weighted digraph can be negative number	– Issue of scaling as the network topology changes
	A*-ants [131]	To find the best optimized multi-parameter direction between two desired points using electronic maps	A* algorithm is run before ants algorithm and updates (increases) pheromones of its resulted paths in ants algorithm	
6	CARPA [132]	Multipurpose route recommendation algorithm	It includes data preprocessing, accessibility metrics definition, and multi-objective path finding	– Without considering stairs, high curbs and busy intersections of roads
7	Kalman filter-based algorithm [133–135]	To support the navigational function of a real-time vehicle performance and emissions monitoring	Kalman filter-based algorithm generates pose estimation (position and orientation) information, which enables faster and more robust tracking	– Problems associated with Kalman filters is how to assign suitable statistical properties to both the dynamic and the observational models

proposed code centric RFID system, which is used to store the information based on smart agents and provide the instructions to system whenever action has to be performed. Still proposed system does not meet the goals like knowledge representation and situation-aware code interpretation. In [36], Huang et al. have done body posture analysis by using collaborative accelerometer sensors on different parts of human body like on neck, wrist, waist and thighs. They have tried to predict the odd situation with the help of predictive body posture analysis whether there is any accident like scenario or not. They are unable to determine the condition of the body once the accident has taken place and planning to use gyroscope for more accuracy of results for falling like scenarios. Jeong et al. [37], have designed and implemented large-scale middleware for ubiquitous sensor networks. This ubiquitous sensor network supports intelligent event processing, various types of sensors, real-time sensed data and management of collected metadata. Further, the authors are keen to extend the support for a variety of wireless communication protocols like ZigBee, Bluetooth, Code division multiple access, etc. In [38], Taylor et al. have focused on the distribution of electricity in future and proposed cost effective and intelligent solutions for electricity distribution network and management scenarios. In [39], Gaoan and Zhenmin have proposed an intelligent method for measuring the heart rate using mobile acceleration sensor. They have suggested using their proposed real-time heart-tracking algorithm to develop low-cost heart rate monitor device. In [13], Brienza et al. have focused on the issue of energy consumption by ICT devices and suggested some intelligent soft sensor methods like bluetooth based, Google calendar based, activity soft sensors, etc., to reduce the energy consumption using these devices.

2.3.5 Smart Objects Based Computing

With the growth of mobile networks, researchers and developers are targeting mobile devices as a smart object to perform predictive computing over collected data. These mobile devices are also working as a middleware for transferring data from one sensor node to another. In [40], Kortuem et al. have presented the concept of 'Internet of smart objects' and classified smart objects into three different categories (a) activity aware objects, (b) process aware objects and (c) policy aware objects. These smart objects are equipped with embedded display and buttons on it. They have categorized between these objects on the basis of parameters like awareness, representation, interaction and augmentation. Figure 2.3 represents various smart objects that can be connected with mobile like smart devices in a ubiquitous network. In this section, we have summarized various mobile computing techniques for ubiquitous computing of received data as shown in Table 2.3.



Fig. 2.3 Smart objects in a ubiquitous network [3]

2.4 Predictive Computing Frameworks

In [9], Kalechofsky has presented a simple framework for developing predictive and statistical models for modern business. The author has mentioned that predictive analytics includes various techniques like predictive modelling, machine learning and data modelling to make predictions. The predictive analytics, in turn, uses the predictive modelling framework to perform predictive computing. This computing technique can be used in almost every sector like healthcare, travel, marketing, e-commerce, etc., by using their modelling framework.

2.4.1 Healthcare Frameworks

The predictive computing plays an important role in the prediction of health related issues and sending the early alerts to the patients. These healthcare frameworks use various predictive modelling frameworks for predictions and that's why their accuracy may differ from one framework to another. Predictive modelling is widely in use in clinical research and analysis. In [41], Ng et al. have described a scalable predictive platform known as PARAMO (PARAllel predictive MOdelling) that can

Table 2.3 Smart object based various computing techniques

S. No.	Author(s)	Proposed technique	Application	Advantages	Challenges
1	Ko et al. [136]	Middleware architecture		Solves the issue of interoperability between sensor and middleware and provides intelligent service	Compatibility of smart object with sensors and service providers
2	Solanas et al. [137]	Smart health (s-Health)	Concept of smart health lies in between mobile health and smart cities	Data is collected from patients and also from sensing infrastructure of smart cities	Requires interactions between actors like government, physicians, researchers, and practitioners, etc. Privacy and security is a major challenge
3	Bottazzi et al. [138]	Socially aware and mobile architecture (SAMOA)	Framework allows creating roaming social networks for mobile users anytime anywhere	Middleware solution to address social network management details	Lack of security and performance issues
4	Soliman et al. [139]	Smart home application	Integrated IoT, cloud computing, and Zigbee technology to design the application	Easy to use with improved efficiency of data access	No focus on security and privacy like issues and interoperability with other protocols and smart objects
5	Kortuem et al. [40]	Interaction between smart objects	Categorized smart objects in three categories	Included interaction and social aspects in design of smart objects	– Developed workflow models and ad hoc combination techniques, – Implementation of these techniques is still remaining
6	Mitton and Rivano [28]	City bike network	Deployed sensors on city bikes while cycling to gather data related to road, environment, or medical purpose	– New concept to promote eco smart driving using IoT – Basis model is proposed for city bike network equipped with sensors and base stations to collect the data	– Real-time implementation is complex in nature and involves more base stations as bicycle is not a stationary object and deployed sensors on bike have range limitation – For transferring of data with one base station object can't wait at one place
7	Siebert et al. [140]	LASEC algorithm and novel mechanism A-Ack	Collaborative composition approach has been implemented by the algorithm between service providers and A-Ack mechanism restricts the number or exchange messages for each service	– Composition algorithm is designed in such way to minimize the cost while object is not stationary – Network overhead is reduced by minimizing the number of messages to be exchanged	– Two layer model i.e. communication layer and request layer – Continuous energy consumption by nodes while they are in composition with other nodes – Object must be in the range of nodes

be used by many predictive applications. Brooks et al. [42] have stated that healthcare organizations can implement a predictive model that uses business intelligence (BI) to improve clinical efficiency. They have proposed a framework for developing a domain specific BI model for an expert practitioner in the field. In [7], Gupta et al. have proposed an IoT-based cloud centric health framework to monitor user's activities in sustainable health centres. This framework regularly predicts the user's activities and stores the details of various parameters like heart rate, pulse rate, timing of activity session, etc., in the cloud database and sends alerts to health care professionals of the user wherever emergency like scenario arises.

In [43], Lu et al. have presented the SPOC framework for secure and privacy preserving computing in mobile health care. This framework extends its functionality in the pervasive environment and introduces the user-centric privacy controls. In [44], Zhang et al. have presented three tier system architecture for healthcare system based on ubiquitous sensing. Tier-1 consists of various objects equipped with ubiquitously distributed sensor nodes. Tier-2 consists of ubiquitous technologies like wireless sensor networks, internet, WiMAX, 3G/4G, etc., to transfer the sensed data to doctors or medical practitioners. Whereas, Tier-3 is an information processing centre and consists of nodes like medical practitioners, doctors, data centres, servers for processing of collected data related to patient's health and to provide the necessary action to be taken by the patient. Similarly, Xu et al. [45], have proposed the semantic data model for interpreting the IoT data and also a data access mechanism has been proposed for emergency medical services in ubiquitous environment. Hu et al. [46], have also used the IoT network of physical objects for monitoring and predicting the health condition of elder person living at home. They have proposed an intelligent and secure health monitoring framework for finding the elder's activity and elders can use the mobile device for getting connected with the IoT network. In [47], Zhao et al. have presented the predictive model for finding the effect of multiple sclerosis in patients. They have used logistic regression and machine learning techniques in predicting disease course. In [48], Abreu et al. have studied about the recurrence of breast cancer and presented a predictive model based on combination of machine learning techniques for accurate prediction of recurrence events. In [49], Rana et al. have introduced the concept of changing interventions on different datasets and proposed a predictive framework that models interventions explicitly. In [50], Sakr and Elgammal have discussed some major challenges in healthcare systems which can be resolved using modern technologies like cloud computing, IoT and big data. The aspects of these technologies can be different that vary from communication to data storage. Authors have proposed a framework known as '*SmartHealth*' and described its various applications in the healthcare domain. Ifrim et al. [51], have highlighted the current status of the evolution, trends and research on IoT from e-Health perspective and performed a comprehensive survey.

2.4.2 *Smart Home Frameworks*

The potential technology used for designing the smart home varies from simple sensors to detect the position of door to more sophisticated sensor systems where the sensors are equipped into various objects and humans reside inside the house. Mulvenna et al. [52] have examined the role of context aware computing in smart home environment and monitored the activity of each individual in the house. Authors have developed various frameworks for monitoring the activity. These smart objects equipped with the sensor, collects the data about user's offline activity performed at home and continuously transmit it on the Internet. Apthorpe et al. [53] have mentioned that IoT devices have always-on sensors that capture the data constantly about the user's physical environment. They have developed a prediction strategy from the obtained data for passive network observer and to find about the various possibilities related to the user. In [54], Raj has presented a framework for smart monitoring of home and its security in owners absence. He has designed the context aware protocol for this system. This system is secure, reliable and user friendly and combination of Zigbee, Wi-Fi and body area network like technologies. By making the use of pervasive computing this framework is known as smart home system where user is connected with the various devices in home remotely. In [55], Aquino-Santos et al. have also presented the use of ubiquitous computing in developing smart home applications and interoperability of these applications. They have discussed the challenges like isolation of subsystem by executing several instances using hypervisor for the connected devices, and implementing a micro middleware. In [56], Hong et al. have analyzed the user's habits and behaviour in a living space and discussed the context aware model for smart home systems and the proposed model is shown in Fig. 2.4.

This model connects the various household devices with the user behaviour and process the collected information in an intelligent environment.

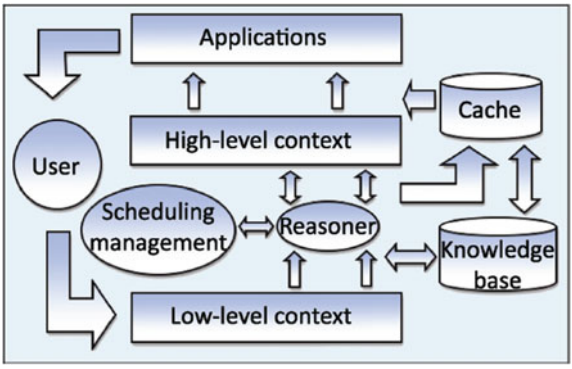

Fig. 2.4 Context aware smart home system model [56]

2.4.3 Navigation Framework

Currently, the road transport of goods or passengers relies on tracking technology. In designing of smart navigation systems, GPS data may be augmented with Wi-Fi and GSM signals to be used to provide location information of vehicle transporting the goods and passengers [57]. At present these systems suffer from limitations like reduced reliability in areas that are not permeated by the necessary GSM or Wi-Fi signals, or areas in which the GPS satellites do not have sufficient coverage. In [5], Malekian et al. have designed and implemented a system which is capable of predicting the navigation path of a vehicle on the basis of the existence of driver's existing driving practices. This system is capable of using RFID based information about navigation paths, in conjunction with predictive algorithms based on the Hidden Markov Model (HMM) to accurately determine the vehicle navigation paths in advance. In HMM, the sequence of observed output values provides information about the sequence of states. If modelled using a HMM, then the observer will only observe a sequence of output tokens directly. Baum et al. [58], have described a model based on this information. The observer can then attempt to infer the sequence of states that yielded the observed output sequence. HMM is an acknowledged tool for predictive solutions to systems that can be modelled as Markov processes. In [59], Simmons et al. have proposed the usage of the HMM to perform predictions on a vehicle's navigation path. In their method, the historical driver data is gathered using GPS information. This is used to supply parameters to the Hidden Markov model. They were able to achieve results of above 98% accuracy in most cases, although the navigation paths they tested had very few places in which choices were required. In [60], Herbert et al. have a proposed a modular framework FaSTrack that provides a safety controller and can be used with most current paths. In [61], Jabbarpour et al. have presented the general framework for vehicle traffic routing system, known as VTRS and used for mitigating traffic congestion on roads. VTRS gathers traffic-related data such as vehicles' speed, travel time and density, user preferences and alternatives paths for preparing the routing tables by calculating the fitness function. In [62], Yang et al. have proposed an autonomic navigation system (ANS) operating over vehicular ad hoc networks (VANETs) for predicting the future vehicle density and adopts hierarchical algorithms for route planning and time dependent routing algorithm for traffic prediction as shown in Fig. 2.5.

In [63], Cebecauer et al. have presented a framework for integrated real-time network travel time prediction of vehicle based on probe data. This framework is capable of predicting short-term traffic conditions, real-time vehicle routing and for trip planning. They have used hybrid probabilistic principal component analysis (PPCA) methodology for short-term prediction of vehicle path. Similarly, a number of frameworks and approaches have been proposed for finding the predictive trajectory guidance, prediction of next turn at road junction and motion planning for autonomous vehicle navigation [64–67].

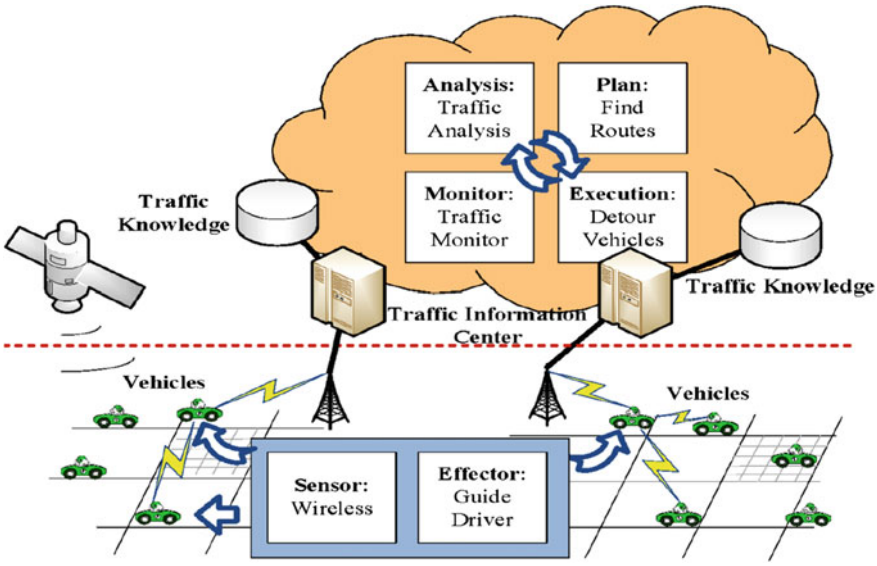

Fig. 2.5 Autonomic navigation system

2.4.4 e-Commerce Framework

Since last decade, a lot of significant developments have taken place in e-commerce market and its applications. The organizations have completely changed the way of marketing by implementing the various data mining rules for predicting the price of product, behaviour of consumer and selecting the appropriate marketing strategy, granting them to make intense and knowledge-driven results. Similarly, change in marketing models is taking place from traditional website based system to knowledge-based system to recommender system. A recommender system predicts about the customer's choice by exploiting ratings made by the customer for the same or similar product in the past. In [68], Qiu has proposed a predictive model, COREL to make purchase behaviour prediction of customers. He has investigated the three factors that significantly affect the purchasing decision of customer in online shopping that is the needs of customers, the popularity of products and the preference of the customers. He has explored associations between products, exploiting them to predict customer needs. In [69], Gupta and Pathak have focused on the dynamic pricing of the product where prices vary according to market demand of the product. Nowadays, dynamic pricing concept is being used by almost all e-commerce sites including retail, automobile, tours and travels, grocery stores and a lot many. They have proposed a model for determining the purchase behaviour and pricing strategy for online customers. This proposed model consists of stages like Data Collection, Preprocessing, Attribute selection, Grouping of customers, Dynamic pricing and Predictive analysis as shown in Fig. 2.6.

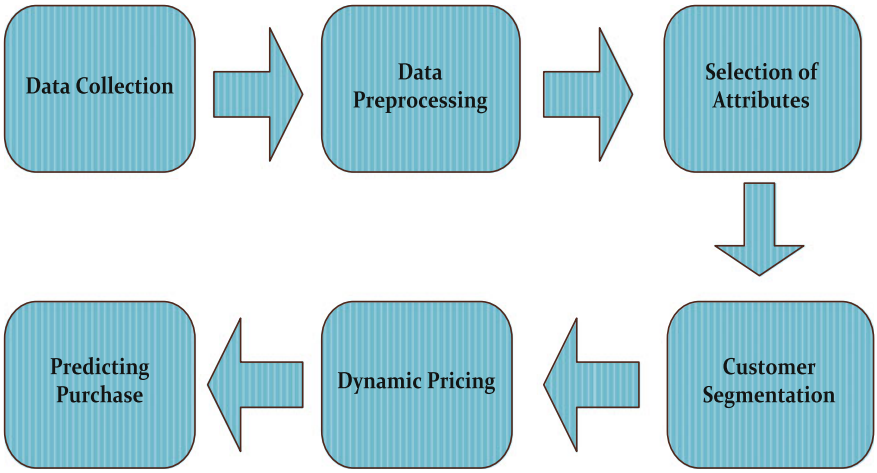

Fig. 2.6 Framework for predicting online purchase based on dynamic pricing

This framework also includes various techniques of Machine learning, Data mining and Statistical methods for predicting the online purchase behaviour of customers by selecting an appropriate price range. In [70], Ahmadi has proposed a framework, e-CLV (Electronic customer lifetime value) for predicting the online customer's behaviour. Proposed model considers real option analysis to predict all future states with probability of each of them. In [71], Lo et al. have tried to characterize, understand the customer's behaviour for developing predictive models of user purchasing intent. They have identified some set of general principles and performed large-scale longitudinal study to model user purchasing intent across many discovery applications. Authors have classified the user's action into four classes known as (i) *searching for a content* (ii) *exploring contents by using provided links* (iii) *getting closer with particular piece of content and* (iv) *saving contents to retrieve it later*. In their predictive analysis, authors have tried to find how engagement in these actions predicts users' future purchasing intent or activity. Similarly, in other studies [72, 73] related to prediction of consumer behaviour, authors have used different perspective of analysis like Badea [72] have used the concept of artificial neural network for predicting consumer behaviour, and Naumzik et al. [73] have performed image sentiment analysis on their proposed model for predicting the increase in rent prices.

2.5 Information Security Techniques

'Data' is becoming a vital component for all kind of computing techniques. Several issues arise with the handling of data like data storage, data access and data usage issues, etc. As discussed earlier, over the period of time various security techniques

have been proposed by the researchers and developers to establish confidentiality, privacy and trust while handling of data. Here we have summarized various security techniques related to cloud computing and IoT.

2.5.1 Security Techniques for Cloud Computing

Security is a major issue in cloud computing as it leads to various types of vulnerabilities while handling of data. Cloud storage and data has to be secured and must ensure various security parameters like authentication, authorization, confidentiality, integrity, availability, etc. In [74], Arockiam and Monikandan have proposed a security technique AROcrypt that ensures confidentiality of data in cloud storage. AROcrypt is one of the symmetric encryption techniques and makes use of ASCII values for processing of plain text into cipher text. In [75], Alsulami et al. have investigated many security techniques and models for cloud computing to main the data integrity and confidentiality. They have identified few of the techniques like encryption, anonymization, separator and multilayering that can have an effect on data integrity and confidentiality. Among these techniques, encryption technique is most widely used for cloud security. In [76], Zhou et al. have presented a scheme to control and prevent unauthorized access to data stored in the cloud. They have proposed a role-based encryption (RBE) technique that integrates the cryptographic technique with role-based access control (RBAC) model. They have also proposed a RBE-based architecture for secure data storage in public cloud. To maintain the privacy of data, policy based encrypted data access approach has been used in which users who satisfy the access policies can decrypt the data using their private key. In [77], another work, Bokefode et al. have used encryption technique AES and RSA for encryption and decryption of data and RBAC used to provide control to users as per their role. In [78], Gugnani et al. have focused on to provide confidentiality to the user while using cloud-based web services, and proposed an approach for selective encryption of XML elements so as to provide confidentiality and to prevent XML document form improper information disclosure. Figure 2.7 represents XML DNA Encryption/Decryption to embed confidentiality. Authors have considered the XPath Injection attacks which take place when web site uses user-supplied inputs to form XPath query for XML data. Terec et al. [79], have discussed the implementation of various cryptographic techniques in Java, MATLAB and Bio-Java and also represented how DNA encryption is implemented in three of them. Besides XML encryption, we have SSL and XML signatures to secure the internet transmission. Users interact with the cloud using XML files and then these XML files and their contents need to be protected so as to safely transfer the confidential information. Also, the communication among Web Service and the clients are mainly done through plain-text XML formats like SOAP messages and WSDL [80].

In [81], Dinesha and Rao have proposed a secure cloud transmission protocol (SecCTP) to maintain data integrity, confidentiality, access management and

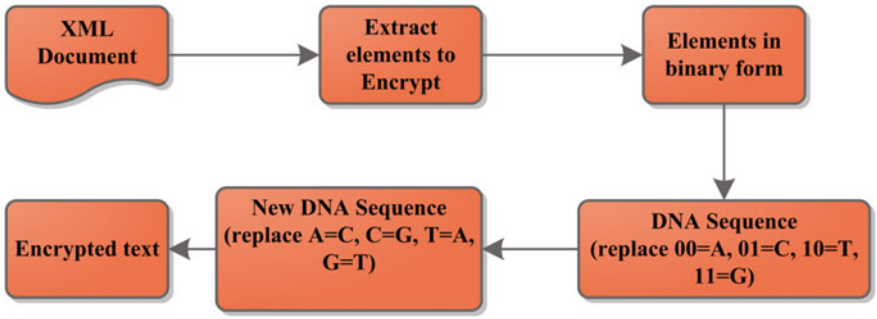

Fig. 2.7 XML DNA encryption approach

identity in the cloud. Proposed technique SecCTP deploys Multi-Dimensional Password (MDP) system, Multilevel Authentication scheme (MLA) and Multilevel cryptography (MLC) system to handle various cloud security issues of authentication, identity and confidentiality. In [82], Yu et al. have proposed an efficient and practical identity based Remote data integrity checking (RDIC) protocol which is based on key-homomorphic cryptographic schemes and maintains perfect data privacy. In perfect data privacy, protocol leaks no information of the stored files to the verifier. In [83], Zhou et al. have stated that the integration of IoT techniques with cloud computing leads to new challenging security and privacy related threats. They have proposed unique security and privacy requirements for cloud-based IoT and addressed the challenging issues of secure packet forwarding and efficient privacy preserving authentication by proposing a new efficient privacy preserving data aggregation without public key-homomorphic encryption. In [84], Choi and Lee have focused on various security issues related to the public sector that restrict any organization from the use of cloud platform. They have proposed a methodology for information security management and adopted a Delphi approach to establish the classification criteria in objective and systematic manner. In [85], Gaetani et al. have focused on data integrity issue in cloud computing and used a *Blockchain-based* method for handling these issues. Blockchain has recently emerged as a fascinating technology that consists of consecutive chained blocks containing records that are replicated on the nodes of a P2P network. These records witness transactions occurred between pseudonyms. They have proposed an innovative blockchain-based database that permits balancing strong integrity guarantees with appropriate performance and stability properties.

2.5.2 Security Techniques for Internet-of-Things

The architecture of IoT converts living and non-living entities into smart objects that can be monitored or used continuously by using internet technologies. These smart objects can communicate with each other, and can respond to the changes in

surroundings intelligently. This intelligent feature derived from IoT architecture includes new security risks and privacy issues. So, maintaining user security and privacy is one of the crucial issues and need to be addressed thoroughly. In [86], Dabbagh and Rayes have presented the security and privacy issues related to IoT platforms. Various security challenges identified by them are Scalability, Multiple verticals, Multiple technologies, Big data, availability, remote locations, etc. They have categorized the IoT architecture into three different domains that include: (a) IoT Sensing Domain, (b) IoT Fog Domain and (c) IoT Cloud Domain. Various security attacks related to cloud domain and IoT are summarized in Table 2.4.

In [87], Nia and Jha have presented a detailed survey and provided a comprehensive list of vulnerabilities and countermeasures against them. Authors have discussed three widely known IoT reference model, i.e. (a) Three-level model [88], (b) Five-level model [89] and (c) Cisco's Seven-level model [90] and discussed various possible applications of IoT. In [91], Singh et al. have discussed state of the art of various lightweight cryptographic primitives that consists of lightweight block ciphers, hash functions, stream ciphers, high-performance systems and low resources devices for IoT environment. They have also analyzed several lightweight cryptographic algorithms like AES, DES, Twine, Seed, RC5, PRESENT, etc., on the basis of their key size, block size, a number of round parameters.

2.6 Information Security-Based Frameworks

As discussed in the previous section, various information security techniques have been evolved to mitigate or to reduce the vulnerabilities in an existing software system, used by business organizations or its customers. For effective implementation of information security and privacy techniques in the system developers and software designers need to modify the existing architecture or framework of software system. It is observed, that in most of the cases these architectures or frameworks are responsible for security-related issues. The reason for this is that security parameters are overlooked by the designers and developers while designing of system. In this section, we have discussed various information security frameworks related to cloud computing and IoT.

2.6.1 Cloud Computing-Based Security Frameworks

Rising demand for storage of data in a cloud environment by the business organizations and customers requires a lot of changes in existing architecture or framework of software systems. Current system design and deployment techniques must be capable enough to accommodate these changes into the system and must ensure the security and privacy of new cloud-based frameworks and architectures. In [92], Chang et al. have presented a multilayered security framework for business

Table 2.4 Security attacks in IoT-based cloud domain

S. No.	Security attacks	Security violation	Reason	Technique(s) to be considered to resolve
1	Hardware Trojans [141–143]	– Confidentiality – Integrity – Availability – Accountability – Auditability – Trustworthiness – Privacy	– Alteration of integrated circuit design – Activation of Trojans based on some external/internal factors	– Circuit design modification, and – Improving Trojan activation method
2	Physical attacks [144–146]		Shared access to components, or network resources	– Hard isolation of devices and software's – Circuit design modification
3	Spoofing/Tag cloning [147]		– Weak security mechanism – Easy to intercept, read and save messages	– Personal firewall – Cryptographic scheme – Hard isolation of devices and software's – Distance estimation – Kill/Sleep command
4	Malicious injection [148]		– Insufficient validation of the input	Pre-testing and validation of inputs
5	Non-standard framework and weak testing [149]		Non-standard coding flaws	– Pre-testing – Designing good framework and policies
6	Virtual machine migration (VM migration) [86]	– Confidentiality – Integrity – Availability	Software bugs, no permission for migration, malfunctioning of device	Server authentication
7	Hidden-channel attack [86]	– Confidentiality	Shared access to components, or network resources	– Hard isolation – Cache Flushing – Noisy data access time, and – Limiting cache switching rate
8	Theft-of-service attack [86]	– Availability	Periodic sampling	– Fine-grain sampling – Random sampling

(continued)

Table 2.4 (continued)

S. No.	Security attacks	Security violation	Reason	Technique(s) to be considered to resolve
9	Insider attack [86]	– Confidentiality – Integrity	Lack of trust	– Homomorphic encryption – Divide the data into multiple chunks and use secret key with certain permutations
10	DoS [150–152]	– Availability – Accountability – Auditability – Privacy	– Node outage because of battery draining – Sending undesired set of requests that seem to be Legitimate – Node outage because of unintended error, sleep deprivation, code injection, etc.	– Securing firmware – Personal firewall, and – Cryptographic scheme
11	Eavesdropping [153]	– Confidentiality – Privacy	– Weak security mechanism – Easy to intercept, read and save of messages	– Personal firewall – Cryptographic scheme – Hard isolation of devices and software's – Blocking
12	Routing attacks [154–156]	– Confidentiality – Integrity – Accountability – Privacy	– Changing routing information	Reliable routing
13	Integrity attacks [157, 158]	– Confidentiality – Integrity	– Manipulating the training dataset – Direct access of server or computing nodes for manipulation	Outlier detection

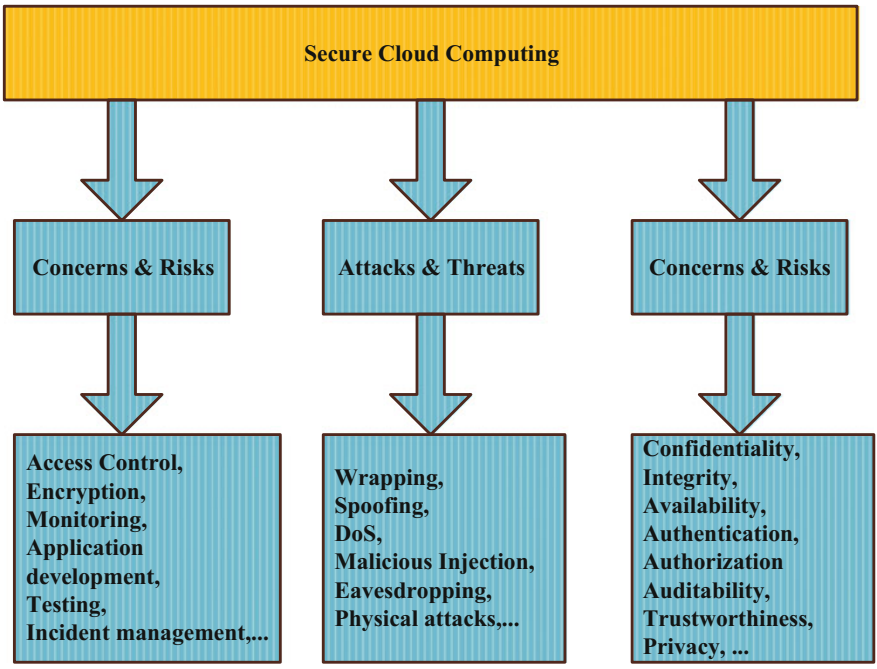

Fig. 2.8 Framework for secure cloud computing

clouds. This Cloud Computing Adoption Framework (CCAF) integrates three major security technologies known as firewall, identity management and encryption. In [93], Mushtaq et al. have presented the quad layered framework for data security, data privacy and data breaches. This layered architecture prevents the confidential information with a variety of quad security layers like Secure Transmission of Data, Encrypted Data and its processing, Database Secure Shell and Internal/external log Auditing. They have also presented a new auditing mechanism where customers can design their own rules for making auditing better. In [94], Youssef and Alageel proposed a framework to identify cloud specific security and privacy challenges, attacks and risks. They have also proposed a security model to perform generic cloud computing and to protect security and privacy requirements from vulnerabilities as given in Fig. 2.8.

In [95], Matte and Kumar have focused on storage of data, and stated that cloud supports data storage in distributed environment. They have provided the solution for security of data in multi-cloud. Multiple copies of data are stored in encrypted form on different clouds. Authors have used plain cipher algorithm for encryption purpose. In another work, Dorairaj and Kaliannan [96] have focused on issue of data migration in cloud, which is accessed by several users. Data protection from unauthorized access becomes important to both organizations and customers. To handle the issue of data sensitivity, authors have proposed an adaptive multilevel

security framework that provides adequate level of security under different classes. This framework provides required access control at each level by using suitable encryption techniques. Similarly, cloud computing-based security framework is being used in every domain like healthcare, vehicle navigation, eLogistics, banking, etc. In [97], Ondiege et al. have mentioned that poor implementation of security in healthcare leaves the patients' data vulnerable to attackers and considered that providing security to remote patient monitoring (RPM) infrastructure is a major issue. They have proposed a new identification technique NFC in their new security framework for monitoring of remote patients in multi-user environment and to keep the patient's information secure. In another work, Jaganathan and Veerappan [98] have proposed a new cloud storage model, CIADS, to keep patient's medical data secure. They have implemented authorization service through certificates, confidentiality by implementing new encrypting algorithm and data integrity is ensured by modified hash algorithm. In [99], Xiao and Xiao have presented the generic ecosystem for cloud security and privacy which employ an attribute driven methodology. This ecosystem employs five security/privacy attributes: (a) Confidentiality, (b) Integrity, (c) Availability, (d) Accountability and (e) Privacy-preservability, as shown in Fig. 2.9. Authors have considered security and privacy separately and demonstrated the connection among vulnerability, threat and defense mechanism for the mentioned attributes in cloud environment.

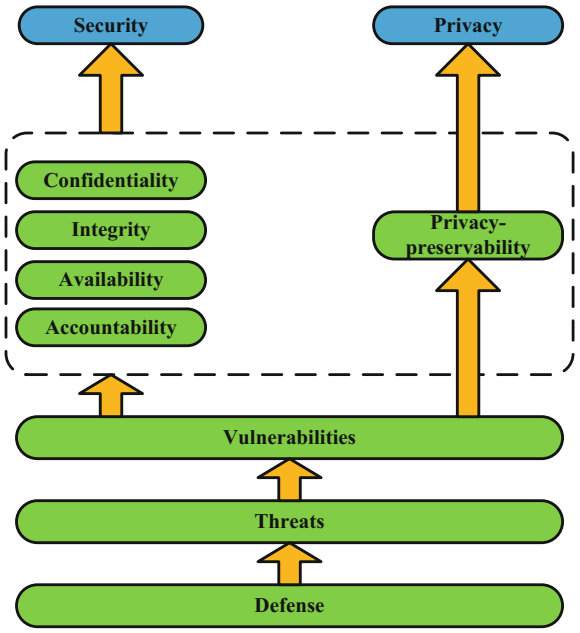

Fig. 2.9 Generic ecosystem based on attributes for cloud security and privacy

2.6.2 IoT-Based Security Frameworks

Significant advancements in the field of information and communication technology (ICT) and wireless technology, lead to development and adoption of various frameworks which are based on cloud computing, IoT, Big data, etc. It is predicted that by 2020, around 50 million of things will be connected to the Internet via IoT [100]. Usage of IoT-based frameworks in every business sector like healthcare, smart home, agriculture, logistics and transportation, is increasing very rapidly as it provides anyone, anytime, anyplace and anywhere type of frameworks for the all connected living and non-living things in the network [101]. However, these technological advancements and adopted frameworks also bring many issues. Security and privacy are considered at the top of all issues that need to handle intelligently for global adoption and use of IoT technology by the humans [102]. Park and Shin [103], have proposed a general security assessment framework for IoT services. They have applied integrated fuzzy multicriteria decision-making (MCDM) approach which uses an analytic network process (ANP) in combination with the decision-making trial and evaluation laboratory (DEMATEL) technique to increase the sensitivity of interrelationships among diverse security requirements. This framework is shown in Fig. 2.10.

In [104], Ge et al. have proposed a framework for modelling and assessing the security of the IoT and provide a formal definition of the proposed framework under five phases known as (a) *data processing*, (b) *security model generation*, (c) *security visualization*, (d) *security analysis and* (e) *model updates*. This framework identifies all possible attack paths in the IoT and evaluates the security level of the IoT through security metrics. In [4], Kang et al. have focused on human centric smart home services and proposed an enhanced security framework for smart

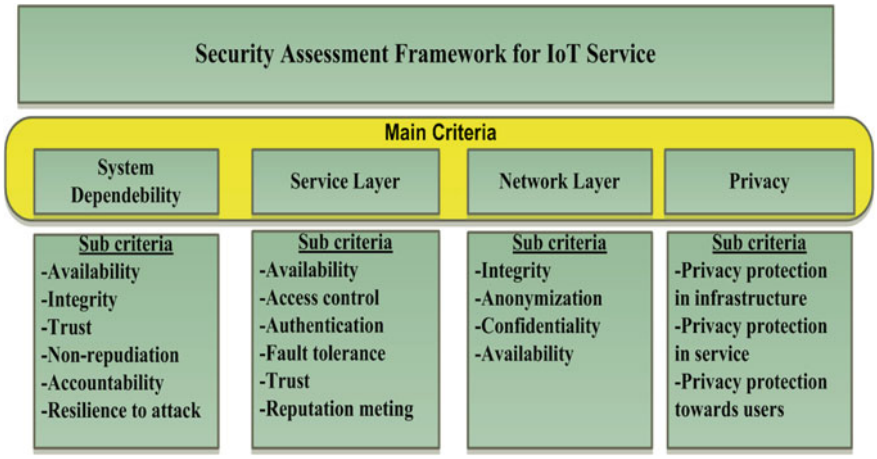

Fig. 2.10 Security assessment framework for IoT

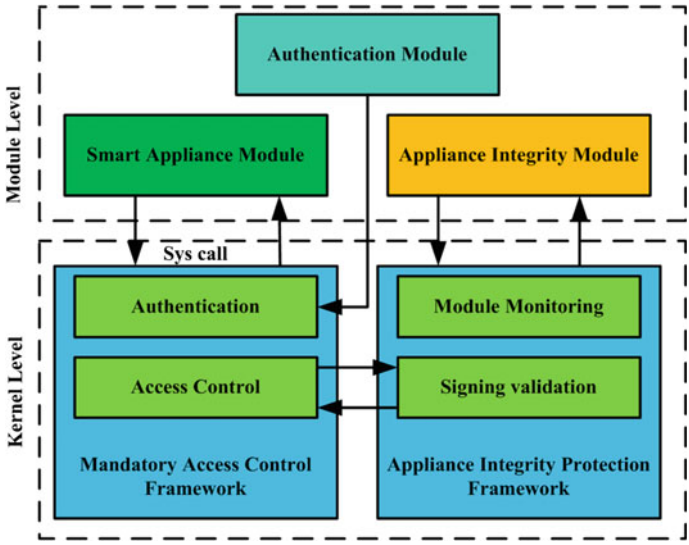

Fig. 2.11 Security framework for smart home

devices in a smart home environment. As shown in Fig. 2.11, this framework is made up of smart appliance module, appliance integrity module, mandatory access control framework and appliance integrity protection framework. This framework provides the security service for ensuring device authentication, integrity and availability.

In [105], Ngu et al. have focused on realization of middleware technologies in IoT systems which represents that software framework play as an intermediary between IoT devices and applications. They have designed an application for real-time prediction of blood alcohol content using smart-watch sensor data and presented a comprehensive survey on the capabilities of the existing IoT middleware. They have also presented a thorough analysis of the challenges and the enabling technologies in developing an IoT middleware. They have captured the key properties of some trusted IoT system as shown in Fig. 2.12. In [106], Ukil et al. have presented privacy preservation framework as a part of the IoT platform and a data masking tool for both privacy and utility preservation. This provides negotiation based architecture to find a solution for utility-privacy tradeoffs in IoT data management. They have also presented a case study on e-Health for this framework.

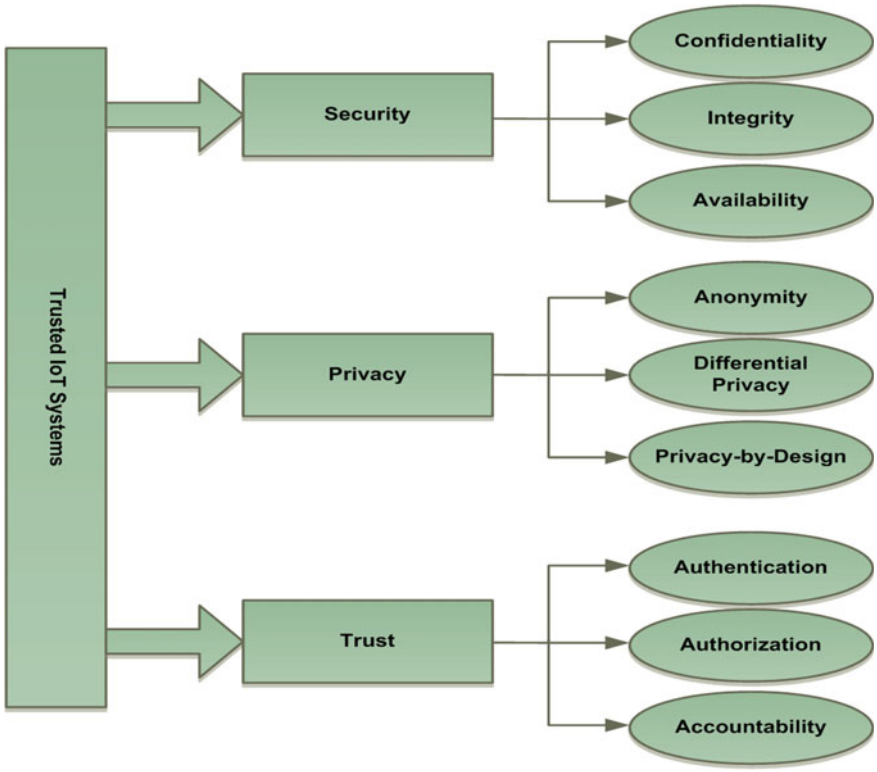

Fig. 2.12 Security, privacy, and trust in IoT systems

2.7 Challenges and Discussions

A primary focus of this chapter is to discuss various techniques and frameworks available for predictive computing and information security. We have found that the security issues in cloud computing and IoT will become a challenging task in near future. According to new research released by TRUSTe, 35% of online US consumers now own at least one smart device other than a smart phone, and the most popular devices are smart TVs (20%), in-car navigation systems (12%), followed by fitness bands (5%) and home alarm systems (4%). In this section, we have summarized few major challenges related to cloud computing and IoT which are listed as follows:

- As per findings from 2015 U.S. IoT Privacy Index, only 79% of consumers are concerned about the idea of their personal data being collected through smart devices, while 69% believed they should own any such data being collected [107].

- In supporting security, privacy and trust mechanisms within IoT middleware has been recognized as a critical and important issue for the successful deployment of IoT applications, and is deemed as one of the major challenges in both industry and academic communities [105].
- As the digital market will be flooded with IoT-based devices and cloud users. It is predicted that by 2020, around 50 million of living and non-living things will be connected to Internet via IoT [100].
- Integration of cloud computing, wireless sensor networks, RFID and other multiple technologies with IoT will increase the complexity of overall system exponentially, as each technology has its own vulnerabilities and integration with IoT will sum up all these vulnerabilities and introduce new security threats to devices and systems [86].
- The modelling security of the IoT is a difficult task as it is characterized by a large number of heterogeneous and mobile devices and facing numerous threats.
- IoT paradigm consists of several verticals that span over e-Health, intelligent transportation, agriculture, smart home, etc. All these verticals have different requirements of security and privacy at device level and at user level.
- IoT framework consists of a number of sensor nodes and scalability of IoT application stored in the cloud, with respect to utilization of CPU, memory and other resources is a challenging task. An IoT solution needs to scale cost-effectively, potentially to hundreds of thousands or even millions of endpoints.
- Another challenge from these endpoints is that they generate heavy amount of data over time and require some effective mechanism in cloud for security and privacy of this data. This large volume of data is also known as Big Data [86].
- The ownership of the data collected from these endpoints must be clearly established and the endpoints and reading devices from the IoT Things should each be equipped with privacy policies. This collected data is further processed to obtain useful information related to health analysis, vehicle route prediction, monitoring a home and environment, etc. [106].
- In [103], Park and Shin have considered service availability challenge at the top priority with increased attention on infrastructure security for networks and systems.
- Further, the nodes in IoT have limited energy and computational power on which implementing complex security measures, is a challenging task. To handle this challenge, security mechanism needs to be developed in context to IoT resources that focus on particular type of attacks like DoS, spoofing, etc., this will help to utilize less energy and computational time.
- In [87], Nia and Jha have also discussed about two emerging security challenges: (1) *Exponential increase in number of weak links*—Currently, available devices in the market don't support complex cryptography algorithms because of these restrictions and this led to number of weak links in the system that can be exploited by the attackers. (2) *Unexpected usage of data*—Growing use of IoT technologies has led to sensor-based connectivity in day-to-day living, this scenario leads to unexpected use of user's data collected by these sensors.

- In another approach, attack paths could be found with the help of framework if node vulnerability and network reachability information is given [103]. The attackers can access these IoT devices and resources with the help of cloud and can use these devices as zombies, so protection of each node becomes important.
- Most of the IoT-based devices are mobile in nature and this mobility has a great influence over security, because attack surfaces changes with the change of network. This challenge involves designing of mobility model for protection of IoT device node in hanging network environment.
- Designing IoT applications and services is yet another challenge as IoT middleware must be available in cloud and on the edges like IoT devices, gateways, etc.
- A big challenge is to ensure the security of IoT application and privacy of users along with semantic service discovery in which a failed IoT service gets replaced with available ones in the network without causing any disruption to the user [105].
- As reported, lack of security mechanisms, auditing mechanisms, data integrity and service level agreements are serious concerns in cloud computing. Some security models have been proposed related to proof of retrievability [108], anonymity based system [109], privacy stabilizing architecture [110], process of access control [111], preserving cloud computing privacy (PccP) model [112] and public auditing mechanism-Oruta [113, 114], to overcome mentioned challenges.
- According to NIST [115], various challenges associated with the cloud computing platform are: designing of policies, standards and procedures that are sufficient to defend organizations from threats.
- The distributing the roles and responsibilities among team members to implement security policy is yet another challenge that should be followed with effective planning at each stage of system's life cycle.
- Implementations of security policies are considered in ad hoc manner in cloud environment to satisfy some set of organizational needs to minimize the risk of threats. The future challenge would involve real-time measures to provide assurance against organizational goals.
- Business outsourcing is common phenomenon of organization and number of organization opt outsourcing to reduce the overall business complexity. The cloud computing facilitates organizations with computational and storage resources at reduced operational cost.
- In cloud environment, data owner lacks full control over outsourced data and finds its management untrustworthy as data may get exposed to various insider and outsider attacks or data leakage related issues could be there [100]. Therefore, maintaining a data confidentiality and privacy is a challenging task to gain users confidence for adopting cloud computing.
- Implementing proper access control mechanism could be challenging issue to maintain user's privacy and unauthorized access to data. As mentioned, in cloud computing data is stored with the third party and in such case implementing a

log monitoring system to analyze the various logs related to a security breach and attacks could be a challenging task [116].
- In clouds, similar to dynamic resource provisioning, automatic resources provisioning is another challenging issue in which by predicting the future demand, resources are allocated and de-allocated from the cloud.
- Server consolidation, and energy efficiency is another big challenge in cloud computing to minimize the power consumption and operational cost of data centers. A key challenge in this is to achieve a good trade-off between energy savings and application performance [117].
- For some specific scenarios, cloud interoperability issue is an emerging challenge where it becomes difficult to integrate existing legacy systems with proprietary cloud APIs to get various cloud services [118].

Integration of cloud computing and IoT provides enormous benefits to the users and organizations in terms of more bandwidth and resources. Due to this reason, it has been widely adopted by the industry but still it has number of issues which need to be addressed and several more challenges are emerging related to applications security and privacy after integration of these technologies.

2.8 Summary

The advancement in computing field has gone through from traditional computing to interactive cloud and IoT-based predictive computing to make our lives easier and comfortable. The predictive computing makes the utilization of wireless sensor network for connectivity of various smart objects with Internet and continuous collection of data from these objects to make predictions related to health, navigation, agriculture, sales, etc. Predictive computing makes effective use of machine learning and data mining approaches to process collected data and produce the results in real time for consideration. However, these technological advancements that predictive computing brings are associated with security risks and privacy issues that need to be addressed thoroughly for effective implementation of predictive systems. Ignoring these risks and issues will adversely affect the system's integrity. In this chapter, we have presented a study on various predictive computing techniques and frameworks that can be applied in a variety of fields including vehicle navigation, sustainable computing, e-health, smart home and e-commerce, etc. As we know, integration of IoT and cloud computing sums up the total possible threats related to user and system in case of predictive computing. We have also presented the various information security techniques and frameworks related to cloud computing and IoT. These security techniques represent various security attacks like hidden attacks, eavesdropping, spoofing, etc., and security violations in terms of confidentiality, integrity, availability, trustworthiness, etc., of data. We have also outlined various challenges related to security and privacy issues of cloud computing and IoT. We hope that in future, researchers and developers

will consider these security and privacy issues and will provide appropriate solutions to these issues at an early stage of system development. Predictive computing is the future that will change the way of application development scenario by changing the existing framework into the predictive framework and will provide short-term or long-term prediction results to enhance the day-to-day life of a user.

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Predictive Computing and Information Security

Authors: P.K. Gupta , Vipin Tyagi , S.K. Singh

Includes the latest research, algorithms, and frameworks in the area of predictive computing and information security

Highlights real-world implementations of the techniques in predictive computing and information security

Provides details of the real-world datasets used in the experiments

Includes supplementary material: sn.pub/extras

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About this book

This book describes various methods and recent advances in predictive computing and information security. It highlights various predictive application scenarios to discuss these breakthroughs in real-world settings. Further, it addresses state-of-art techniques and the design, development and innovative use of technologies for enhancing predictive computing and information security. Coverage also includes the frameworks for eTransportation and eHealth, security techniques, and algorithms for predictive computing and information security based on Internet-of-Things and Cloud computing. As such, the book offers a valuable resource for graduate students and researchers interested in exploring predictive modeling techniques and architectures to solve information security, privacy and protection issues in future communication.

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Chapter 3
Predictive Computing: A Technical Insight

3.1 Introduction

Predictive analytics is used to derive information in real time from existing datasets for finding patterns and predicting outcomes of existing problems. Predictive analytics encompasses of the advanced analytics and statistical techniques which come from predictive modelling, data mining, machine learning and artificial intelligence. Also, predictive analytics analyzes the datasets to make predictions about future trends. Datasets may be generated from various heterogeneous sources based on the current and previous facts. The patterns could be derived from existing dataset on the basis of the previous historical and transactional data and also to identify various security risks and attacks in near future. These predictive models analyze the relationships among many factors and present the various set of conditions. This set of conditions helps to assign a weight which contributes to assessing the risk. On successful implementation of predictive models, organizations can easily interpret the big data to gain maximum benefit. These predictive models work in association with data mining and text analytics and create predictive intelligence by finding hidden patterns and relationships in the dataset that consist data in structured and unstructured manner. Unstructured data represents the data collected from different sources like call center notes, social media content, or from a different type of open text which is extracted from the main text. The data which can be used readily for analysis is structured data, e.g. sales, income, age, gender and marital status. The sentiment is also extracted along with the text to build the model.

Currently, Predictive Analytics is also an emerging area related to big data. It has been gaining more proliferations in recent years [1, 2]. Despite this current majority and popularity, the underlying data is at least 20–30 years old. Many researchers, engineers and scientists have applied the predictive models for interpretation of the big data and prediction [3]. The definition of big data concerns with massive volume, complex and growing data sets with multiple and independent sources

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[4, 5]. Accompanying with the above example, the era of big data has appeared [4–6]. Every day, nearly 2.5 quintillion bytes of data are generated from the different websites, autonomous sources, emerging ubiquitous devices. 93% of the data in the world today is created within the past few years [5–7]. In the direction of big data generation, social websites, online shopping websites such as Facebook, Yahoo, Amazon, tutor Flickr, etc., have got proliferation and received 1.8 million photos per day on an average during 2015–2016 [8]. This requires nearly 100 terabytes (TB) storage space every day. The billions of pictures on Flicker and other social sites are included as treasure tank to explore and retrieval of data items of the human society, social cultural events, public discussions and affairs, awareness of disasters, genetically encoding and decoding of gene expressions and so on, only if human society have the power to harness the massive amount of data [8–12].

These examples provide a good demonstration of the rise of big data applications. The data collection has grown massive and tremendously in the recent time. It is beyond the ability of commonly used traditional computing paradigm, statistical programme's applications and software tools to capture, manage and process this massive amount of big data within a defined tolerable elapsed time. The major challenges for big data applications are to explore the massive volumes of data and to extract discriminatory information or knowledge for future trends [8, 9, 12, 13]. In many cases, knowledge extraction is done in real time or near real time so it could be difficult to store all the observed data. As a result, the unprecedented data volumes require an effective data analysis and prediction platform to achieve fast response and real-time classification for such big data [10]. The recent research in the modern big data and data sciences provides new paradigms for computation and handling for the massive amount of data and learning approaches aimed at effectually searching through the enormous volume of data [10–12, 14].

Predictive analytics in big data is recently one of the active research areas because of its wide proliferation, application and uses in different research fields such as online photo-sharing like Flickr, social search, online video-sharing sites similar to YouTube, monitoring of ubiquitous computing, smart device, IoT-based intelligent systems and communication over internet services [10, 11, 13, 15, 16]. However, due to the ever-growing size of the web services, simple text-based communication or classical techniques for visual feature-based approaches for retrieving meaningful information from huge data may not be sufficient for optimal search results [13, 14, 17]. Data science also prompted multidisciplinary researchers to use various mathematical models, tools, technical innovations like big data analytics, predictive analytics, data mining concepts, coherent set of machine learning algorithms, deep learning algorithms and pattern recognition techniques to extract knowledge of the data information and help in decision making. With the promises of predictive analytics and computing in big data, the use of machine learning and pattern recognition algorithms predicting future are no longer challenging [5, 6, 18], especially for e-transportation, health monitoring, medical sciences, smart sensors and prediction of incurable diseases as predictive analytics play a vital role in the analysis and prediction of massive amount of data sufficiently. Predictive analytics and computing paradigms can be applied to data

science [4], for analysis of customer behaviour to predict market value, to enhance financial services, to promote telecommunications, analysis of retail, object mobility, healthcare [19] and other fields [11, 20].

3.2 Design Architecture of Predictive Computing

3.2.1 Predictive Analytics Process

Predictive analytics process is the complete study from data collection to prediction. It is a cyclic process as shown in Fig. 3.1. This process starts from problem definition where problem statement is defined then data is collected based on problem definition. Further preprocessing techniques like data cleaning, data transformation are applied to make data appropriate for predictive modelling. Finally, deployment of prediction system takes place.

- *Problem definition*: In this segment, following project outcomes, scope, deliverables and business objectives are identified. The dataset to be used is identified and properly defined.
- *Data collection*: Dataset is prepared by collecting data from various sources that may be homogeneous or heterogeneous, that can provide a complete view of prediction pattern or trends.
- *Data preprocessing*: is the way of finding useful information by cleaning, transforming, inspecting and modelling data.

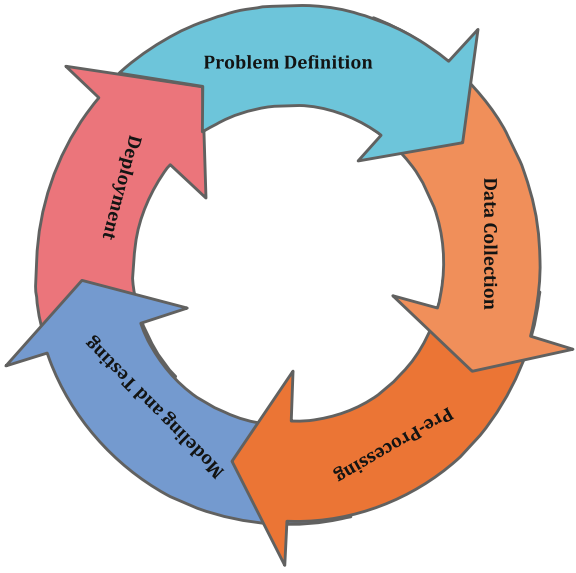

Fig. 3.1 Predictive analytics

- *Modelling and testing*: is the process of creating a predictive model that provides suitable probability of an outcome.
- *Deployment*: Predictive deployment model gives the option to deploy the result into the everyday decision making process to automate the process of results and results based on applied modelling techniques.

3.3 Predictive Model

The term predictive analytics is defined as a technique to predict the various kinds of the patterns or behaviours patterns of the massive amount of data. It is applied as predictive modelling-based systems. The basic working of predictive analytics paradigm is based on a coherent set of concepts of statistical techniques, pattern recognition and data mining algorithms [21]. It extracts a discriminatory set of information from the massive amount of data and performs the prediction and analysis of unknown data with the trained model. It predicts different types of trends and behaviour patterns of unknown data [22].

Predictive analytics is associated with the use of predictive modelling, forecasting and scoring data with predictive models. However, this term can be used to refer analytical disciplines, such as descriptive modelling and decision modelling or optimization. In statistics, a model is defined as a representative model of a relationship between variables (independent or dependent variable) in the data. The representational model illustrates how one variable or more variables are related to other variables. It also shows the changes in the behaviour patterns in the given data [23, 24]. The basic working principle of the model is a process in which an illustrative abstraction is developed from the set of observed data.

3.3.1 Predictive Model for e-Transportation

Urbanization in developing countries like India and China has led to massive population burst in their metro cities like New Delhi and Beijing. Mobility in these cities or the transport network within cities tremendously impacts both the city's and the nation's socio economic growth [25]. Due to increase in vehicles on roads, traffic congestion has become a severe problem in urban areas. Traffic congestion constrains the growth of Gross Domestic Product (GDP) of any developing country. Due to traffic congestion various problems arise such as increase in air pollution, vehicle operating costs, travelling time, etc. According to a report [26], Rs. 600 billion are lost every year due to traffic jams or delays on high volume roads and highways which also includes fuel wastage. Hence, it is obligatory that systems and algorithms be designed in such a way that people are able to avoid the traffic congestions in real time. Proposed e-Transportation system [27] is based on Global

Positioning System (GPS) enabled mobile phones which are abundantly available making the system particularly suitable for developing countries. Proposed real-time congestion avoidance method highlights prediction of the shortest route based on *k-means* Clustering of traffic data points. The proposed methodology can predict which road segments are congested or cleared through real-time GPS data. The system informs the driver about real-time traffic conditions and adjusts the route so as to avoid congestions and reduce travelling time drastically.

– ***e-Transportation Methodology***

The major objective of e-Transportation system is to identify the shortest path from the driver's current location (source) to the destination avoiding any traffic congestions in the best possible fashion. To accomplish this objective, the proposed e-Transportation system identifies road networks of a particular area using Google Maps. The system then converts the road network into a weighted graph where each intersection is denoted by a node and each edge represents a road. Based on the weighted graph, a neighbourhood metric is generated with all intersecting nodes; further applying Dijkstra's algorithm to discover the shortest path (with minimum traffic congestion) from source to destination. The proposed real-time traffic congestion avoidance system as shown in Fig. 3.2 is primarily composed of five basic steps:

(a) Fetch road map of the driver's vicinity. Assume the driver's current location is the source, and ask the user to feed in his/her destination.
(b) Identify the shortest path from source to destination in ideal condition, i.e. without traffic.
(c) Collect real-time GPS data of vehicles (through GPS-based mobile phone app) and plot the real-time traffic data onto the road map.
(d) Use the real-time traffic data attained in the previous step to create traffic clusters using *k-means Clustering* algorithm.
(e) Formulate the density of traffic clusters and identify the alternate shortest routes to avoid congestion. Reiterate the process in real time until the driver reaches the destination.

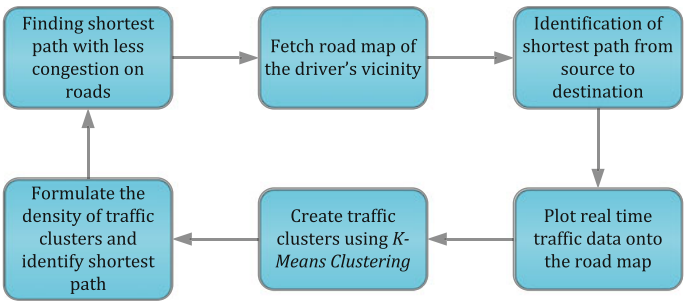

Fig. 3.2 Predictive model for finding shortest route with less traffic congestion on roads

– ***Road map to graph conversion***

The e-Transportation system fetches the road map of driver's local area from sources like Google Maps, Open Street Map, etc. The labelled map is processed using image processing techniques to fetch road map data only as shown in Fig. 3.3. The system further converts the road map image ($n \times n$ matrix) into neighbourhood matrix ($n^2 \times n^2$ matrix) where each element represents the relationship with its neighbouring pixels. This matrix represents whether a directly connected road is available or not. Weights of all directly connected nodes are initialized to 1 in the initial road network because different vehicles may pass through these road segments. The road network can be represented as a weighted graph $G = (V, E)$, where each intersection is denoted by a node V and each edge

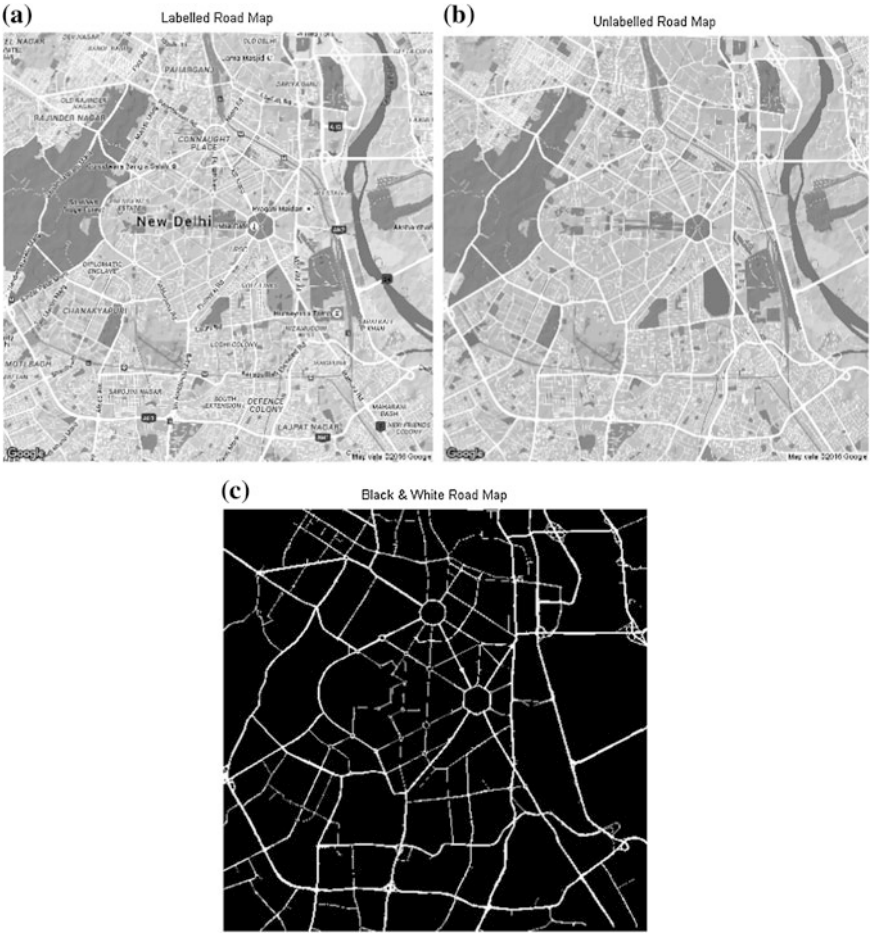

Fig. 3.3 Conversion of google road map from **a** labelled map to **b** unlabelled map to **c** *black* and *white* 2D matrix

E represents a road in the graph. When a vehicle is driven from a source S to destination D, an ordered set of roads in the route is defined as $A_i = (a_1; a_2; a_3; ...; a_n)$ where A_i represents the ith road and n is a total number of roads. According to graph theory, every route can be represented as $A_i = (e_1 \rightarrow v_1, v_2; e_2 \rightarrow v_2, v_3; \ldots; e_n \rightarrow v_n, v_{n+1})$.

– ***Traffic clustering and congestion estimation***

To get the current traffic condition of driver's local area, the system uses real-time GPS tracking of vehicle users using android application. The GPS location data transmitted by the vehicles gets collected by local clouds. The real-time data transmitted by an App includes vehicle location (longitude and latitude), speed, drive time, direction, etc. An institution-based proof of concept Android App was developed to do the same, although there are few alternative applications or services available on the internet which can be exploited to accomplish the above-mentioned tasks.

The GPS data with vehicles locations received from the application is fed into a two-dimensional problem space of size $n \times n$. The vehicle data is plotted on to driver's local road map. k-means clustering is then implemented so as to create traffic clusters with minimum Euclidean distance. Higher number of vehicle points within a cluster would then denote higher density or more congestion. Based on similarity or dissimilarity metric, clustering in N-dimensional Euclidean space is the process of partitioning a given set of N points into m clusters. Let, a set S is representing n points (n_1, n_2, n_3, ..., n_n) and m clusters be representing (a_1, a_2, a_3, ..., a_m) then (Eq. 3.1),

$$\begin{aligned} &A_i \neq \Phi \quad \text{for} \quad (i = 1, 2, 3, \ldots, m) \\ &A_i \cap A_j \quad \text{for} \quad (i = 1, 2, 3, \ldots, m); \\ &\text{Here,} \quad (j = 1, 2, 3, \ldots, m) \text{ and } i \neq j \\ &\bigcup_{i,j=1}^{m} A_i, A_j = S \end{aligned} \tag{3.1}$$

The road network is represented as neighbourhood matrix where each intersection is represented by a node and each edge represents a road segment. The initial weights are assumed to be 1, if two vertices' are directly connected with each other which represents the estimated travel time. When the GPS data is plotted on road segments to show the availability of vehicles on a particular road, the weights are updated periodically according to every vehicle available on each road segment. These updated weights are used to estimate the travel time or, to calculate the shortest path from current location to the desired destination with congestion avoidance. To estimate the travel time Greenshield's model is used. The model considers that there is a linear relationship between vehicle per metre traffic density D_i on road i and estimated road speed S_i. One can formulate this situation according to following formula (Eq. 3.2):

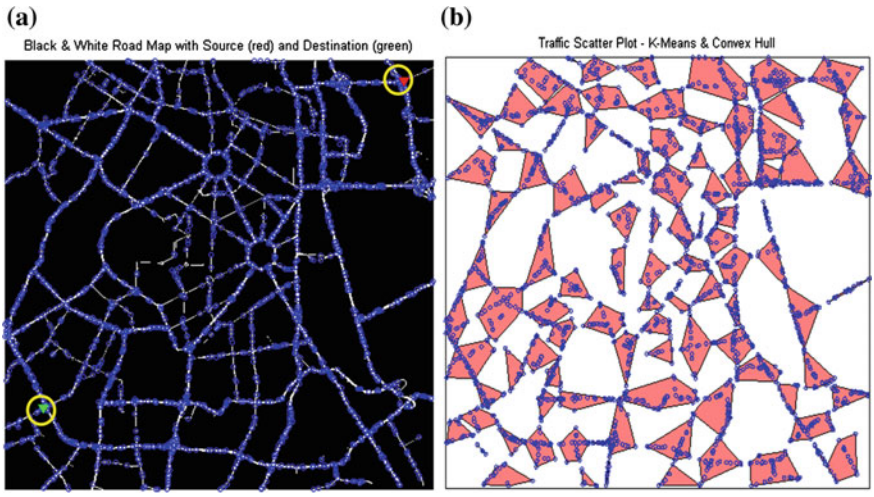

Fig. 3.4 *Red*, *green* and *blue points* on **a** *black* and *white* road map represent driver's location, destination and other vehicles, respectively **b** visualization of convex hulls for traffic clusters

$$S_i = S_j\left(1 - \frac{D_i}{D_j}\right) \tag{3.2}$$

where D_j is traffic density in jam and, S_i represents the speed flow on ith road segment (Eq. 3.3)

$$A_i = \frac{P_i}{S_i} \tag{3.3}$$

where A_i is the estimated travel time and P_i is the path length of the same road segment. Road density is calculated with Convex Hull algorithm on each identified *k-means* cluster. Dataset of vehicles available on road is provided to the algorithm to create convex hulls. Convex hulls represent the traffic congestion on particular road segment as shown in Fig. 3.4.

Now with the help of Dijkstra's algorithm, the system finds an alternate shortest path P_i' to avoid the congested roads and save travelling time. During the alternate path finding, road segments with higher weight in neighbourhood matrix are ignored to avoid the congestion and estimate the new travel time with the alternate path (Eq. 3.4).

$$A_i = \frac{P_i'}{S_i} \tag{3.4}$$

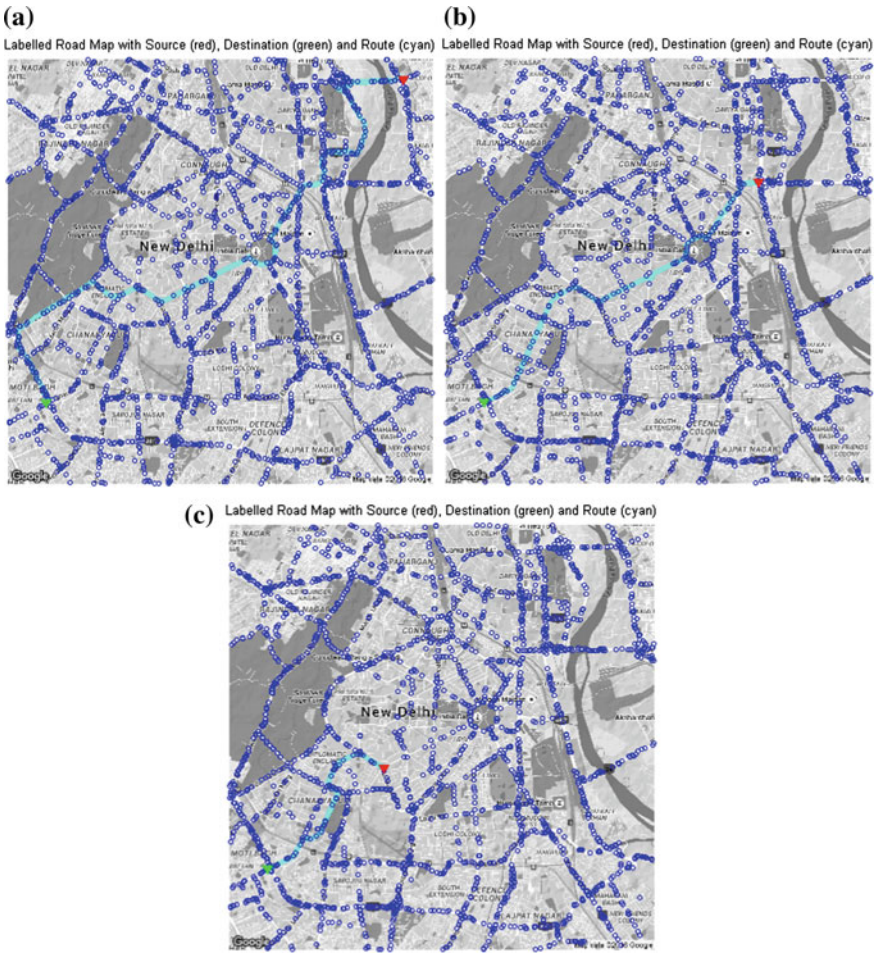

Fig. 3.5 *Red*, *green*, *blue* and *cyan points* on road map represent driver's location, destination, other vehicles and predicted path, respectively. The path changes dynamically with driver's location, starting from **a** position p_1 to **b** position p_r, and **c** position p_s

Figure 3.5 shows predicted routes from different positions p_1, p_r and p_s. As it can be seen in the figure, the routes predicted by the system are dynamic and change with traffic density on various roads from source to destination.

3.3.2 Predictive Model for Banking

In banking sectors, the predictive computing-based model predicts the customers' needs to be based on their money requirements. The predictive models extract

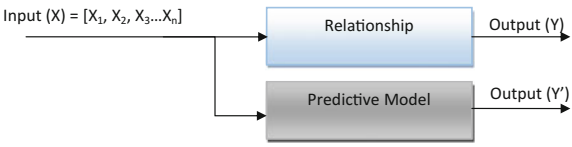

Fig. 3.6 Working of a predictive model

relevant information from customer data. It calculates the credit score, income level and requested loan amount to ascertain the basic interest rate of the loan [28].

For this work, it is required to have observational data (customer data) with the calculated credit score, loan amount, income level and interest rate of respective banks. Figure 3.6 illustrates working of a predictive model. The predictive computing model takes input from the set of observational data based on generalization techniques. Based on provided data, representative model can predict the value of the bank interest rate, based on all the input values $[X] = [X_1, X_2, X_3, \ldots, X_n]$. Here, X_1 = credit score, X_2 = income level and X_3 = loan amount, etc. In predictive computing, data mining plays a vital role in the process and building the representative model.

The predictive model works in following ways: (1) It predicts the output based on provided inputs (calculation of interest rate) and (2) It can be applied to understand the inferences and relationship between the variables (output variable and all the input variables) as shown in Fig. 3.6. Therefore, the building of predictive models based on machine learning and statistical techniques can be applied in both predictive analysis and critical applications such as e-health monitoring, security issues, resource utilization of clouds, public awareness, e-governance and diagnosis of dangerous diseases in medical fields [29, 30], etc.

3.4 Algorithms for Predictive Computing

To convert predictive model into a working machine, predictive algorithms play an important role. These algorithms are implemented on stored big data for further extraction of knowledge. In this section, we have discussed some major predictive computing algorithms, their advantages and disadvantages.

3.4.1 Local Learning and Model Fusion for Multiple Information Sources

Big data applications are mostly highlighted with independent sources, decentralized controls and systems and aggregating distributed data sources to a centralized site for mining is systematically prohibitive due to its high transmission cost and privacy concerns like issues [23, 31–33]. However, analysis and data

mining-related activities can be carried out at each distributed sites around the globe, but this activity leads to biased view of the data collected at each location [34–36]. Under such a condition, a big data mining system has to facilitate a knowledge exchange and fusion mechanism to guarantee that all shared sites or sources can work collectively and mutually to achieve a global optimization objective [23, 34, 37–39]. More specifically, the global mining can be emphasized with a two-step correlation. It is known as local mining-based correlation and global mining-based correlation process, at data, model and at knowledge levels. Further, at the data level, each local systems can determine the data statistics and relations based on the local information of given data sources [40]. At the system model or pattern level, each control site can give the local mining set of activities, on the different localized data, to discover local discriminatory patterns [36, 40–42]. At the information level, model correlation analysis investigates the relevance of models generated from various data sources to decide how important the data sources are correlated with each other, and how to form accurate determinations based on models built from independent sources.

3.4.2 Mining from Sparse, Uncertain and Incomplete Data Representation

Sparse, uncertain, complex and incomplete data are the common defining features for big data applications. If data is sparse then it becomes difficult to take an appropriate decision or reliable conclusion on few data points [23]. This issue arises because of data dimensionality and it becomes difficult to obtain a clear trend or distribution from data. General approaches to resolve these issues are to apply dimension reduction or feature selection to reduce data dimensions by including additional data samples to minimize data scarcity. Dimensional reduction techniques carefully include more additional samples to improve the data scarcity using generic unsupervised machine learning methods and pattern recognition approaches in data mining and big data analysis [43, 44].

In case, data is uncertain then it represents inaccurate data readings and collections where data fields are no longer deterministic and represents some random/error distributions. General approaches to resolve data uncertainty issue are error-aware data mining, Naïve Bayes model, etc.

Incomplete data refers to the missing of data field values for some samples. This scenario takes place because of failure or malfunctioning of a sensor node or system involved in generation of data. However, modern data mining techniques are efficient and have in-built solution like data imputation to handle with these missing values and produce more improved models.

3.5 Mathematical Modelling and Algorithms

In this section, we have discussed big data-based analytics and prediction techniques. In order to provide useful insight to the organizational data and to gain correct content, data must be processed with advanced algorithms and available tools (e.g. analytics and algorithms) for generation of meaningful information from huge data and clusters, and further classify this obtained information or data into various classes based on various interests and meaningful information provided by different customers [39, 45]. These algorithms can be divided into following subgroups.

3.5.1 Probabilistic Learning Model and Statistical Analysis

As stated earlier, uncertain data represents the major challenge in which each data item can be considered as a sample distribution and not like a single value. Therefore, the common solution is to estimate model parameters by taking data distribution into consideration. For example, error-aware data mining [40] can be used to build Naïve Bayes model by finding the mean and the variance values on each single data item. Whereas, in incomplete data, missing value can take place because of many reasons like malfunctioning of the sensor node, use of systematic policies for collection of values after regular interval of time, etc. [42, 44, 46]. Modern computing algorithms are designed in such a way that they can handle missing values efficiently. Data imputation [42, 44, 47] is also another approach designed to handle missing values and to produce improved models.

3.5.2 Fuzzy Rule-Based Expert Systems

It is considered that both model performance and interpretability are of major importance, and require efforts to keep the rule base small and comprehensible. Therefore, Computational Intelligence (CI) approaches for data mining and analysis of big data have been developed for feature selection, feature extraction, model optimization and model reduction [45, 48]. For analysis of massive amount of data, fuzzy logic-based approaches, probabilistic reasoning based, neural networks technique and a set of evolutionary algorithms play a vital role during processing and analysis of big data. These are considered as major components of CI. Each of these algorithms caters the big data committees with complementary reasoning and searching approaches to solve complex and real-world problems.

The selection of a classifier-based model system is defined as the construction of the mathematical model. The mathematical model predicts that a given pattern,

$x_k = [x_{1k}, \ldots, x_{nk}]$, in which $x_k = f_{c1}, \ldots, f_{Cg}$ class should be classified. The classic approach for this problem with C classes is based on Bayes' rule [40, 46, 49].

3.5.3 Rule Base Reduction Techniques

Mostly, algorithms are used to obtain suitable classifiers which are based on accuracy or interpretability. In recent study, some algorithms for having been reported which are designed on combining the use of these properties; fuzzy clustering is one of the approaches that can derive transparent models [13], linguistic constraints is another approach that can be are applied to fuzzy modelling and rule extraction from neural networks [9, 13, 47].

3.5.4 Recommendation Mining

Recommendation mining-based systems consider input from users' behaviour and from the provided input data. Recommendation systems try to make possible predictions about customer behaviours, their likes and dislikes, and how much attention they have given for each attractive class of advertisements [23, 48].

3.6 Clustering Algorithms

The clustering algorithms are used to design the different clusters of the user or customer interest's on the basis of provided inputs to the recommendation systems or recommendation mining systems [23].

The clustering is a simple approach for grouping a set of objects into classes of similar objects or items. In general, the definition of similarity varies from one clustering model to another. In most of the cases of these models, the concept of similarity has been measured based on various distances such as Euclidean distance or cosine distance. The major objective of data clustering techniques is to arrange a set of n objects into k clusters such that objects in the same cluster are cohesive in nature than objects in different clusters. Therefore, clustering is one of the most popular tools for data exploration and data organization [49]. There are following basic requirements for clustering algorithm to assign any group of similar data items or objects:

- An algorithm
- Similarity and dissimilarity criterions
- A stopping condition

There are various types of the clustering algorithm in data mining that can be used for predictive computing, few of them are explained below.

3.6.1 k-Means Clustering

This clustering technique is categorized under unsupervised learning algorithms. Here, dataset can be classified into different clusters, say k clusters. The major objective is to define or find k centers randomly. A method for finding these k centers might be ad hoc or cunning in nature. It is because by changing the location of k centers will impact on result accordingly. That's why these k centers must be placed far away from each other [49]. In further step, a data point is selected from the dataset and associate to the nearest center. When no point is left, and an early grouping is done [23], k new centroids must be recalculated from the resulting cluster of the previous step. Finally, the squared error function represented by using this algorithm (Eq. 3.5):

$$J(V) = \sum_{i=1}^{c} \sum_{j=1}^{c_i} \left\| x_i - v_j \right\|^2 \tag{3.5}$$

where '$\|x_i - v_j\|$' represents the Euclidean distance, c_i represents the number of data points in ith cluster and c represents the number of cluster centers.

3.6.2 Centroid Generation Using Canopy Clustering

It is also an unsupervised clustering algorithm, often used as preprocessing step for the k-means algorithm or the Hierarchical clustering algorithm. It speeds up the clustering operations on large data sets, whereby the other algorithms may be impractical due to the size of the data sets [50, 51].

3.6.3 Fuzzy k-Means Clustering Technique

As discussed in k-means clustering, on the basis of feature of vector x these clusters can be categorized as 'hard' or 'crisp' clusters. It is because vector x may or may not belong to particular cluster, whereas in fuzzy k-means these clusters are categorized into 'soft' or 'fuzzy' clusters, where feature vector x can have a degree of membership in each cluster [52].

3.7 Classification Algorithms

The classification algorithms classify various provided input to the recommendation systems that learn from existing labelled or categorized documents. The working of classification is based on supervised learning approaches and classifies what documents of a specific category look alike and can assign unlabelled documents to the correct category [52].

The main objective of classification approaches is to classify the labelled unseen documents; therefore, the classification approaches perform the work for grouping the different items with same labelled and together. The classification approaches are the basic machine learning approaches to provide an efficient way for computers to make decisions based on experience and, in the process, emulate certain forms of human decision making. The classification techniques are divided into two groups (1) supervised classification technique and (2) unsupervised classification technique [52]. Table 3.1 illustrates the differences between supervised learning and unsupervised learning-based approaches for the classification.

Various classification algorithms are:

1. Naïve Bayesian [52–54]
2. Complementary Naïve Bayesian [53]
3. Stochastic Gradient Descent (SDG) [55]
4. Random Forest [53]
5. Support Vector Machine [56]

3.8 Summary

In this chapter, we have illustrated the use of predictive computing techniques for predicting the outputs of the massive amount of data. We have described the predictive models for e-Transportation and for the banking sector. e-Transportation is sufficient to predict the shortest route with less traffic congestion on roads. In the current state-of-the-art methods, different organizations in every industry are developing new sensing devices to sense massive big data, as well as to develop analytic computational models and platforms that can help to synthesize the traditional structured data with semi-structured and unstructured sources of information. When

Table 3.1 Differences between supervised and unsupervised machine learning-based approaches

Supervised learning	Unsupervised learning
– Use training data to infer model – Apply model to test data – e.g. Maximum likelihood, perceptron, SVM [52]	– No training data – Model inference and application – Both rely on test data exclusively – e.g. k-means

properly used, predictive computing can provide unique insights into market trends, equipment failures, buying patterns, healthcare, maintenance cycles and many other business issues, lowering costs and enabling more targeted business decisions.

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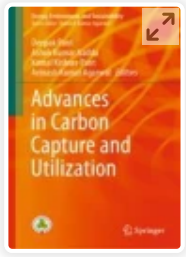

Advances in Carbon Capture and Utilization pp 297–312

Progresses in Bioenergy Generation from CO_2: Mitigating the Climate Change

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Abstract

In these days, the interest in vitality has quickly expanded a direct result of the monetary development around the world.

Tanvi Sharma, Reva Bhardwaj and Rupali Bhardwaj have equal contribution to this manuscript.

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Chapter 13
Progresses in Bioenergy Generation from CO_2: Mitigating the Climate Change



Tanvi Sharma, Reva Bhardwaj, Rupali Bhardwaj, Anand Giri, Deepak Pant, and Ashok Kumar Nadda

13.1 Introduction

These days, the interest in the clean energy generation has been quickly expanded as a direct result of the monetary development around the world. To fulfill this developing need, a bounteous measure of non-renewable energy sources is required (Giri et al. 2020; Leung et al. 2014). The depletion of non-renewable energy sources is frequently considered as one of the dangers to nature in context of the carbon dioxide (CO_2) discharge. CO_2 is primary green house gas (GHG), present on the land surface, sea, and environment where animals, plants, and microorganisms, assimilates and produces it every day (Kapoor et al. 2020; Spigarelli and Kawatra 2013). Notwithstanding, the pattern of discharging and expending CO_2 must be adjusted essentially. To diminish the GHGs, CO_2 sequestration and conversion capacity has increased to a great extent. In any case, we must develop the techniques and measures for capturing the CO_2 as a feedstock. In this way, using CO_2 and converting it into synthetic substances, will be useful to mitigate the CO_2 emission (Peters et al. 2009). During the recent years, the transformation of CO_2 into value-added synthetic compounds utilizing various methods are getting an incredible consideration from the researchers as it results in reducing the harmful GHGs (Kumar et al. 2019; Sharma

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et al. 2020a, b). So, we need to find alternatives that uses the CO_2 present in the atmosphere and converts it into valuable products (Sharma and Kumar 2021). Methanol is one of the important product that can be made from CO_2. Methanol does not emit extra CO_2 into the atmosphere, and it has high volumetric and gravimetric energy density and is a very important fuel that is replacing the use of fossil fuels (Patterson et al. 2019). Its prime benefit is to reduce greenhouse gas emissions from vehicles. It has the highest hydrogen to carbon ratio in comparison with any liquid fuel and can be readily degraded in both aerobic and anaerobic environments. Methanol has the potential to reduce carbon emissions by 65–95%. It is highly versatile in making everyday products, and it is efficiently combustible, easily distributed, and widely available, making it affordable to use. Out of the total energy consumption of the world, 49% of it is met by fuels like gasoline, diesel, jetoils, etc. (Lewis and Nocera 2006). As compared to conventional fuels, its benefits are high as compared to gasoline and diesel. Recently, indeed, the various industries across the globe are using methanol as a crude material for making various items. Methanol is utilized in the production of solvents such as the acids. It can also be utilized in direct methanol powered devices which are utilized for the transformation reactions in the industries (Fig. 13.1). Methanol is viewed as the significant natural feedstocks that are utilized in businesses with a yearly production of 65 million tons around the world (Dalena et al. 2018). Various aspects of conversion of carbon dioxide to bioenergy based

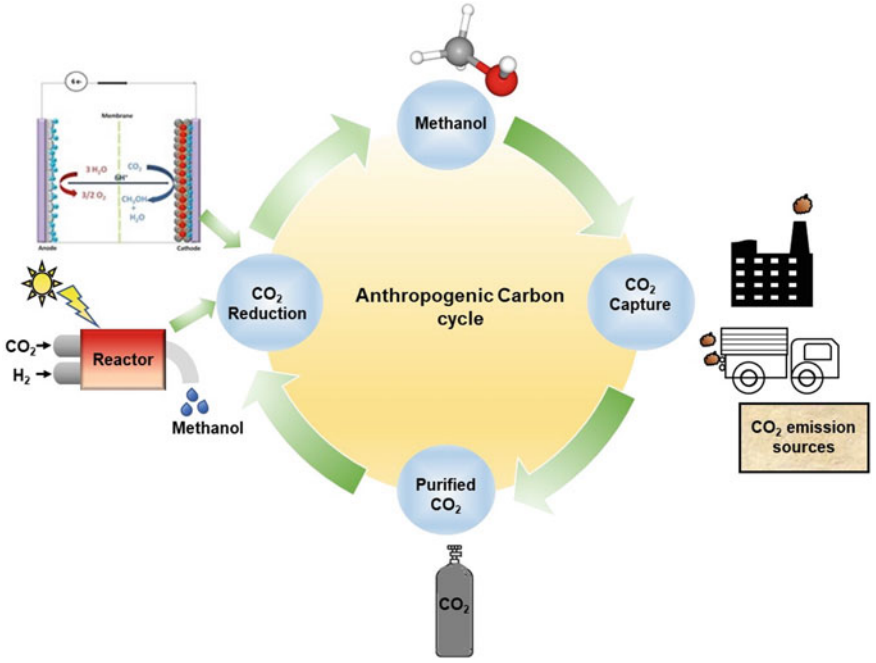

Fig. 13.1 Description of the anthropogenic carbon cycle for the production of methanol

products such as methanol and fixation of CO_2 using microbes and other biological entities have been discussed in this chapter.

13.2 Conversion of CO_2 into Methanol by Chemical Methods

The methanol production from direct hydrogenation of CO_2 is an attractive strategy, as this process has several advantages such as it requires less energy for product purification and fewer by-products formation. CO_2 can be valorized through hydrogenation, focusing on reverse water–gas shift reaction (RWGS), methanation, and methanol production (Gutterød et al. 2020). In literature, various metal organic frameworks have been reported for the CO_2 capture, and they have great potential to convert the atmospheric CO_2 in heterogeneous catalytic system. The methanol synthesis from CO_2 hydrogenation and RWGS is a thermodynamically limited reaction, and equilibrium conversion of CO_2 decreases with increasing reaction temperature; therefore, it needs a catalytic system (Kaisar and Sreedevi 2018). Methanol is also prepared by the hydrogenation of carbon dioxide by reverse water–gas shift reaction. The catalyst used is $Ni/Al_{12}O_{19,}$ and this process is largely used in an industrial scale (Samimi and Rahimpour 2019). Lately, it has been observed that indium oxide is a highly selective catalyst in the thermal hydrogenation of CO_2 to methanol, and hydrogenation of CO_2 to methanol is being carried out commercially using heterogeneous CuZnO supported on Al_2O_3 (Chun 2020). Methanol formed by carbon dioxide via catalytic CO_2 hydrogenation is efficient for storing energy and CO_2 capture. Methanol thus formed has a neutral carbon footprint and is a clean source of energy.

In the European Union, a pilot plant was built by the MefCO_2 project that produces 500 tons of methanol per year (Bowker 2019). In Iceland, CRI has a commercial plant that has 4000 metric tons per year of methanol production capacity. They utilize this renewable methanol for bio-diesel production, automobiles, and the production of synthetic material (Olah 2013). Nonetheless, the heterogeneous catalyst has numerous focal points regarding partition, strength, taking care of, cost, and reusing of the catalyst.

13.2.1 Heterogeneous Catalytic Method

Heterogeneous catalysts for conversion of CO_2 to methanol are widely used for the industrial purposes. It generally involves the rapid separation of fluid from the solid catalyst, and the catalyst that is used can be again produced (Table 13.1). Among heterogeneous catalysts, $Cu/ZnO/ZrO_2$ have been mostly studied due to their high selectivity and conversion rate. In this catalyst, ZnO increases the Cu dispersion and

Table 13.1 Various methods for conversion of CO_2 into methanol

S. No.	Methods	Catalysts/Photocatalysts/Electrode	Comments	References
1	Heterogenous	Cu ZnO ZrO_2	High selectivity and conversion rate	Zhong et al. (2020)
2	Homogenous	$Ru_3(CO)_{12}$ $MO(CO)_6$ $Rh(CO)_{12}$ $CO_2(CO)_8$	Involves rapid separation of methanol and recycling of catalyst.	Kothandaraman et al. (2016)
3	Electrochemical	Cu Fe Mo Pt Hg	Cu is considered as a more promising electrode, utilized in conversion of CO_2 into methanol and other value-added products	Albo et al. (2015)
4	Photochemical	CdS/TiO_2 Bi_2S_3/TiO_2	Reduction of CO_2 into methanol using visible light	Gondal et al. (2013)

both ZnO and ZrO_2 improve the stability and CO_2 absorption capacity. The incorporation of metal oxides such as Ga_2O_3, Al_2O_3, MgO, SiO_2, and La_2O_3 enhances the activity and modifies the redox properties (Zhong et al. 2020). Various companies such as Sinetix, HaldorTopsoe, and Mitsubishi Gas Chemical are producing a highly stable catalyst for the production of methanol (Al-Saydeh and Zaidi 2018).

13.2.2 Homogenous Catalytic Method

Different types of homogeneous catalysts are also being used for the conversion of CO_2 into valuable compounds (Table 13.1). The catalysts for CO_2 conversion are available in the form of metal complexes, organic solvents, and ionic solvents (Zarandi et al. 2019). Referring to different studies, it has been observed that some basic heterocyclic organic compounds like pyrimidine elevate the CO_2 reduction

reaction and its conversion as compared to other heterogeneous catalysts. Recently, it is observed that basic heterocyclic organic compounds like pyrimidine increase the reduction reaction of CO_2 conversion as compared to other homogeneous catalysts (Albo et al. 2015). A distinctive heterogeneous catalyst was tried for immediate CO_2 conversion into methanol. In a previous study, $Ru_3(CO)_{12}$ catalyst in the presence of potassium iodide was studied for the hydrogenation of CO_2 to CH_3, CH_4, and methanol (Tominaga et al. 1993). Furthermore, it was reported that $Ru_3(CO)_{12}KI$ was better for CO_2 conversion than another metal carbonyl including $Fe_2(CO)_9$, $Mo(Co)_6$, $Rh_4(CO)_{12}$, $W(CO)_6$ and $Co_2(CO)_8$ (Huff and Sanford 2011; Tominaga et al. 1993). Kothandaraman et al. (2016) firstly captured CO_2 directly from the air and converted it into methanol. In this process, Ru-based catalyst and polyamine were used for methanol production. After CO_2 conversion, methanol was separated and the catalyst was recycled to produce more methanol.

13.2.3 Electrochemical Reduction of CO_2 to Methanol

The electrochemical reduction method attracted the interest of the researcher which is eco-friendly and has economic benefits. This process is simple and can be used under ambient conditions (Zarandi et al. 2019). The electrochemical strategy is utilized for CO_2 conversion to important synthetic compounds, for example, methanol by utilizing electricity as the energy source. In this method, electric energy is applied to create a potential between two electrodes to transform CO_2 into reduced form (Yaashikaa et al. 2019). Reduced chemical species are obtained after the electrocatalytic CO_2 reduction reaction (Fig. 13.2). The electrolytes used in these reactions affect the reduction of CO_2. Solvents used also play a key role in maintaining pH, conductivity, and toxicity. Various experiments have been reported for CO_2 conversion on the terminals of metal (Kuhl et al. 2014). Various metal electrodes such as copper, ruthenium, molybdenum, titanium, iron, mercury, and platinum have been studied for electrochemical reduction of CO_2, but among them, copper (Cu) is one of the most promising electrodes (Albo et al. 2015).

The hydrogen evolution reaction (HER) is significant in the CO_2 electrocatalyst reduction in which water presents as an electrolyte. Consequently, the reported metals that have been utilized as electrocatalyst in CO_2 reduction should have moderately greater HER (Goeppert et al. 2014). In a previous study, it was found that methanol production rate was 1.2×10^{-4} $molm^{-2}$ s^{-1} on electrodeposited cuprous thin-film electrodes in potassium carbonate solution (Le et al. 2011). Moreover, MoS_2-rods/TiO_2 nanotubes electrodes were reported for electrochemical CO_2 reduction and found that CH_3OH yield reached 202.2 mgL^{-1} at 6 h (Li et al. 2014). Qu et al. (2005) reported the RuO_2/TiO_2 nanotubes and nanoparticles for the methanol production and showed 60.5% CO_2 conversion efficiency. Wu et al. (2019) revealed that when a cobalt phthalocyanine was dispersed on carbon nanotubes, it has high selectivity and catalytic activity for the electrochemical CO_2 reduction to methanol. Modification is done in electrocatalysts to increase the reduction efficiency and increase

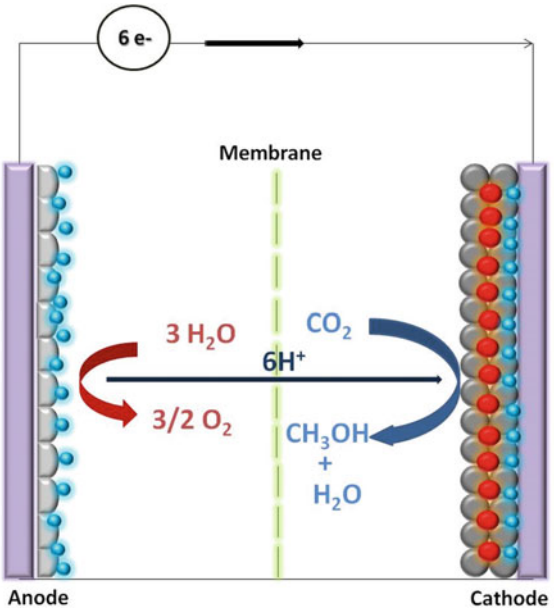

Fig. 13.2 Schematic representation of electrochemical system for the conversion of CO_2 into methanol

the faradaic efficiency. Recently, the catalysts are being modified and designed to control the dimensions of nanoparticles showing a mono-dispersive configuration (Zarandi et al. 2019). In most recent years, electrochemical CO_2 transformation is broadly utilized in a research field; however, it has not been effectively utilized in mechanical procedures.

13.2.4 Photochemical Reduction of CO_2 to Methanol

Normally, this CO_2 transformation technique is utilized to convert captured CO_2 to methanol and other value-added products by utilizing sunlight, (Fan et al. 2013) (Table 13.1). Nowadays, this technique has attracted the interest of people and is being considered as one of the most appealing strategies for the utilization of CO_2. The photocatalytic CO_2 transformation process is a blend of photochemical and photophysical procedures together (Gondal et al. 2013). Although this strategy has a few resemblances with electrolytic CO_2 reduction in both these methods, molecular catalyst is used. Various experiments have shown the ability of metal oxides and semiconductors such as titanium dioxide, silicon carbide, zinc oxide, and tungsten trioxide, for the conversion of CO_2 to methanol (Zhang et al. 2019). Li et al. (2012) proved that CdS/TiO_2 and Bi_2S_3/TiO_2 are promising photocatalysts to reduce CO_2 into methanol using visible light. The methanol production efficiency of TNTs-Bi_2S_3 and TNTs-Bi_2S_3 was 224.6 μmol/L and 159.5 μmol/L, respectively. In another study, the ability of Nd/TiO_2 synthesized by the sol–gel method was studied, and they found

that the maximum methanol production yield was 184.8 μmol/g for 8 h (Luo et al. 2009). The main drawback of CO_2 reduction to methanol using the photochemical method is that the reaction is reversible. Thus, to alleviate the methanol oxidation, it is important to find new methods so it can be applied to the industrial level too.

13.2.5 MOF for CO_2 Reduction

Various classes of a porous material including zeolites, porous organic polymers, porous carbons, covalent organic frameworks (COFs), and metal–organic frameworks (MOFs) have been reported for CO_2 capture (Ding et al. 2019). Recently, MOFs are emerging out as a new class of crystalline materials due to their unique features such as large surface area, crystalline nature, handy pore structure, and chemical tunability (Fig. 13.3) (Maina et al. 2017). Debatin et al. (2010) synthesized zinc-imidazolate-4-amide-5-imidate framework, and CO_2 uptake capacity of these MOF was found to be 2.1 mmol g^{1}at 1 bar and 298 K. Furthermore, MOFs incorporated with nanoparticles, metal oxides, and other catalytically active species have also been studied for CO_2 conversion. As an example, Ag NPs were impregnated into the cavities of MIL-101 by a liquid impregnation–reduction method. The resultant Ag@MIL-101 materials had excellent catalytic activity (96.5%) and stability

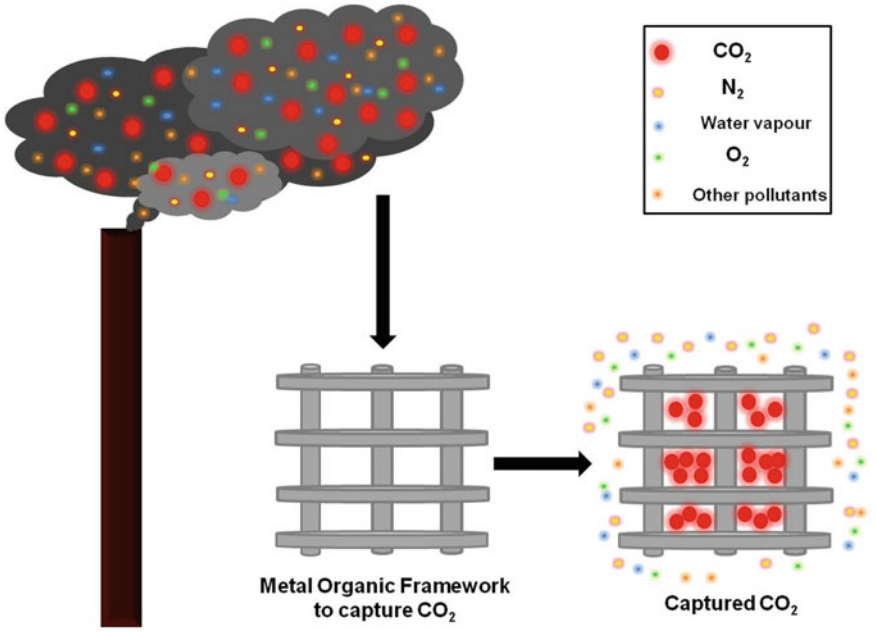

Fig. 13.3 Metal organic framework (MOF) for the CO_2 capture and conversion

at 50 °C (Liu et al. 2015 Sharma et al. 2018). Gutterød et al. (2020) studied the role of the platinum nanoparticles impregnated in ZR-based UiO-67 MOF in the hydrogenation of CO_2 into methanol using a kinetic analysis. In the resultant MOF, methanol was formed at the interface of platinum nanoparticles and linker-deficient Zr_6O_8 nodes.

13.3 Use of Biological Systems for CO_2 Capture and Utilization

Various photosynthetic microbes such as algae and bacteria can assimilate CO_2 (Table 13.2). Moreover, some of the autotrophic bacteria were also studied for utilizing CO_2. The most important advantage of microbial CO_2 conversion is the natural ability of microbes to take up CO_2 through their metabolic pathways. The CO_2 fixing routes have been developed through enzymatic processing of CO_2 by formulating C–H, C–O, and C–C bonds cleavage (Ramsey et al. 2009). The most commonly used pathways for CO_2 reduction are pentose phosphate, citric acid cycle (Peters et al. 2011). Furthermore, various microbial enzymes have been utilized for the conversion of CO_2. The direct use of microbes is affected by environmental factors, low product yield, and growth. In this context, protein engineering and synthetic biology are ideal methods for engineering the microbes, and thus making the process economically viable.

Table 13.2 Biological agents involved in conversion of CO_2

Class	Species	Comments	References
Algae	*Nannachlorissp* *Chlorella vulgaris* *Chlamydomonas reinhardtti* *Scendesmusquadricauda*	High photosynthesis rate Rapid reproduction rate	Pavlik et al. (2017); Sharma et al. (2020a, b)
Bacteria	*Clostridumaceticum* *Clostridium kluyveri* *Clostridium ljungdahli* *Acetobacteriumkloodii*	*Clostridium*is considered best for CO_2 fixation and having numerous biotechnological applications Assorted pathway for creation of metabolites Resistance to poisonous metabolites and substrates	Jajesniak et al. 2014
Yeast	*Saccharomyces cerevisiae*	Involved in CO_2 fixation	Zelle et al. 2008

13.3.1 Algae for CO_2 Fixation

Algae are present throughout the world and one of the most commonly researched organisms for CO_2 fixation. Algae can be found in freshwater–water or marine ecosystems individually or in a form of chains. They lack stems, leaves, or roots and have a vast range of sizes. CO_2 is utilized as a carbon source by them for photoautotrophic growth and produces over half of the atmospheric oxygen (Shi and Theg 2013). As algae use the CO_2 by the Calvin–Benson pathway and convert the inorganic carbon to organic compounds. One molecule of phosphoglycerate is diverted to focal on pathways of metabolic activity, while the other is used in the continuation of the cycle. The key enzyme for carboxylation of CO_2 is RuBisCO, and it has a high affinity for CO_2 and O_2. So, it creates a problem in an environment because of the high O_2 affinity and low fixations present in the atmosphere. Algae possess three significant constituents of CCM including dynamic bicarbonate take-up transporters, a set of carbonic anhydrases (CAs), and a subcellular small-scale compartment inside which most of RuBisCO is found. Furthermore, micro and macroalgae can fix inorganic carbon effectively. Various algal species, such as *Nannochlorissp., Scenedesmus quadricauda, Chlorella vulgaris*, *Nannochloropsis sp.*, and *Chlamydomonas reinhardtii*, have been studied to CO_2 fixation (Pavlik et al. 2017). Microalgae have a high photosynthesis rate due to their small size, rapid reproduction rate, and synthesis of oil, pigment, etc., because of its complex metabolic reactions. Hence, making microalgae is highly efficient for converting carbon dioxide (Yen et al. 2013). *Chlamydomonas reinhardtii* and *Volvox carteri* have been genetically engineered for increasing the CO_2 fixation efficiency (Beer et al. 2009; Walker et al. 2005). To improve the CO_2 fixation efficiency of algae species, screening and domestication would be major promising strategies.

13.3.2 Bacteria for CO_2 Fixation

Various carbon-capturing bacteria are *Acetobacterium woodii, Clostridium aceticum, Clostridium kluyveri, Clostridium ljungdahlii, Rhodopseudomonas palustris, Rhodococcus erythropolis, Ralstonia eutropha, Synecococcus elongatus, Rhodobacter sphaeroides,* etc. (Jajesniak et al. 2014). Among various bacteria reported for CO_2 fixation, *Clostridium* fixes CO_2 using the Wood–Ljungdahl pathway. They are anaerobic and gram-positive microbes, but their cultivation is difficult and expensive because of its obligate nature (Tracy et al. 2012). Numerous strains in the *Clostridium* class can fix CO_2, as a carbon source. *Clostridia* shows numerous attractive attributes for biotechnological applications such as the capacity to use a wide range of carbon substrates, assorted pathways for the creation of helpful metabolites, and resistance to poisonous metabolites and substrates (Durre and Eikmanns 2015). Typical environmental condition is normally deadly to most of its species.

Early work with *Clostridium* concentrated mostly on the creation of acidic corrosive and related items. In any case, the collection of hereditary material relevant to *Clostridia* has altogether extended after the improvement of plasmid DNA innovations and chromosomal control advances. The utilization of the portable gathering II introns for focused quality disturbance (Targetron or ClosTron) is well known for the hereditary building of *Clostridium*. The utilization of ClosTron was shown by designing *Clostridium acetobutylicum* for butanol–ethanol formation (Cooksley et al. 2012). Moreover, in the cyanobacterium *Synochococcus elongates the* carbon assimilation mechanism was studied, and it produces 2,3-butanediol from CO_2 and glucose in dark (Kanno et al. 2017). Furthermore, the various microbial enzymes has been used for the conversion of CO_2. Formate dehydrogenase enzyme is a good biological catalyst known for its reversible reduction of CO_2 (Ruiz-Valencia et al. 2020). Another enzyme used for the conversion of CO_2 is carbonic anhydrase. It is present in various organisms like eubacteria, vertebrates, algae, archaea, plants, and animals (Moroney and Ynalvez 2007; Sharma and Kumar 2020). This enzyme is efficient in capturing CO_2 in a cost-effective and eco-friendly manner as raw materials such as metal oxide ores, industrial waste, and marble mines are easily available (Bhagat et al. 2018). In recent study, carbonic anhydrase immobilized onto electrospun nanofiber is used for the conversion of CO_2 into bicarbonates, and the bicarbonate solution formed was utilized for microalgae growth (Jun et al. 2020). Moreover, an organic procedure for CH_4 formation from CO_2 is named as biogenic methane. Nitrogenase is an ATP-dependent enzyme that carries out the multi-electron reduction of an inert molecule. Fixen et al. (2016) expressed nitrogenase enzyme in an anoxygenic phototroph of *Rhodopseudomonas palustris* and found that it is capable of CO_2 reduction to methane in the presence of light under in vivo condition.

In another study, Zhang et al. (2013) expressed phosphoribulokinase (PRK) with ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO) in *E. coli* and converted CO_2 into a fermentation product. Microbes can be used as biocatalysts for converting CO_2 into useful products. They can be used in microbial electrochemical technologies using these biocatalysts in electrochemical cells to supply or gain electrons from various biochemical reactions that utilize CO_2 as a carbon source for the production of fuels and other products. Worldwide attempts are being made to convert methane into methanol using CO_2 as a source; due to the increase in production of methanol, its price is also decreasing and has got equal to the price of glucose (Antoniewicz 2019).

13.3.3 Yeast for CO_2 Fixation

As compared to *E. coli*, *Saccharomyces cerevisiae* has pulled in less consideration as a potential answer for anthropogenic CO_2 emanation (Guadalupe-Medina et al. 2013). To acquire a critical number of useful RuBisCO units, co-articulation of *E. coli* protein collapsing chaperones GroEL and GroES was essential. The created framework was described by a 90% decrease in the side effect glycerol development

and a 10% expansion in ethanol production, for a sugar-constrained culture (Natesh et al. 2018). Another pertinent model is the improved creation of malic corrosive in *S. cerevisiae* by building a CO_2 focusing pathway that returns through the carboxylation of pyruvate (Zelle et al. 2008).

13.4 Bio-based Products from CO_2

13.4.1 Bioplastics

Many bacteria are capable of converting CO_2 into eco-friendly plastic, i.e, polyhydroxybutyrate (PHB) using sunlight. PHB is a biodegradable as well as biocompatible, thermoplastic as comparable to petrochemically inferred polypropylene (Markl et al. 2018). *Cupriavidusnecator* is a gram-negative facultative hydrogen oxidizing bacterium; it produces single cell proteins and polyhydroxybutyrate (PHB) depending on the supply of nutrients. It can be converted into valuable products like crotonic acid and other fuels (Yu 2018). This bacterium was cultured on a mixture of gases like hydrogen, oxygen, and carbon dioxide. *C. necator* fixes CO_2 under aerobic conditions using the Calvin–Benson–Bassham cycle and has more CO_2 fixing capacity as compared to green algae. It grows on glucose and glycerol under aerobic conditions (Shimizu et al. 2015). There are certain pathways for converting inorganic CO_2 into its organic form. This has instigated an impressive enthusiasm for the business creation of this polymer. PHB is appropriate for use as nourishment bundling material taking into account its protection from water and UV radiation and its impermeability to O_2. Additionally, it is being applied in careful stitches. Significantly, PHB can be prepared to utilize previous advances and in blend with other manufactured polymers (Mozumder et al. 2015).

13.4.2 Bio-alcohol

The use of CO_2 to synthesize bio-alcohols have concentrated on ethanol using microbial genera such as *Rhodobacter spp.* The utilization of ethanol as a substitution for ordinary gas is tested by the fact that ethanol has short half life, low vitality, and is destructive to current motor and fuel foundation (Costa et al. 2015). Further, it promptly assimilates the water and weakening in the capacity tank. The natural synthesis of isopropanol is possible using microbial systems. Similarly, it can be used to esterify fat and oil for bio-diesel production, which diminishes its propensity to take the shape at decreasing temperatures.

13.4.3 Bio-diesel

Because of their high lipid contents and simplicity of development, the bio-diesel is used as non-inexhaustible oil-based fuel. Lipids, as triacylglycerides (TAGs), commonly provide the energy to the living cells. Once removed, the lipid can be changed into unsaturated fatty acid methyl esters (FAME) or bio-diesel through transesterification (Sharma et al. 2012; Sharma et al. 2019). The physical attributes of FAME are like those of fossil fuels. Critically, it is non-poisonous and also biodegradable. The utilization of bio-diesel as a low-mix part in the vehicle fuel does not require any progressions in the framework.

13.5 Conclusion

Carbon dioxide transformation is introducing both a chance and a test widely for the supportability of conditions. The fundamental systems of CO_2 mitigation should concentrate on the use of CO_2, reusing CO_2 with the sustainable methods. In this way, the change of CO_2 into synthetic products for example, methanol will expend an enormous conversion of captured CO_2 where the market size of methanol is possibly broad. Moreover, the synthesized methanol can be utilized rather than the non-renewable energy source, accordingly lessening the reliance on petroleum based derivative and contributing to the market development of CO_2 use. Thus, the various strategies for CO_2 transformation into methanol have been accounted in this chapter. This incorporates homogeneous/heterogeneous catalysts, electrochemical, and photochemical based methods. In any case, the superior in the CO_2 transformation procedure can be accomplished by utilizing a successful impetus. The poor item selectivity and the low/high response temperatures are viewed as the primary boundaries in the heterogeneous CO_2 conversion process. The above findings showed that among different strategies proposed for CO_2 transformation to methanol or to other value added products, the electrochemical cells are ideal over various other techniques. Also, photochemical procedures offer an appealing way to convert CO_2 to methanol utilizing sun-based energy. In future, more techniques should be discovered which use the principles of green chemistry and convert more CO_2 into methanol rather than emitting other hazardous by-products. The techniques should be cost effective and should be implanted on large scale in an environment friendly manner.

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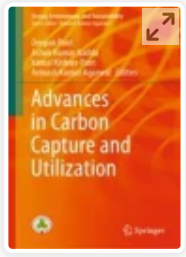

Advances in Carbon Capture and Utilization pp 313–326

Recent Advances in Enzymatic Conversion of Carbon Dioxide into Value-Added Product

Anand Giri, Suman Chauhan, Tanvi Sharma, Ashok Nadda & Deepak Pant

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Abstract

Nowadays, climate change and global warming are major environmental issue due to continuous increase to atmospheric carbon dioxide concentration and vast growth in industrialization (Yaashikaa et al. in J CO_2 Utiliz 33:131–147, 2019).

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Chapter 14
Recent Advances in Enzymatic Conversion of Carbon Dioxide into Value-Added Product



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14.1 Introduction

Nowadays, climate change and global warming are major environmental issue due to continuous increase to atmospheric carbon dioxide concentration and vast growth in industrialization (Yaashikaa et al. 2019). Due to extensive deforestation, agriculture, population growth, rapid industrialization, the current overall concentration of atmospheric CO_2 is 400 ppm as compared to preindustrial level 280 ppm (Giri and Pant 2018) so requires to minimizing of atmospheric CO_2. Carbon dioxide (CO_2) capture, sequestration, and utilization process has been widely recognized effective techniques for reducing CO_2 concentration from the atmosphere. IPCC estimated in 2001 the global average annual mean surface air temperature which is increased between 1.4 and 5.8 °C till 2100. This rise in temperature has been causing global warming, and other climatic changes like in 2006 Australia faced extreme drought of in 1000 years (https://www.theguardian.com/world/2006/nov/08/australia.drought), deadly dust storms in India in May, 2018 (Sarkar et al. 2019), deadliest hurricanes in U.S. (Great Galveston hurricane in 1900, Okeechobee hurricane in 1928, hurricane Katrina in 2005) , forest fire, sea level rise, tsunami, etc., are the main consequences of global climate change (Pant et al. 2017). Currently, different technologies have been used for CO_2 capture and storage (CCS) by carbon capture, transportation, and storage which are main three steps (Huntley and Redalje 2007). The rise in CO_2

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levels in the atmosphere could also minimize by transformation of carbon dioxide into value-added products by different physical, chemical, electrochemical, photochemical, and biological or enzymatic methods. The biological or enzymatic method provides an environmentally friendly and promising way for effective CO_2 conversion or fixation due to high stereo-specificity and chemo-selectivity of enzyme (Shi et al. 2015; Giri et al. 2020; Sharma et al. 2020), while all methods mentioned above have some major drawbacks of these include: large investment and high energy input, high transportation cost, reusability, and environmental toxicity (Irfan et al. 2019). Strategies for CO_2 conversion or fixation by enzymatic method to value-added products not only offer promising new technologies for carbon dioxide reduction but also for an efficient production of value-added products. Enzymes catalyze the biotransformation CO_2 at moderate reaction conditions (temperature, pressure, less require energy) and provide high yield than other transformation methods. This enzymatic transformation of CO_2has attracted increasing international interest for its industrial applications and its capability to turning this greenhouse gas into added value products (Long et al. 2017). The molecule of carbon dioxide shows chemically inert and thermodynamically stable, and some external energy requires an energy input for CO_2 transformation; thus, it would be reasonable to think about suitable enzymatic catalyst as energy sources for CO_2 conversion. The biotransformation of carbon dioxide by enzymatic method is currently under investigation worldwide in various aspects like fuel production of biofuels along with different value-added products and chemicals (methane, organic acids, bicarbonate, glucose, alcohols, etc.) (Yaashikaa et al. 2019).In short, today, it is an urgent need to reduce the rising atmospheric carbon dioxide from the environment and emphasis on green and renewable energy to decrease dependency on conventional fossil fuels. In regards to industrial application, an enzyme system for CO_2 biotransformation simply chooses a potential for carbon dioxide conversion into useful chemicals and fuels for sustainable and clean environment. Finally, the present book chapter mainly focused on enzymatic transformation of CO_2, as well as the future perspectives.

14.2 Enzymatic Transformation of CO_2

Enzymatic CO_2 transformation can be categorized into two types: direct and indirect transformation of carbon dioxide. They are addressed further in the following in more detail.

14.2.1 Indirect Transformation of CO_2

Indirect transformations of CO_2 involve indirectly utilization of carbon dioxide to produce useful chemicals are discussed below. Photosynthesis is one of indirect transformation of CO_2 through microbial transformation or through plant bio-fixation.

14.2.1.1 Natural Transformation of CO_2 in Cells

In natural, CO_2 fixation/ transformation into organic materials are important for biological evolution and essential factor for regulating atmospheric CO_2 concentrations (Fuchs 2011; Shi et al. 2015). The carbon dioxide (CO_2) assimilation into organic matter is facilitated by major six CO_2-fixing pathways including the reductive pentose phosphate cycle (Benson–Calvin cycle), the reductive citric acid and acetyl-CoA pathway, 3-hydroxypropinate cycle, 3-hydroxypropinate/4-hydroxypropinate pathway, and the dicarboxylate/4-hydroxybutyrate cycle and converts atmospheric CO_2 to organic compounds (Wolosiuk et al. 1993; Shi et al. 2015). The reductive pentose phosphate cycle or Calvin cycle is one of the most important pathways for photosynthetic organism to incorporate CO_2 into the cell carbon cycle with 7×10^6 g carbon consumption rate on the annual basis (Berg 2011). The key enzymes in Calvin cycle are ribulose-1,5-bisphosphatecarboxylase/oxygenase (RubisCO) and phosphoribulokinase (PRK) which are potential to photosynthetic carbon reduction cycle. Ribulose-1,5-bisphosphatecarboxylase/oxygenase (RubisCO) catalyze the electrophilic addition of carbon dioxide to ribulose-1,5-bisphosphate (5C) compound (Fast and Papoutsakis 2012) and transform to several intermediate products like 3-phosphoglycerate, 1,3-diphosphoglycerate, and 3-phosphate glyceraldehyde, and in the final stage, 3-phosphate glyceraldehyde transform into 5-phosphate ribulose. Furthermore, 3-phosphate glyceraldehyde can be converted into amino acids, sugar, and fatty acids (Shi et al. 2015).

The reductive citric acid cycle or tricarboxylic acid cycle (TCA) converts carbon dioxide and water into carbon compounds. The main following enzymes 2-oxoglutarate ferredoxinoxido reductase, ATP citrate lyase, isocitrate dehydrogenase, pyruvate ferredoxinoxido reductase are involved in the reductive tricarboxylic acid cycle or CO_2 fixation pathways (Hügler et al. 2005). The reductive citric acid cycle involves four steps of carboxylation reactions, in which, succinyl-CoA is reductively carboxylated with carbon dioxide into α-ketoglutarate/2-oxoglutarate in presence of a-ketoglutarate synthase/2-oxoglutarate synthase. Further, α-ketoglutarate/2-oxoglutarate and CO_2 are transformed into verity of compounds like isocitrate, citrate, pyruvate, etc. The pyruvate is then converted into phospho-enolpyruvate (PEP) in presence of pyruvate kinase, and then, oxaloacetate is formed. Finally, oxaloacetate is converted into succinyl-CoA in presence of series of key enzyme (Thauer 2007; Fuchs 2011).

The reductive acetyl-CoA pathway is a major CO_2 fixation mechanism in anaerobic environments to turn CO or CO_2 into carbon cells (Roberts et al. 1994) and mainly found in acetogenic, methanogenic bacteria and Eubacteria. In the reductive acetyl-CoA pathway, CO_2 is converted into formate and carbon monoxide by formate dehydrogenase and CO dehydrogenase (CODH), respectively (Roberts et al. 1994; Berg 2011). Similarly, 3-hydroxypropionate, 3-hydroxypropionate/4-hydroxybutyrate, and dicarboxylate/4-hydroxybutyrate all above six major pathways catalyze the conversion CO_2 or bicarbonate in cells.

14.2.2 Direct Transformation of CO_2

In the direct transformation process, carbon dioxide is converted directly using biocatalysts into useful chemicals. In this method, carbon dioxide is used as substrate and source of hydrogen, and biocatalysts are the additional requirements for conversion. The role of enzyme and products in direct transformation of carbon dioxide is discussed in this section briefly.

14.2.2.1 Transformation of CO_2 to Formate

Demand of future and sustainable energy needs alternatives to current energy technologies mainly based on fossil fuels. Hydrogen has been considered a promising alternative energy feedstock, but hydrogen storage and transportation is a major complexity for its optimum utilization (Schlapbach and Züttel 2011). Schuchmann and Müller (2013) discovered hydrogen-dependent CO_2 reductase from *Acetobacteriumwoodii* bacteria which directly uses dihydrogen and catalyze the hydrogenation of carbon dioxide to formate or formic acid (FA) which is a promising and intermediate reservoir for hydrogen storage and distribution. Formate/formic acid (FA) also used for various chemical intermediates, silage preservation, animal feed additives, and most promising candidate for low-temperature fuel cell (Rees and Compton 2011). NAD-dependent formate dehydrogenase (FDH) from *Candida boidinii* is also used for various CO_2 reductions into formate (Kim et al. 2014) and showed very less CO_2 reducing activity. The formate dehydrogenase (FDH) from *Thiobacillus sp.* (TsFDH) exhibits the high CO_2-reducing activity and showed 5.8 time higher formate production rate as compared to formate dehydrogenase (FDH) from *Candida boidinii* (CbFDH) (Choe et al. 2014).

14.2.2.2 Transformation of CO_2 to Carbon Monoxide

Carbon monoxide dehydrogenase (CODH) is a type of dehydrogenese enzyme that can convert carbon dioxide into carbon monoxide in the presence of the required electron donor like NADH, NADPH, MV^{+2}, etc. by following equation (Sultana

et al. 2016). The reduction of carbon dioxide into carbon monoxide possesses fuel value that offers a feasible new alternative energy sources (Olah 2005).

$$CO_2 + 2H^+ + 2e^- \longleftrightarrow CO + H_2O$$

The reduction of carbon dioxide into carbon monoxide is primarily catalyzed by Ni and Fe containing CO dehydrogenases ([NiFe] CODH) through reversible redox reaction and the synthesis of acetyl-COA (Jeoung and Dobbek 2007). The active site of ([NiFe] CODH) contains Ni and Fe centers bridged bound to three sulfur ligands (3Fe-4S) which is coordinated with His, Cys amino acid residue, sulfido, and a H2O/OH-ligand. In the catalyzing reaction of CO_2 reduction, two-electron process occurs during the reduction process and form reduce Ni center followed by carbon dioxide is bound to the Ni center with Ni-C bound and stabilized by Fe center. Simultaneously, the hydrogen bond is formed between carboxylate oxygen atoms (O_2) and protonated histidine residue (His93). The Fe_1 loss water molecule and formed a CO_2 complex, and another oxygen molecule (O_1) of CO_2 complex is bound to Fe_1 and formed hydrogen bound with a protonated lysine residue (Shi et al. 2015). First time in 2003 (Shin et al. 2003) implement the reduction of CO_2 to CO in vitro by utilizing ([NiFe] CODH) from *Moorella thermoacetica* which showed efficient combination of enzyme conversion of CO_2 to CO. The expression of Fe proteins (vnfH- and nifH)-encoded of Mo- and V-nitrogenases in *Azotobacter vinelandii* strains commonly the reduction of nitrogen (N_2) to ammonia (NH_3) also capable to catalyze CO_2 to CO in vitro and vivo (Seefeldt et al. 1995; Rebelein et al. 2016).

14.2.2.3 Transformation of CO_2 to Methanol

The enzymatic conversion of carbon dioxide into methanol is a promising new recycling technique not only for green house management but also for efficient fuel production (Obert and Dave 1999). The use of enzyme for transformation of CO_2 to methanol provides a facile low-temperature route and higher energy capacity for direct fuel generation from carbon dioxide. In 1994, Kuwabata et al. used two-enzyme system for conversion of carbon dioxide into methanol using FateDH and methanol dehydrogenase (MDH) as catalyst and pyrroloquinolinequinone (PQQ) as an electron mediator. The enzyme FateDH reduces CO_2 to formate, and the enzyme, methanol dehydrogenase (MDH), reduces formate into formaldehyde and then methanol.

The conversion of CO_2 to methanol is catalyzed by three oxido-reductases: formate dehydrogenase (FateDH), formaldehyde dehydrogenase (FaldDH), and alcohol (ADH) dehydrogenases like methanol dehydrogenase (MDH) which are dependent on the reduced form of cofactor β-Nicotinamide adenine dinucleotide (NADH) (Amado 2013). The following enzymes are able to catalyze the sequential reduction of CO_2 to value added products like formate, formaldehyde, and methanol, presented in Fig. 14.1.

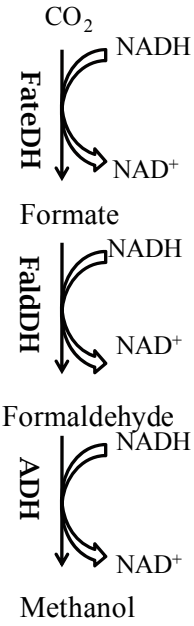

Fig. 14.1 Enzymatic transformation of CO_2 to methanol promoted by FateDH, FaldDH, and ADH

However, this method still has several problems like deleterious of enzyme by cosolvents and catalyst in sol–gel process needs some modification in process to improve the stability the biological activity (Xu et al. 2006). The immobilization of enzyme and hybrid enzymetic/photocatalytic approach for high enzymatic activity improved stability for efficient CO_2 transformation into methanol which was recently proposed in many studies (Aresta et al. 2014; Luo et al. 2015). The photocatalytic/enzymatic integrated approach combining by heterogeneous photocatalysts in the process of NADH regeneration from NAD^+ represents an important step toward the potential application in hybrid CO_2 reduction technology to methanol.

14.2.2.4 Transformation CO_2 to Methane

Recently, researchers found remodeled nitrogenase of *Rhodopseudomonas palustris* is able to take CO_2 from the air and turn it into methane. Purified remodeled nitrogenases of Rhodopseudomonas palustris containing two amino acids substitutions (α-195 by Gln and α-70 by Ala) near the site of its FeMo cofactor are able to CO_2 transformation into methane (Shi et al. 2015; Fixen et al. 2016). The bacterial Mo-dependent nitrogenase enzyme catalyzes the dinitrogen (N_2) to two ammonia molecule and evolution of H2 by following equation.

$$N_2 + 8H^+ + 16ATP + 8e^- \longrightarrow 2NH_3 + H_2 + 16ADP + 16Pi$$

Remodeled nitrogenases reduce CO_2 to methane by eight electrons and make it unique among all known catalyzed enzyme reactions. Furthermore, the reduced CO_2

is also able to react with acetylene to form propylene by following reactions (Omae 2012; Yang et al. 2012).

$$CO_2 + 8H^+ + 8e^- \longrightarrow CH_4 + 2H_2O$$

$$CO_2 + HC = CH + 8H^+ + 8e^- \longrightarrow H_2C = CH - CH_3 + 2H_2O$$

14.2.3 Transformation of CO_2 to Bicarbonate

Another strategy of enzymatic CO_2 conversion into value product is CO_2 mineralization in bicarbonate by enzyme carbonic anhydrase (CA) with high turnover rate. Recently, CA mediated conversion of CO_2 has attracted much attention toward green house management. Carbonic anhydrase is zinc containing metalloenzyme comprises three histidine residues, and a hydroxide ion or water molecule catalyzes the carbon dioxide by following equation (Giri and Pant 2019a).

$$CO_2 + H_2O \longrightarrow HCO_3^- + H^+$$

The CO_2 sequestrating by carbonic anhydrase for precipitating carbonate minerals are being actively investigated (Prabhu et al. 2011; Giri et al. 2018; Giri and Pant 2019a). CA can categorized into five distinct classes of α, β, γ, δ, ζ with few structural similarities, but all CAs similar active site of a divalent zinc ion or associated metal ion. The proposed mechanism of CO_2 hydration and CO_2 mineralization by CA could be summaries as follows: Nucleophilic attack on C atoms of CO_2 by zinc (Zn^{2+}) bound –OH to yield bicarbonate then displaced by molecule of water (Giri and Pant 2019a) (Fig. 14.2).

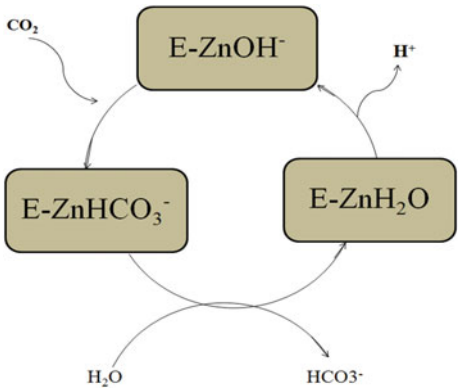

Fig. 14.2 Schematic representation of CA reaction mechanism to accelerate CO_2 uptake to facilitate carbonate precipitation

The first CA was discovered in 1933 by Meldrum and Roughton from erythrocytes in the role of transition of the bicarbonate anions (Meldrum and Roughton 1933) and in 1940 Neish identified the first plant originated CA and its different characteristics from previously known erythrocytes CA (Neish 1940). The prokaryotic CA was discovered by Veitch and Blankenship in 1963 and extracted from *Neisseria Sicca* in 1972. The active center of α CA contained by Zn atom and tetrahedral coordinated with three histidine residues and single water molecule, predominate in mammals (Domsic and McKenna 2010; Giri and Pant 2019a). However, the β CA shows oligomeric quaternary structure and Zn atom tetrahedral coordinated with two molecule of cysteines, and single molecules of histidine and aspartate. In the γ class of CA, the Zn atom is coordinated in a penta mode to three molecules of histidines and two water molecules (Alber and Ferry 1994). The β CA predominate in eukaryotes and γ CA were mostly present in Archaea. The δ class of CA found in *Thalassiosira weissflogii* showed a different amino acid sequence, compared to other α, β, and γ CAs (Tripp et al. 2001). Several research group purified carbonic anhydrase from organisms that thrive in extreme environments utilize to formation of calcium carbonate (Capasso et al. 2012). The converting CO_2 into bicarbonate by using enzyme CA in biomimetic approaches is thermodynamically favorable compared to other CO_2 mitigation techniques and carbonate minerals further used for building and industrial applications (Giri et al. 2018; Sharma and Kumar 2020).

The urease is also a metalloenzyme containing nickel belonging to the group of hydrolases that play an important role in nitrogen requirement in plants and microorganism. The function of urease is to catalyze hydrolysis of urea into ammonia and carbamate. The carbamate further hydrolyzed into the additional mole of ammonium and carbonic acid. The shifting of bicarbonate toward carbonate ion increases the influx of calcium ions and obligates the bacterial export of calcium ion outside the bacterial cell. The availability of calcium and dissolve inorganic carbon in the microenvironment precipitated calcium carbonate outside the cell by following equation (Castro et al. 2016) (Fig. 14.3; Table 14.1).

$$CO(NH_2) + H_2 \longrightarrow NH_2COOH + NH_3$$

$$NH_2COOH + H_2O \longrightarrow NH_3 + H_2CO_3$$

$$H_2CO_3 \longrightarrow HCO_3^- + H^+$$

$$2NH_3 + 2H_2O \longrightarrow 2NH_4^+ + 2OH^-$$

$$HCO_3^- + H^+ + 2NH_4^+ + 2OH^- \longrightarrow CO_3^{2-} + 2NH_4^+ + 2H_2O$$

$$Ca^{2+} + \text{Cell} \longrightarrow \text{Cell} - Ca^{2+}$$

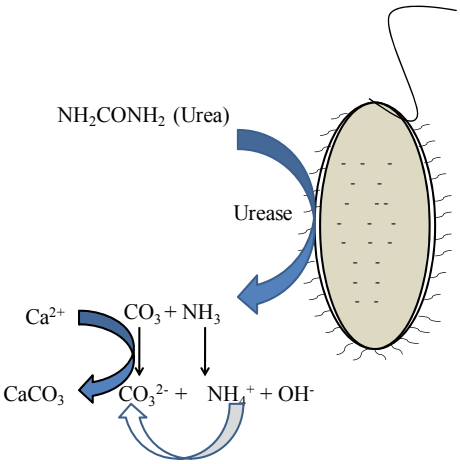

Fig. 14.3 Schematic diagram of carbonate formation by urease activity

Table 14.1 Bacterial carbonic anhydrase and role in bicarbonate precipitation

CA source	Isolation site	Calcite precipitation	References
Bacillus sp.CR2	Mine tailing soil	2.32 mg/cell mass (mg)	Achal and Pan (2011)
Lysinibacillus sp. strain LHXY2	Karst cave	980 mg/100 ml	Lü et al. (2019)
B. pasteurii NCIM 2477	Culture	–	Sarada et al. (2009)
Bacillus and *Virgibacillus*	Desalination plant	–	Silva-Castro et al. (2015)
B.megateriumSS3	Calcareous soil	187 mg/100 ml	Dhami et al. (2013)
B.turiniensis	Calcareous soil	167 mg/100 ml	Dhami et al. (2013)
Bacillus sp. strain (5C-1)	Karst cave	–	Wang et al. (2010)
Citrobacter freundii	Himalayan rocks	230 mg CaCO3/mg of purified CA	Giri et al. (2018)
Pseudomonas spp.	Himalayan rocks	–	Giri and Pant (2019b)

$$\text{Cell} - \text{Ca}^{2+} + \text{CO}_3^{2-} \longrightarrow \text{Cell CaCO}_3$$

In general, enzyme carbonic anhydrase and urease play an important role in production in carbonate by biomineralization. Biocementation and biodeposition are also new emerging technologies which offer a cost effective, environmentally sound, and appropriate alternative on the conventional construction industry. Furthermore, the use of these technologies promises to reduce CO_2 emissions and mitigate the effects of climate change.

14.2.3.1 Conversion of CO_2 to Other Chemicals

Beside CA, there are several other types of carboxylases in cells and have also been explored to catalyze the carboxylation of raw materials and have potential to other biocatalytic applications including: carboxylation of epoxide, aromatic compounds, hetro-arometic compounds, and aliphatic substrate (Glueck et al. 2010). The enzymatic carboxylation reactions derived mainly from catabolic pathways with potential for biocatalytic applications given. The reactions are categorized into four classes, by according to substrate type:

Biocarboxylation of Epoxides

A novel enzymatic reaction has been investigated involving the metabolism of aliphatic epoxides by *Xanthobacter* strain Py2 (Allen and Ensign 1996). The pathways of epoxy degradation seem to be regulated by the presence or absence of CO_2. In the absence of CO_2, propene-grown *Xanthobacter* Py2 catalyze the isomerization of aliphatic epoxides. On the other hand in the presence of CO_2, the carboxylation reaction of epoxide formed acetoacetate and beta-hydroxybutyrate (Glueck et al. 2010; Shi et al. 2015). Both CO_2 dependent and no-dependent pathways were reported to be dependent on NAD^+. A novel type NADPH-dependent pyridine nucleotide-disulfide oxidoreductase is very essential protein for epoxide degradation (Swaving et al. 1996).

Biocarboxylation of Aromatic (Phenolic) Compounds

The second route of carboxylation reaction is also called aromatic carboxylation. Initially, partially purified phenylphosphate enzymes from *Thauera aromatic* were used in the carboxylation of phenol in presence of CO_2 to synthesize p-hydroxybenzoic acid under ambient conditions (Aresta Dibenedetto 2002). The metabolism of aromatic (phenolic) compounds in aerobic bacteria is commonly proceeding via oxidation using molecular oxygen as a co-substrate. The anaerobic carboxylation in *Thauera aromatic* proceeds via involving two enzyme system (i) phenylphosphate synthase (ATP-dependent activation of phenol to phenylphosphate) and (ii) regioselective (para-)carboxylation of the activated intermediate to p-hydroxybenzoic acid by metal (Mg^{2+}, Mn^{2+} and K^+)-dependent phenylphosphate carboxylase. The divalent metal ion in enzyme acts as a Lewis acid by increasing the electrophilic nature of CO_2. Acetyl-CoA is the final product of aromatic (phenolic) degradation by oxygen-sensitive phenylphosphate synthase (Glueck et al. 2010). The first example of biotechnological application of a carboxylase was phenol to p-hydroxybenzoic acid at ambient temperature and pressure (Aresta et al. 1998). 4-hydroxybenzoate decarboxylases purified from *Enterobacte spp.*, *Clostridium hydroxybenzoicum,* and *Chlamydophila pneumonia* can also catalyze phenol in the presence of CO_2 to yield 4-hydroxybenzoate. Similarly, 3,4-dihydroxybenzoate

decarboxylase from *Clostridium hydroxybenzoicum* can catalyze phenol and catechol in the presence of bicarbonate into 3,4-dihydroxybenzoate (Miyazaki et al. 2001).

Biocarboxylation of Hetero-aromatic Compounds

Pyrrole-2-carboxylate decarboxylase is an important enzyme for hetero-aromatic compounds synthesis. The Pyrrole-2-carboxylate decarboxylase from Bacillus megaterium PYR2910 can be used for formation of Pyrrole-2-carboxylate, which is a potential herbicide used in agricultural purposes (Omura et al.1998).

14.2.3.2 Biocarboxylation of Aliphatic Substrates

Pyruvate decarboxylase can be used for enzymatic synthesis of pyruvic acid from acetaldehyde and CO_2, which again converted into lactic acids by using multi-enzyme systems. Lactic acids can also be formed from ethanol and CO_2 which can be used in food, cosmetic, pharmaceutical, and chemical industry (Miyazaki et al. 2001; Tong et al. 2011).

14.3 Future Perspectives and Conclusion

Biocatalysts are generally expensive, stability issue, activity, and reusability, which restrict their optimum use in industrial purposes. Several enzymatic engineering such as chemical modification, genetic engineering, and immobilization need further optimum use of enzyme with economic viable, improving enzymatic activity and stability and reusability (Giri and Pant 2019b). Biocatalysts are needed faster CO_2 transformation for industrial and environmental purposes. Thus, considerable research is required toward the CO_2 management into valuable products by discovery of novel enzyme system as well as enzyme engineering system.

Although, a considerable research should also been focus in novel enzymatic and multi enzymatic technologies for CO_2 conversion into different products. Scientific and technical advances are still needed for link between fundamental and industrial research in CO_2 transformation and mitigation.

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Sentiment Analysis of Tweets by Convolution Neural Network with L1 and L2 Regularization

Abhilasha Rangra, Vivek Kumar Sehgal & Shailendra Shukla

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Abstract

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Keywords

CNN **Tweets** **Bigdata** **Regularization** **n-gram**

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Sentiment Analysis of Tweets by Convolution Neural Network with L1 and L2 Regularization

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Abstract. Twitter data is one of the largest amounts of data where thousands of tweets are generated by the Twitter user. As this text is dynamic and huge so, we can consider it as a big data or a common example of Big data. The biggest challenge in the analysis of this big data is its improvement in the analysis. In this paper, there is an analysis by using semantic features like bigram, tri-gram and allow to learn by convolution neural network L1 and L2 regularization. Regularization is used to overcome the dropout and increase the training accuracy. In our experimental analysis, we demonstrated the effectiveness of a number of tweets in term of accuracy. In the result, we do not obtain any specific pattern but average improvement in the accuracy. For the analysis, we use 10 cross-validations and used to compare the outcome with max-entropy and SVM. Here we also analyze the effect of convolution layer on accuracy and time of execution.

Keywords: CNN · Tweets · Bigdata · Regularization · n-gram

1 Introduction

In the past few years, there was the enormous number of utilization of micro blogging platform like Facebook, Twitter, etc. For the purpose of growth and development, many organizations and companies used to extract the sentiments from the tweet data which also termed as big data. Big data is nothing but a large number of data like Twitter data which we use to analyze the sentiments. We can term tweet data as big data because big data are a set of large data that is used to analyze by using computation methods to demonstrate the trend, association, especially related to human behavior as we are used to exert in Twitter data. In the given paper, we also used to analyze the data from twitter data or we say big data [1, 2]. There are numbers of companies and organization which used to analyze the big data by using several means to identify the opinion of the masses about their product and services [1, 3]. The intention of this paper is to spot some light on the processes, issues, and methods used to analyze the sentiments of big data. This big data contains the number of Twitter messages termed as the tweet, Twitter post, etc. [1, 2]. There is numerous information

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on the word floating in the big data whether it is related to any organization or any political and social issues. The content in the big data demonstrates real-time events in day to day life or daily routine, these contents are full of social information and temporal attributes. This information, data used to analyze sentiments of human beings, because every person uses to express their view on social sites. After analysis of these data valuable information can be extracted that helps to predict any situation or result easily. Twitter gives fine-grained information about each and every-events, instances, perspectives, etc. [5]. The main intention of sentiment analysis is to evaluate the state of mind of the speaker. In sentiment analysis, most of the work has been done to find sentiment regarding a general topic by taking an assumption that viewer talks about an individual topic. In such reviews, it is easy to analyze the sentiments of the subject [7]. This analysis is used to differentiate the opinion of users or speaker on the basis of its binary polarity. This analysis is done in documents, the single sentence or word for word. The classification of sentiments is done in two ways positive or negative. It is very difficult to make 100% accuracy while analyzing the sentiment, but the main goal of this paper is to provide such approach that assures to make the result as more as possible. We propose CNN for learning purpose which helps to give accuracy in the result. As there are various challenges during analysis of sentiments form big data like to evaluate the data parallel, if we have no previous result Real-time opinion mining becomes the very difficult task, classification of argument statement, the variation of sentiment from person to person or of a person with the passage of time. The sentiment of analysis is done by extracting (REST API), classifying (tokenization, stemming, stop word removal) and last learning (CNN). There is the number of methods, framework, models, etc. given by researchers to the analysis of sentiments of big data in an accurate manner some of the approaches are represented in Sect. 2. The rest of the paper is organized as follows: Sect. 2 gives the detail on the research given by a number of researchers in related work, in Sect. 3 there is a discussion about the proposed work and algorithm, in Sect. 4 there is a discussion about the experiments and result, and at last there is a summary of the conclusion of the whole paper, and the work which is to be done in the future given in Sect. 5.

2 Related Work

To analyze the sentiments of the tweets there is a utilization of lexicon approach and learning based method. Sentiment analysis is performed by collecting big data from the micro blogging site (Twitter) [9]. To execute the analysis, brilliant system with the help of machine learning like Naïve Bayes, Random Frost, or SVM are used [10, 18]. There is a complete description given by [11] about the working during analysis of twitter big data which start from extracting data from social sites and they allow for preprocessing and at last connected with the Alchemy API by Rest Call Method. There is also an evaluation of polarity and accuracy of twitter big data [12] by pre-processing. It is very difficult to analyze the complete paragraph taking adverb, adjective, and verb in a single framework. An AVA framework special for recognizing sentiments in a line, paragraph, etc., where the user has to select topic, line or paragraph, denoted as (t) and any document (d), AVA use to return a score that d used to express (t) [13]. This score

expresses in the form of +1 or −1 where +1 means maximally positive and −1 maximally negative. As we discuss above CNN is used in this paper for learning process. Here to extract features from visual and textual modalities by using deep CNN. By using this method in multi-kernel learning classifier we can easily increase the performance to identify the multimodal emotion recognition and sentiment analysis on the different dataset [14]. To analyze the sentiments of the sentences CNN architecture is presented [15] here there is a utilization of 3 pairs of convolution layer and pooling layer in the given architecture. To enhance the given model [15] utilizes parametric rectified linear Unit (PReLU), normalization and Dropout technology.

3 Proposed Work

This section presents the explanation of the proposed methodology and proposed algorithm to analyze the sentiments on big data. Here we give a brief description about the working of CNN and preprocessing methods. Methodology is described in a number of steps with proper flow chart. In algorithm part there is a stepwise discussion about the working of whole methodology and sequence of their execution.

3.1 Preprocessing

In the given paper overall, proposed system is segregated into four steps. In the first step, we use to collect big data and it's pre-processing. In the third step, we use to extract the feature by its classification and at last applied CNN on the labeled feature and classify the outcomes by using soft-max classifier. In Fig. 1, initially, there is a collection of big data with the help of the REST API. Rest API is an application program interface which utilizes an HTTP request to GET, PUT, POST and DELETE data. It is an interface which helps to collect the Twitter data from its site. And in the second step, we use to pre-process the collected tweet for reducing noise. Then apply for tokenization, stop word removal and stemming. In tokenization, we use to make an alphanumeric sequence of collecting data having length character 3 or more. They use to segregate punctuation marks or special characters from the character length and to convert uppercase into lower case [16].



Fig. 1. Pre-processing of big data

In another method [16] given in Fig. 1, there is a removal of the stop word from the sentence and termed as stop word removal. Here it used to remove the word which seems to stop the word. For example, a) "I love Chandigarh but I also love Kinnaur" here, but is utilizing a stop word so this approach used to remove the word 'but'. It also uses to remove extra words or characters, for example "Blasssting day after many days, reeeallyyy enjooooyingggggg" here there are many extra words who only

increasing the data size, this approach used to remove these extra words an left with " Blasting day after many days, really enjoying". It also helps to reduce the data size. This approach uses two methods for removing the words termed as TBRS methods which stand for Random sampling on the basis of a term expressed as:

$$S_z(r) = P_z(r).log_2 \frac{P_{z(r)}}{P_{(r)}} \tag{1}$$

And Mutual interference Method (MI)

$$P(B;M) = \sum_{b \in B} \sum_{m \in M} p(m,b) \log \left[\frac{p(m,b)}{p(m).p(b)} \right] \tag{2}$$

3.2 Semantic Features Extraction

In the third step of Fig. 1, stemming approach [17] is utilized to DE noise the tweets. In this approach, we use to recognize the root word or stem word from the given data. Here we use to remove the plural word like "foods → food and affix word from the data. These are the three methods which are used for the extraction, now we use to classify the given result in the form of n-grams (unigram, bigram and trigram). There are some formulas with help of which we used to classify the features; Fig. 4 represents the flow of feature classification after pre-processing.

In this process, we use to classify the outcome from preprocessed data in term of unigram, bi-gram, and tri-gram. Unigram is utilized to use every individual word as a feature. These features are used for utilization of term frequency, inverse document frequency as the feature value. In unigram n = 1 (Fig. 2).



Fig. 2. Classification of feature

Where,

$$\text{Inverse document frequency} = \log\left[\frac{\textit{total number of documents}}{\textit{number of documents containing} - t}\right] \quad (3)$$

Bigrams are used, two consecutive words as features. It is a n-gram where n = 2. It helps to provide the previous token while allowing relation of conditional probability:

$$P\left[S_I|S_0.\ldots\ldots\ldots\ldots.S_{I-1}\right] \quad (4)$$

$$P\left(S_1^V\right) = \prod_{i=1}^{v} p(S_i|S_{i-1}) \quad (5)$$

and if we talk about the tri-gram having n = 3. It is a group of three consecutive written units like letter, syllables or words. There is one common example of all the three n-grams shown in Table 1.

$$\mathrm{P}(S_i|S_0.\ldots\ldots\ldots\ldots.S_{i-1}) \approx \mathrm{P}(S_i|S_{i-2}S_{i-1}) \quad (6)$$

$$\mathrm{P}\left(\mathrm{S}_1^v\right) = \prod_{i=1}^{v} p(S_i|S_{i-2}S_{i-1}) \quad (7)$$

Table 1. Accuracy variation in the given three parameters.

	Statistical data for two classes			Statistical data for three classes		
Number of tweets(K)	SVM (Accuracy)	Max-entropy (Accuracy)	CNN (Accuracy)	SVM (Accuracy)	Max-entropy (Accuracy)	CNN (Accuracy)
2	85.62	89.23	92.52	85.23	88.2	90.23
10	86.6	88.42	94.62	87.23	87.98	93.23
40	87.13	86.23	93.23	86.73	85.46	95.67
80	88.23	90.23	96.23	88	88.23	96.23
100	88.47	90.13	97.82	87.98	89.13	97

3.3 Learning Features with Label

After classification of features, we use to apply CNN tool which stands for convolution neural network for learning purpose. Before applying we use to give labeling to the feature by using the correlation method. We use labeled feature for learning like which feature having “positive” sentiments or “negative” sentiments or “neutral” sentiments. CNN is a tool which is very useful or enhanced tool in term of document recognition (LeCun et al. 1998) [18]. It contains any convolutional layers and many fully connected

layers. There are two layers named as pooling layer and normalized layer in between the convolution layer. It is a supervised learning algorithm where parameters of various layers are used to learn from back propagation. In the previous year it is very hard to learn large feature set, but after the extension of the computational power of GPU, it is possible to train a deep convolution neural network on the large dataset (Krizhevskhy, Hinton 2012). In our work, there is a use of CNN to learn classified feature in terms of n-grams. There are three main processes in the CNN are pooling, convolution and soft-max model which perform their function on the features. The flow of CNN is represented in Fig. 3.



Fig. 3. Learning process

After labeling the data into a set of vectors which is instantly segregate into a training set and test set. The process of convolution is started from locating word indices into the lower dimensional vector where the distance of the word is directly proportional their sentiments in a layer termed as an embedded layer. In the next layer termed as convolution layer where convolution performs over the embedded words by using various filter sizes which are sliding over 6–7 words at a time. This is a method to understand the activity of words in terms of sentiments in n-grams. After every convolution, there is a utilization to segregate the most significant feature from the set of feature and used to convert them into the feature vector by using the max-pool layer or pooling layer [4]. The combination of convolution and pooling layer is used to make tensor with several shapes and has to create the layer for every individual layer and focus their result of a single big feature vector. Then at last there is a utilization of soft-max model to classify the features as an outcome of pooling layer. The main function of the soft-max model is to optimize the layer by the formula given below [6]. As it is a classifier, it is used to classify the features. [18] L_1 regularization express in Eq. 8.

$$\sum_{r=1}^{N} l(\mathrm{f}(\mathrm{Z}_r), \mathrm{I}) + \lambda\left(\sum_{r.e=1}^{M+u} L\,\mathrm{f}(\mathrm{Z}_\mathrm{r}).\,\mathrm{f}(\mathrm{Z}_\mathrm{e}), \mathrm{b}(\mathrm{r}, \mathrm{e})\right) \tag{8}$$

At last to examine the result from learning approach soft max classifier used to classify the outcome in term of accuracy and time execution. L_2 regularization is express in Eq. 9.

Algorithm 1

Step 1: Collection of tweets from Twitter by using REST API.

Step 2: *Pre-process the tweets*

Tokenization → Stop word removal → Stemming

Step 3: *Extraction of processed tweets in the form of n-grams where n = 1 or 2 or 3 respectively. The evaluation is done by using equation 4 and 5 for bigram and 6 and 7 for trigram from the above equation.*

Step 4: *String all the feature.*

Step 5: *Labeled the entire feature by using the correlation method.*

Step6: *These labeled features are applied for learning with the help of CNN.*

$$F_r(z) = \sum_{v=1}^{a} B_v^{0,r} \; y^{M}{}_v(z) + w^{0,r},\ r = 1,2....K \qquad (10)$$

Where,

M is the weight of random value

Optimization of feature by using soft-max layer equation (8).

Step 7: *Classification of features and the analysis of accuracy and time of execution of the model using equation (9)*

$$\xi_c : x \rightarrow \sqrt{\frac{2}{\prod} \sum_{u \in \Omega_{c-1}} e^{\frac{-1}{W_C^2}\|u-x\|^2} - \xi_{c-1}(u)} \qquad (9)$$

4 Experiment

4.1 Experiment Setting

Our experiment is executed on the analysis of sentiments of tweets where we use rest API for the collection of tweets and CNN as a learning approach for the collected data. We used to classify the data in two forms (a) two class which contains positive and negative sentiments (b) three class which contain positive, negative and neutral. We use to analyze the accuracy and execution time for different classes.

4.2 Datasets

To analyze the accuracy in terms of SVM, Max-entropy and CNN we use the dataset from 2 k which having various values for SVM stands for support vector machine, Max-entropy and CNN, similarly for 10 K, 40 K, 80 K and 100 K. These tweets are collected from twitter website with the help of rest API. Tables 1 and 2 shows the statistical data and also provides side-information about the accuracy in SVM, CNN, and max-entropy. Secondly, a number of convolution layers are used to analyze the execution time of CNN where time is considered in seconds. Execution time is represented in the different layer of CNN like 2, 4, 8 and 10 correspond to the accuracy of CNN. Tables 1 and 2 represents the time execution with the accuracy in CNN with the passage of convolution layers.

Table 2. Time taken by the classifier

	Statistical data for two classes		Statistical data for three classes	
Convolution layers	CNN (Accuracy)	Time of execution	CNN (Accuracy)	Time of execution
2	89.92	60	88.23	120
4	92.32	180	92.2	200
8	94.62	240	94.62	320
10	97.82	600	97	800

4.3 Baseline

To represent the analysis we use to compare the accuracy of two classifiers i.e. SVM and Max-entropy and also a deep learning method CNN. There is a comparison of these three approaches to demonstrate the accuracy of the analysis. Here we use to compare the accuracy rate of these three approaches. (Jaynes, 1957) states that max-entropy is the way by which one can explain the data in the best manner with its entropy value. (Berger, 1996) and (pang, 2002) demonstrate the efficiency of max-entropy as compare to NLP and naive Bayes. (Cortes, 1995) and (Renie, 2003) shows the efficiency in classification for selected documents or data. By taking these paper with [19] paper as a base paper, we use to analyze the sentiments of the tweet with statistical data. To generate the statistical data we use to study the behavior of approaches.

4.4 Evaluation Metrics

For recommendation we normally split our measures into three categories Accuracy used to evaluate the overall effectiveness of selected classifier. It is the ratio of Total corrected sentiment (positive + negative) to the complete data used for analysis or classification.

4.5 Results

For the purpose of comparison, we use the number of tweets collected by rest API. The number of tweets varied from 2 K to 100 K for both two class and three class (10-cross-validation). The comparison is done between SVM, CNN, and max-entropy. SVM stands for support vector machine is a state-of-the-art classifier for large data which is used to classify the sentiments of tweets whereas Max-entropy is also used for classification purpose. CNN is described in Sect. 3. Table 1 represents the accuracy variation in the given three parameters.

Table 2 represents the time taken by the classifier (CNN) for attaining the maximum accuracy in the different convolutional layer. There is the various layer of convolution where the value of time varies. Time execution is considered in seconds. Here we use the 100 K number of tweets in 2, 4, 8, 10 layers of convolutions. The given table shows the value of two classes and three classes of (100 K) for CNN execution time in seconds.

4.6 Results Analysis

Tables 1 and 2 demonstrate the values of CNN, SVM, and max-entropy in terms of accuracy and CNN and its execution time with respect to the convolution layers respectively. In Table 1 we use to compare the values of Entropy, SVM, and CNN in terms of accuracy and in Table 2 we use to compare the time with respect of accuracy given by CNN in different layers. The graphical representation of Tables 1 and 2 are shown in Figs. 4 and 5. Figure 4 represents the accuracy of two class and three class given by SVM, max-entropy and CNN for 2 K, 10 K, 40 K, 80 K and 100 K. The graphical result shows the superior performance of CNN in terms of accuracy as compared to the two classifiers in both the cases. Further Fig. 5 represents the execution time of CNN in seconds in term of accuracy. The graphical result demonstrates that with increase in the layer, time execution also increases and accuracy too. We can say that with the increase in this accuracy increase in the layer.

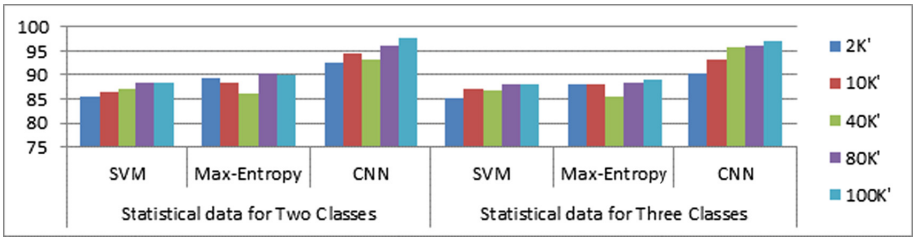

Fig. 4. Comparision of approaches in terms of accuracy

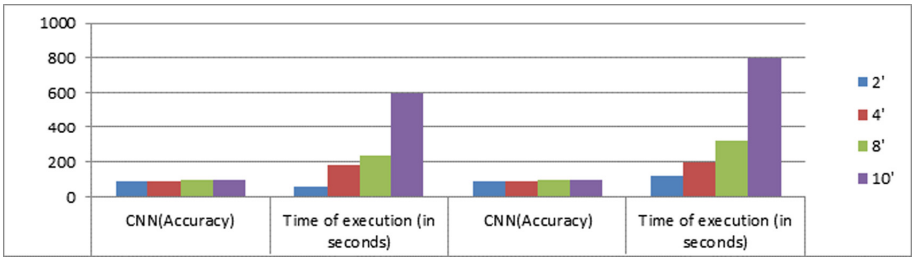

Fig. 5. Comparison of CNN accuary with time (seconds)

5 Conclusion

In the analysis of big data, the important factor is to understand the domain by number of instances. In this paper, experimental analysis is done by using various classifier with different number of instances which starts from 2 K to 100 K. In every case we use 10 cross-validations and generate accuracy. In the experimental result, CNN provides better or effective result as compare to max-entropy and SVM but it also requires more trade–off execution time for two class and three class. The accuracy is near about 97.82 with execution time 600 s and 97 with execution time 800 s for two class and three class respectively. So, if we ignore execution time then we can conclude that CNN shows effective enhancement in accuracy with L1 and L2 regularization from our experimental result in higher number of tweets.

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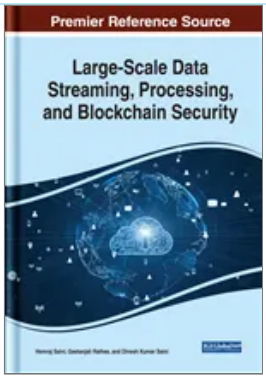

Understanding Blockchain: Case Studies in Different Domains

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Abstract

In this chapter, the authors have detailed the need of blockchain technology along with its case studies in different domains. The literature survey is described that describes how blockchain technology is rising. Further, a number of domains where blockchain technology can be applied along with its case studies have been discussed. In addition, the authors have considered the various use cases with their recent issues and how these issues can be resolved using the blockchain technology by proposing some new ideas. A proposed security framework in certain applications using blockchain technology is presented. Finally, the chapter is concluded with future directions.

Chapter Preview

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Introduction

Blockchains have pulled in overall consideration lately and is characterized as an immutable, successive chain of records called blocks. The record contains transactions, documents or some other information, and are fastened together utilizing hashes. It is executed and overseen by a peer-to-peer network (Christin, N., 2011; Iansiti, M., & Lakhani, K. R., 2017; Swan, M., 2015; Cachin, C., 2016) of computers (also called peer nodes) spread everywhere throughout the globe. Blockchain likewise called distributed ledger which utilizes independent PCs (nodes) to record, share and synchronize transactions in their particular electronic ledgers, rather than keeping information incorporated on a server as in a customary record (Nandwani, K., 2018). A Schematic outline of the blockchain is depicted in Figure 1. Blockchains have the potential to disrupt any industry that employs the use of a trusted middleman and gives direct control back to the end-user. In any case, similarly, as with any technological revolution and the paradigm shift that joins it is a procedure of trial and error. What works and what does not and we are as of now in that stage with blockchain advancements. 99% of the business sectors are filled by an unadulterated hypothesis (Peters, M. A., 2017). There are no completely useful blockchain items that can oblige the requests of the majority. Blockchains must be less expensive, snappier, simpler to utilize and similarly as versatile, if not more thus, than the present frameworks set up. The coming of the web drove the technological revolution of the 90's and the industrial upheaval was in the late eighteenth century (Peters, M. A., 2017). These quantum jumps in human capacity and accomplishment change our whole reality and disturb pretty much every settled industry. They change the manner in which we travel, cooperate, communicate, business with one another. All that we once knew is flipped on its head and life gets improved, making things a lot less demanding and progressively productive. The same is the appearance of blockchain technology where the component of trust is the whole sudden put under the control of target numbers and PCs.

Figure 1. Schematic outline of Blockchain


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Blockchain is the initial step at placing trust into PCs. It sounds kind of terrifying where it would state that however, the seasons of Skynet and eliminators are far away and except if we create methods for keeping self-aware robots from turning into a reality, at that point we ought to be safe. Blockchain technology is still without a doubt so in its earliest stages. Blockchains are moderate, user-unfriendly, unscalable, and costly. For instance, DApps created on ethereum require the end-user to initially buy ethereum and afterward pay a transaction fee each time they accomplish something in the DApp. Then again, EOS expects developers to buy over the top expensive RAM to build up a DApp while the users get transaction fees, simply after the user gets some EOS, downloads an EOS wallet from Github, make a key pair and sends EOS to that key pair. Not to speak to the average consumer who could think less about decentralization. The fact of the matter is that blockchain technology needs to develop before mainstream adoption happens. A blockchain that takes care of enormous real-world problems, finds a harmony among decentralization and administration while giving speed, scalability, cost viability, and overall smooth user experience will be the blockchain that ascents above them all. 2018 was an incredibly dynamic year for blockchain and cryptocurrencies (Houben, R., & Snyers, A., 2018). Numerous jumps in advancement were made and blockchain is entering the worldwide awareness increasingly every day. The subject of mass selection is when, not in the event that it occurs. We unquestionably observe this occurrence very soon, however as things remain at the present minute, the blockchain space still makes them develop agonies to traverse.

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Chapter 9
Understanding Blockchain:
Case Studies in Different Domains

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ABSTRACT

In this chapter, the authors have detailed the need of blockchain technology along with its case studies in different domains. The literature survey is described that describes how blockchain technology is rising. Further, a number of domains where blockchain technology can be applied along with its case studies have been discussed. In addition, the authors have considered the various use cases with their recent issues and how these issues can be resolved using the blockchain technology by proposing some new ideas. A proposed security framework in certain applications using blockchain technology is presented. Finally, the chapter is concluded with future directions.

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INTRODUCTION

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Blockchain is the initial step at placing trust into PCs. It sounds kind of terrifying where it would state that however, the seasons of Skynet and eliminators are far away and except if we create methods for keeping self-aware robots from turning into a reality, at that point we ought to be safe. Blockchain technology is still without a doubt so in its earliest stages. Blockchains are moderate, user-unfriendly, unscalable, and costly. For instance, DApps created on ethereum require the end-user to initially buy ethereum and afterward pay a transaction fee each time they accomplish something in the DApp. Then again, EOS expects developers to buy over the top expensive RAM to build up a DApp while the users get transaction fees, simply after the user gets some EOS, downloads an EOS wallet from Github, make a key pair and sends EOS to that key pair. Not to speak to the average consumer who could think less

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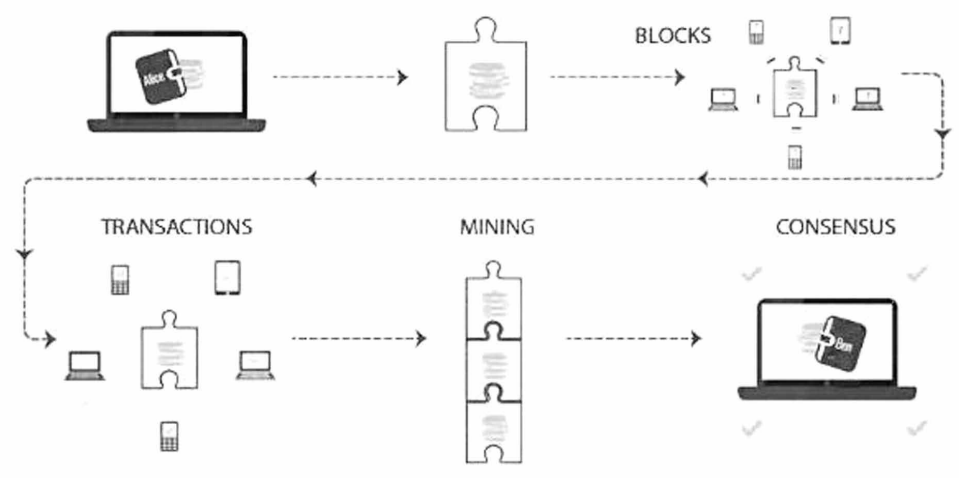
Figure 1. Schematic outline of Blockchain



Key Advantages of Blockchain

A. Distributed

Blockchain enables a wide assortment of PCs to partake in a network, circulating the processing power. For instance, Amazon purchases and keeps up a private arrangement of computing power for AWS, nobody, however, Amazon can contribute this. Interestingly the blockchain association Ethereum permits nearly anybody to contribute their PC to their system, just by introducing their product. Distribution decreases the chance of altering, extortion, and tampering. With more hubs ready

to partake, frameworks are difficult to "takedown" by means of customary brute force network attacks.

B. Trustless

Blockchain enables advanced exchanges to occur between gatherings who don't confide in one another. Envision a digital coin stored in a document on your PC. You may read the document an endless number of times. The estimation of this digital currency would near zero. Previously, focal experts (banks) have gone about as records, tracking the number of coins every one of us has access as a bought together to evade the issue of duplication. By distributing the Ledger to numerous nodes, and synchronizing the ledger through Consensus, blockchain permits parties who don't confide in one another, to trust that the exchange is genuine and not useless. After some time, trust can be expanded further, by means of shared procedures and permanent records of exchanges. This encourages a monstrous scope of potential digital transactions that couldn't have occurred before without a focal specialist overseeing them.

C. Immutable

When a transaction is concurred and shared over the distributed system it turns out to be near difficult to fix. Indeed, after some time, it ends up increasingly hard to fix. In an open record, like Bitcoin, this implies you can investigate the blockchain and find the number of Bitcoins in anyone's record, or follow where reserves were distributed. In different situations, this could be utilized to follow supply chains, or check who got to specific documents on a system.

D. Decentralized

Blockchain likewise underpins the decrease in centralized monopolies infrastructures or "middlemen" and expels costs. By distributing systems, blockchain can discover economies of scale, without single incorporated speculation. This builds rivalry in the market, by bringing down the hindrances to the passage, putting pressure on all members to turn out to be progressively effective. In addition, enabling peers to transact with no prerequisite for trust upsets the present business practices of associations who encourage trust for example Banks. Transactions straightforwardly between peers may prompt a decrease in "middle man" steps, further expanding business sector effectiveness.

Challenges of Blockchain

Wasteful

Each node runs the blockchain so as to keep up Consensus over the blockchain. This gives outrageous dimensions of adaptation to non-critical failure, guarantees zero downtime, and makes the information stored on the blockchain perpetually unchangeable and restriction safe. Yet, this is inefficient, as every node rehashes a task to achieve consensus consuming electricity and time in transit. This makes calculation far slower and more costly than on a customary single PC. There are numerous activities that look to diminish this cost concentrating on elective methods for looking after Consensus, for example, Proof-of-Stake.

Network speed/cost

Blockchain systems expect nodes to run. However, the same numbers of the systems are new, they do not have the number of nodes to encourage broad utilization. This absence of resource shows as:

- Higher costs—as hubs look for higher prizes for finishing transactions in a supply and demand situation
- Slower transactions—as hubs organize transactions with higher prizes, backlogs of transactions develop.

After some time, effective public blockchain networks should incentivize nodes, while making ideal expenses for clients, with transactions finished in a significant time allotment. This balance is key to the financial matters of each blockchain.

The size of the block

Every transaction or "block" added to the chain builds the span of the database. As each hub needs to keep up the chain to run, the computing necessities increase with utilization. For substantial public usage of blockchain this has one of two effects:

- Smaller ledger—Only one out of every odd node can convey a full copy of the blockchain, conceivably influencing immutability, consensus, etc.
- More centralized— There is a high obstruction to a passage to turn into a node, empowering a bigger measure of centralization in the network, with greater players ready to take more control.

Neither of these situations is alluring, without thinking about the full ramifications, as it will probably influence the utilization cases for blockchain variations.

Speculative markets

Numerous blockchains are run utilizing token/currency models to support advancement or deal with the financial matters of nodes. For instance, Ether (ETH) is the currency used to pay for computing power (or Gas) on the Ethereum organizes. In this manner, ETH is a cash for computing power.

Customary currencies like USD, GBP, EUR (additionally called Fiat currencies) are commonly connected to the estimation of their particular economies for example GBP to the UK. These economies are very much created, directed and stable. In any case, because of the possibly troublesome nature of Blockchains, individuals have taken to guessing on the estimation of the digital economies they create.

As these business sectors are liable to restricted guidelines and are exceedingly theoretical they are inclined to quick variance and control, spiking transaction value. This presents specific dangers while transacting from Fiat currencies into blockchain currencies. For instance, 1 ETH may cost ~$200 today, yet ~$180 tomorrow, a 10% price fluctuation (Ametrano, F. M., 2016). While this can make vast rewards, it likewise introduces high degrees of vulnerability for undertakings created on public blockchain innovation.

Hard and Soft Forks

Numerous blockchains and currencies decentralize their basic leadership. For instance, Bitcoin enables nodes to "signal" support for upgrades deeply software that runs the system. This permits the blockchain to stay away from bringing together basic decision making, yet in addition, it presents challenges when communities are partitioned about the best course.

At the point when nodes change their software, there is potential for a "Fork" in the chain. Nodes working the new software won't acknowledge indistinguishable transactions from nodes working the former one. This makes another blockchain, with a similar history as the one it is based on.

Forks make noteworthy uncertainty, as they can possibly piece the intensity of the blockchain arrange into loads of variations. They are additionally prone to be essential, as, without the ability to refresh the software, the blockchain is probably not going to be future proof.

Immutable Smart Contracts

When the smart contact is added to the blockchain, it ends up permanent, in that it can't be changed. In the event that there are imperfections in the code that might be misused by hackers, they are there until the end of time. This isn't a worry when a smart contract isn't being utilized, however as smart contacts carry on like records, they can be utilized to store a lot of significant worth.

This can make situations where hackers can abuse code defects to send the substance of smart contracts to their very own records. As the blockchain is permanent, these transactions are extremely difficult to fix, which means a lot of significant worth might be lost until the end of time.

Solutions of Weaknesses of Blockchain

All the weaknesses of the blockchain can be removed using three different consensus protocols named proof-of-work, proof-of-stake and proof-of-useful-work (Vukolić, M., 2015; Yu, B., Liu, J., Nepal, S., Yu, J., & Rimba, P., 2019; Baldominos, A., & Saez, Y., 2019; Zheng, Z., Xie, S., Dai, H., Chen, X., & Wang, H., 2017). A brief summary of these three protocols is given below.

Proof-of-work

A self-explanatory pictorial representation of proof-of-work is shown in Figure 2.

Proof-of-stake (virtual mining)

A self-explanatory pictorial representation of proof-of-stake is shown in Figure 3.

Proof-of-useful-work

A self-explanatory pictorial representation of proof-of-useful-work is shown in Figure 4.

Table 1 represents the comparison of proof-of-stake and proof-of-work and proof-of-useful-work.

CASE STUDIES

Beyond the simple applications, bitcoin has transcended the environment in the cloud, ensuring data privacy and other major issues. For the future of blockchain, it

has great potential in empowering the citizens of developing countries in different sectors like healthcare, identity management, and other commercial uses. Some of the following case studies represent the strength of blockchain.

Figure 2. Proof-of-work

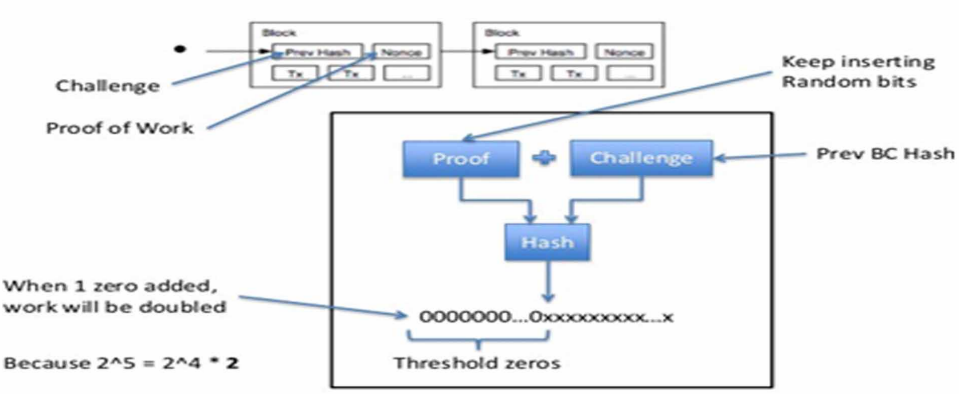


Figure 3. Proof-of-stake



A. Proposed Decentralized Voting Application

Our application determines the vote count of the voter for certain people who are to be selected. Firstly, in this application, we determine the illegibility of the voters

using blind signatures. For high availability and result immutability of privacy using double private blockchain and using bitcoin logic to redesign transactions and new protocols to cast a vote. The proposed system contains:

Figure 4. Proof-of-useful-work

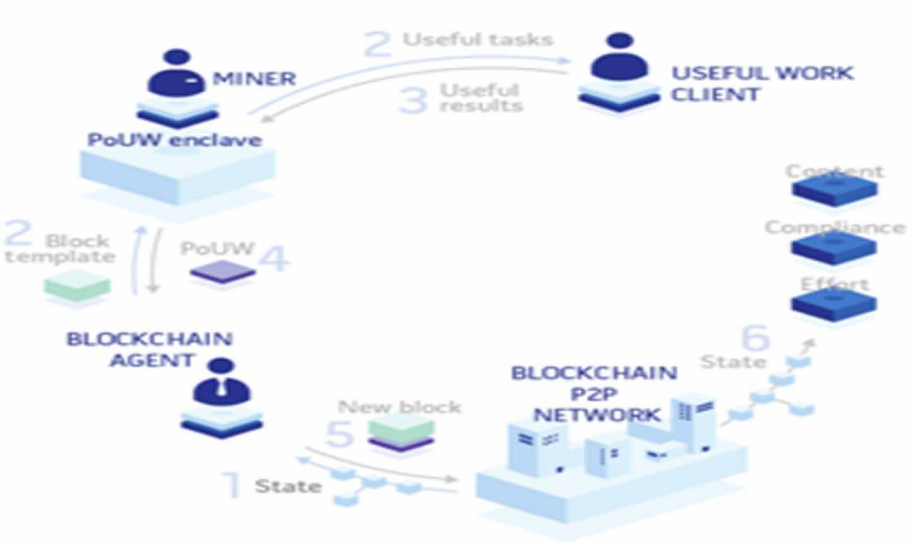


Table 1. Proof-of-stake, Proof-of-work, and proof-of-useful-work

Proof-of-work (PoW)	Proof-of-stake (PoS)	Proof-of-useful-work (PoUW)
Power-hungry, enough energy to power a small country is required to secure the blockchain.	ECO-friendly, minimum recourses required to secure the blockchain	Very much power-hungry
Incentivizes centralized mining farms.	Truly decentralized mining.	Truly decentralized mining.
Advanced technical knowledge required.	Very little technical knowledge required.	Very little technical knowledge required, mining scheme requires training deep learning models
It requires constant tweaking and monitoring.	Set it and forget it.	Set it and forget it.

- Anonymity
- Check flag for voter's illegibility
- Voting integrity with the system.

- Vote Verification

Different Phases in the System

Publishing phase

It's a dummy approach to publicize the system and generating candidate ballots. The Authority has eligible bling signature which is communicated securely to prevent any attacks like DOS, Men-in-the-middle Attack

Login phase

After the publishing phase, the voter's will login and then verification will be done for eligibility. This phase also deals with the impersonation and EIDs establishment.

EID generation phase

This phase will be used to generate the public-private key for electronic identity. For every identity made, an EID password will be established in order to prevent tampering and impersonation. The generation of OTP can also be done.

Voting phase

For the generation of Blockchain transactions, our Voting phase ensures data consistency and isolation as depicted in Figure 5.

Blind signatures

These digital signatures (Seo, J. H., 2019) are heavily used in our application for transactions working for eligible voters sign and extract public and private keys and encrypt them in Ballot. The Ballot is sent to Electoral Authority (admin) and verifies the source of the ballot, removes the outer envelope and Encrypts the keys and sends back to the eligible voter.

System Protocol

This phase depicts the working of the voting application using different phases as per the sequence provided in Figure 6.

Figure 5. Implementing blind signatures

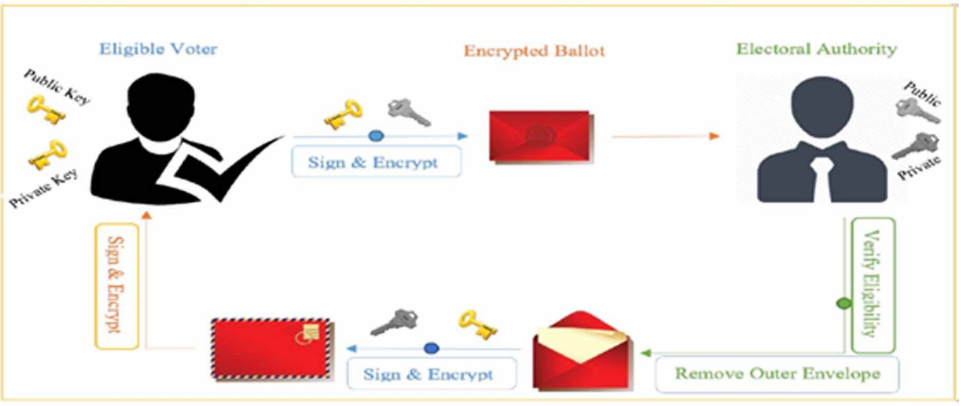
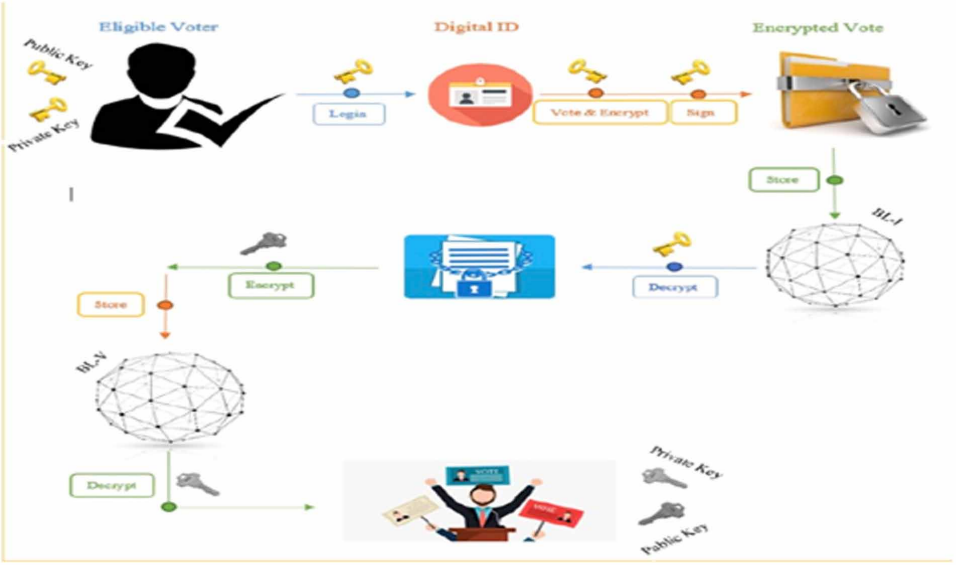


Figure 6. Proposed complete Solution



Threat Model

Various models have been taken in care for the full functionality of the Blockchain without any foreboding of threat initiation. As Blockchain helps with decentralization, and impenetrable security level, various threats are seldom to be seen. Some of the most common threats (Saini, H. Rao, Y.S., Panda, T. C., 2012; Rathee, G., Saini,

H., 2016) are DDoS Attack, Sybil Attack, Freak Attack, Malwares, Cross-Site Scripting (XSS), etc.

Evaluation

After the completion of the project, we will study all the sufficient properties of the proposed system design and these are the availability of the project, integrity with the OS and web page, uniqueness, accuracy, and election secrecy.

SOME OTHER SECURITY ANALYSIS AND LEGAL ISSUES

Security Analysis

DDoS

For the application to fail under DDOS Attack, the attacker must perform it on every node in the network. But tampering with the boot nodes will eventually inform the institution and the location could be found out. For locating failed blocks, we can use a fault-tolerance algorithm

Authentication Vulnerability

As the value of the hash will be unique to each and every individual or eligible voter, there is seldom a chance of multiple voting process by the voters. This will not only help with the ease to finalize the output result with incrementing by +1 but also eradicates out the total chances of the system malfunctioning.

Sybil Attacks

The consensus algorithms implemented in the project are prone to these attacks. Furthermore, with the incoming of the strong cryptography features and limited access to the ledger, Blockchain solves today's most often security problems

Legal Issues

Transparency

No method of transparency can be offered to the voters in today's electoral scheme. Without some other tech involvement, transparency in the system is a very tedious task with the formulation of a new law by government officials.

Voter Privacy

Voter privacy in pen and paper scheme is meandering which may involve leakage of voter credentials and vote to the party or the candidate. To satisfy the privacy, initiation of the non-traceable vote will be prominent to implement.

Remote Voting

To prevent coercion resistance in the election, remote voting could be of good use. If the results can be used in websites or mobile applications, there is no chance of misconfigured results, but on the negative side, people with good hacking skills can take down the host website and different threats can be introduced. We can use Blockchain features to subdue these effects.

Comparison

Traditional Blockchain Solution

In the traditional Blockchain solution, we can observe the common implementation of litecoin, dash, ripple and many other programming languages based bitcoin implementation. There is less privacy needed even though implemented in a suitable domain of programming languages.

Proposed Blockchain Solution

The platform implements all the solutions in ethereum, solidity and other bitcoin consensus protocols using of RSA algorithm implemented with the generation of private keys. The main idea of proposing this blockchain solution for the voting system is to make the electoral system cheaper and quicker. By doing this, the barrier between voters and officials to be elected will be an endgame. Furthermore, with ease in operation, we can assure a direct form of democracy as people will be in more ease to use it and give a better result in return without any involvement of a central

agency. We also implemented a simple voting application using smart contracts (solidity, ethereum) for the proper conduct of system execution while maintaining security features like privacy and authentication verification. By comparing with the current process of the electoral system, we can observe that blockchain technology has a new future for democratic countries where most of it is pen and paper-based. Using the ethereum private blockchain, we can transmit hundreds of transactions in one second, for countries with bigger democracy, this system can provide a well-executed result with seldom chances of result tampering. The use of modern hash algorithms makes the data fetching impenetrable and isolated within each and every block. Decentralization has made the platform much more secret and private than that of centralized systems. Our proposed system will ensure that all the blockchain concepts will be executed properly resulting in a better approach to implement the platform practically in the provinces or the region. The pros and cons of our solution are represented in Table 2.

Table 2. Traditional Blockchain Solution Vs Proposed Blockchain Solution

Traditional blockchain solution	Proposed blockchain solution
Operated with decentralized property	Operated with decentralized property
Programming tools: Native Programming Languages (Java, Python, C++, ASP.NET, C#)	Programming tools: Ethereum, Solidity, web3.js
Time of Transaction: Minutes	Time of Transaction: Seconds
Implementing client-server architecture and RDBMS	Facilitates P2P architecture and smart contracts; no RDBMS required

B. Proposed e-Waste Management System

India is the fifth-biggest maker of the e-waste on the planet amazingly has not many arrangements with regards to reusing and appropriately arranging e-waste (Terazono, A., et al., 2006). Therefore, e-waste is an inevitable problem, but this problem can be stopped before it turns into a disaster. The current solutions are not enough to properly dispose of e-waste, the present scenario can be changed very easily if the proposed solution is applied to it.

The proposed e-waste Management system depends upon resourceful contracts made by utilizing blockchain progression. Bringing government work environments, clients and assistants on the corresponding blockchain stage will incite improved checking and higher transparency at the same time. Blockchain will empower the appropriate maintenance of records of the electrical and electronic supplies launched

in the technical market by various makers and retailers (Gupta, N., & Bedi, P., 2018). This will empower smart contracts to verifiably choose collectors and disapprove of inappropriate collectors at whatever point required. In a similar manner, we provide the inclusion of clients as individuals from this blockchain. Offering motivations to lure clients to channelize their e-garbage to the formal part can fill in as the hidden stage in lessening the nature of the tangled division in e-waste management. Also, collection centers, as well as recycling units, are being included in our proposed system. These bright contracts will help control the initial point and extent of e-waste collected, delivered and reused all over in the framework.

Table 3. List of all the nodes

S.No	Node	Description
1.	Producer(PR)	A node association with Ethereum arranges a producer/provider/ merchant of EEE in India.
2.	Retailer(RT)	A node associated with the Ethereum arranges the largescale purchaser of the EEE from PR and pitches to the clients.
3.	Collection Centre(CC)	Spot where the E-waste is briefly put away by the PR, which is gathered by RT from clients. Proprietors of CC are associated with Ethereum organize as nodes.
4.	Recycling Unit(RU)	A Government Certified Unit where E-waste from CC is reused in a situation well-disposed way. The proprietors of RU are additionally associated with Ethereum organize.

Table 4. List of other participants in e-waste management

S. No.	Participant	Description
1.	Government's Agency(GA)	An initial point on the Ethereum organizes as in-charge of composing and keeps up savvy contracts for the EWM framework.
2.	Consumer(CS)	A hub on the Ethereum arranges that utilizes the EEEs for their very own advantage.

In our proposal, we use Ethereum blockchain to approve Electronic Wate Management in India. Table 3 and Table 4 represent the list of all types of nodes used in the solution and list of other participants in e-waste management respectively. The center addressing GAs manages the smart contract for coordinating the surge of e-garbage across over multiple accomplices and CSs. GAs endorse only those PRs and RTs who will join this e-waste administrator blockchain. Owners of CCs and RUs, who wish to set up their associations in our country, ought to similarly transform into a bit of this EWMB. CSs will benefit from this project by getting

pre-portrayed spurring powers for channelizing their e-squander to real accomplices present on the blockchain. The splendid contract made by GAs will contain the following components that will track the activities of every part. The complete flow diagram of our e-waste management system is depicted in Figure 7.

Figure 7. e-waste Management System



Table 5. Traditional Blockchain Solution Vs Proposed Blockchain Solution

Current Solution	Proposed Solution
Local market using ends up in black market recycling units use toxic chemicals, and use child labor.	E-waste recycling unit is trackable, easy to manage the operations, and easy for the administration to use.
The capital generated from this solution is often miscalculated and is often very less from what it should be. Most of the capital earned from this process ends up in the hands of illegal recycling unit owners.	The capital generated through this system Will be properly calculable and this would Help the government generate more capital from E-waste.
User is mostly in dark and not aware where their E-waste ends and unfortunately, most of them don't even care about what happens to their E-waste. At least the user should be aware of how much their E-waste is worth.	Through our proposed Solution users and manufacturers of the E-waste would have an insight where their E-waste ends up. It would be a more responsible and manageable operation for the manufacturing side.
The current situation of E-waste recycling exposes a lot of workers to toxic chemicals Like lead, mercury, etc. And these units also don't have proper equipment and techniques to deal with generated this E-waste.	Although the use of Hazardous chemicals cannot be stopped, it can be reduced. Recycling E-waste is Manageable through our solution. If proper recycling units are set up properly. This solution will bring proper standards in the E-waste recycling industry.

Utilizing of blockchain, all the participating parties can be easily connected to each other and will be able to track and use this proposed solution to efficiently manage E-waste management and the government to generate appropriate capital from this recycling of the E-waste through our proposed solution. Clients and makers of the E-waste would have a knowledge where their E-waste winds up. It would be a progressively mindful and reasonable activity for the assembling side.

In order to fulfill this goal, the government needs to associate with the cooperative authorities who are supposed to handle the process. Also, the awareness also plays a very important role in order to get the people on the track of the recycling process. For this to happen, the government needs to take it seriously (Nandwani, K., 2018).

Despite the fact that the utilization of Hazardous synthetic can't be halted yet can be diminished. At last, as Blockchain is public to everyone and is able to access where the E-waste went and who handled this information would be very useful for government and manufacturing companies to plan and efficiently manage E-waste and also be responsible for proper recycling E-waste. A comparative analysis is given in Table 5.

C. Decentralized Kickstarter Crowdfunding

Kickstarter is an application as depicted in Figure 8 that allows investors, no matter big or small to invest in projects they see on the application, again, the projects can also be of varying sizes and require a varying amount of investments. This is a very useful and unique application as the investors are paying the project owner some amount of money in return for the stocks, or profits or whatever their agreement is and the owner gets the required funding to start his business.

A very important feature of kickstarter is that it only allows money to be transferred from an investor to an owner when a certain threshold limit is touched that has been set by the owner in order to start his project. This is something that needs to be taken special care of. Now, like all applications and especially the applications that involve money kickstarter hits certain road bumps and problems. The biggest issue with kickstarter is the fact that money is not tracked. Once the investor gives his money to the owner, he can do whatsoever he wishes with that money, he can use it for his personal use or he can be honest and use it for the project as he mentioned before. Another problem with it is that as the project owner can also work with fiat money in the physical world, it is nearly impossible to know how much money did he actually make and what share of it is to be given to the investor.

The proposed kickstarter clone will be hosted on the RinkebyTestnet which is a free Ethereumtestchain, the same code can then be shifted to the real Ethereum Blockchain with minimal effort. This would allow us to test the application as if it was hosted live and not spend any Ether doing it either. The application we tend to build will be nearly the same as kickstarter when it comes to features and procedures to be followed to host your project on it or be an investor on the application. The frontend will be nearly identical to the real kickstarter application in terms of general usage. Where the difference lie is in the use of smart contracts to restrict the usage of money invested and in the participation of the investors every time the owner wants to spend money. If the owner wants to spend money, he will issue a request in

the application and the smart contract will make sure that 51% of voters have voted favorably for the spending of money and only then that money will be moved from the project account to the account destined for. This will nullify the possibility of the project owner using project money for personal usage and benefits. Also, the investors will be able to track and know where there invested money is being used.

Figure 8. A generic model for Kickstarter



In order to be an investor in the first place, a certain amount of money have to be donated by the investor. Once that is done, that money will be submitted to the project account and that investor will be added to a list of investors for that project and will get his voting rights for any spending in the future.

The project owner is the only one who can make spending requests on the application and can need to make genuine requests as otherwise the investors will vote NO and that transaction will be canceled. As the money will be in the account of the project account (that is possible using a contract account instead of externally owned account), the owner cannot spend money on his own and has to abide by the rules.

Once the request is approved, that money will be transferred to whatever destination address was. This will solve both the major problems –money tracking and proper usage of money. Table 6 represents the comparison of the traditional and proposed blockchain solution.

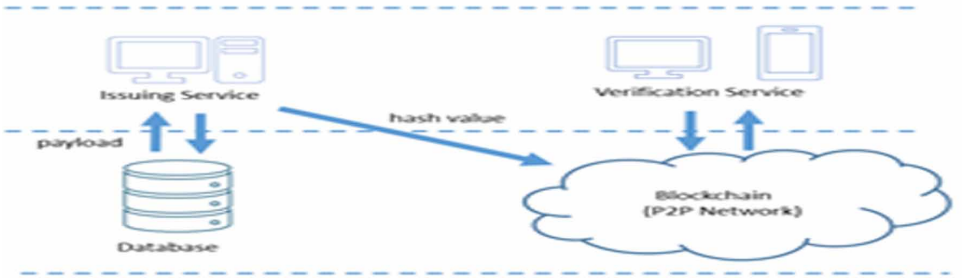
Table 6. Comparison of a traditional and proposed blockchain solution

Traditional solution	Proposed block-chain solution
Centralized controlled	Decentralized controlled
Integrity: Not always possible	Integrity: every user can be sure that the data they are retrieving is uncorrupted and unaltered since the moment it was recorded
Transparency: same as Integrity	Transparency: every user can verify how the blockchain has been appended over time
The traditional application uses a traditional database, on which a client can perform four functions on data: Create, Read, Update, and Delete.	The blockchain is designed to be an append-only structure. A user can only add more data, in the form of additional blocks. All previous data is permanently stored and cannot be altered.
Traditional application incurs transaction cost.	A blockchain carries no transaction cost. (An infrastructure cost yes, but no transaction cost.)
Selected users can see the data.	All participants see consistent data.
Scalability is a major issue	Blockchain simplifies the processes and thus scalability is not an issue.

Issuing and Verifying College Degree using Blockchain

It is easy to use, yet the secure application of issuing and verifying college degrees. Authorized personal can issue the degrees in blockchain, and anyone can verify its existence or validity.

Figure 9. Generic Architecture



The goal is to create a De-centralised application for issuing and verifying college degrees using blockchain. Following are the goals for the setup process for building the application which is also depicted in Figure 9:

- Setup the development environment.
- Learn how to write a contract, push degree data (pdf) into the block, compiling it and deploying it to our development environment.
- Interact with the smart-contract on the blockchain.
- Propose a simple and easy to use applications to deploy degrees on the blockchain.

Advantages of the proposed approach can be as follows-

- No central authority or a third party required. All the functionality and working will be taken by the peer to peer networks.
- There is no way of tampering of college degree's as concepts of "PROOF OF WORK" and "PROOF OF STAKE" are highly maintained.
- No individual can try and change the data in the degrees present in the block.

For the basic idea, we will go with the smart contracts and object-oriented programming in Solidity.

CONCLUSION

In this manuscript, we have reviewed the state-of-art of the blockchain technique along with its case studies in various fields. Further, we have described various blockchain uses cases and explored the different applications in the blockchain with a significant proposed scenario. The aim of this paper is to point out the significance of blockchain in various fields. Further, we have defined how blockchain technology could be helpful in various fields having a decentralized network. In our future work, we will propose a solution corresponding to the above IIoT blockchain discussion with some analyzed and evaluated parameters.

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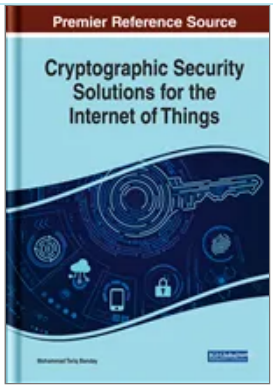

An Adaptive Security Framework for the Internet of Things Applications Based on the Contextual Information

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Abstract

With the growth of Internet of Things and user demand for personalized applications, context-aware applications are gaining popularity in current IT cyberspace. Personalized content, which can be a notification, recommendation, etc., are generated based on the contextual information such as location, temperature, and nearby objects. Furthermore, contextual information can also play an important role in security management of user or device in real time. When the context of a user or device changes, the security mechanisms should also be updated in real time for better performance and quality of service. Access to a specific resource may also be dependent upon user's/device's current context. In this chapter, the role of contextual information for IoT application security is discussed and a framework is provided which auto-updates security policy of the device based on its current context. Proposed framework makes use of machine learning algorithm to update the security policies based on the current context of the IoT device(s).

Chapter Preview

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Introduction

With the advancements and successful adoption of network connecting technologies such as LTE, 3G, WiMax, etc., the Internet has become a necessity in a current era of living. Around 3.5 billion Internet users are available in the world which is around 40% of the total population (“Internet Live Stats,” 2014). Due to such colossal connectivity, a new paradigm has evolved in which not only humans but other things such as fan, machine, car, etc., also connect to the Internet, share data and execute certain tasks with or without any human intervention. This novel paradigm is known as the Internet of Things (IoT). As the name suggests, it is the interconnection of things (sensors, RFID tags, smart devices, etc.) with each other using the Internet so that these things can share information and make some useful decisions (Sandhu and Sood, 2016). In 1998, IoT was first coined by Kevin Auston in his presentation on future of networks. Later, it has been introduced in the Oxford dictionary with the following definition: *“The interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data.”* IoT has multiple application areas such as smart healthcare, smart home, smart school, smart transport and many more. Out of the many challenges of IoT, effective decision making with relevance to the current context of the user or the thing is very important. Any decision made by IoT based application which is out of the current context of the user/thing affects the overall performance and accuracy of the system. However, with real-time data available through the IoT devices, smart context-aware applications can be developed. On the other hand, the IoT framework consists of billions of sensors deployed around the world where the analysis of the data generated by all connected sensors is not feasible. Integration of context awareness in the deployment and usage of IoT devices will provide a method in which only suitable sensors can be prompted to make any decision. This will yield the better performance and scalability of IoT based applications.

Context-aware IoT paradigm proves to be novel for application users. However, security remains the essential requirement in any application. Security mechanism in IoT applications is usually handled in a traditional way such as assigning a role to the application user, grant for resources, etc. These traditional methods are independent and proved to provide the desired security, but the consideration of context also plays an important role and can be very helpful. The security in IoT applications should be highly dependent upon the context of the device and security policies should be updated if the context of the IoT device changes. Consider a scenario when the context (location) of a user/device changes from a public Internet access area to private network. Based on the context, security policies can be updated so that overall QoS of application is optimized. This will make IoT based applications more secure and reliable.

Securing data during transmission and at the interfaces is one of the significant challenges of IoT based smart applications. Any unauthorized change in data can lead to unintended results which further decreases the reliability of IoT based applications. Proper cryptographic techniques should be employed so that IoT based applications are not hacked. However, memory and energy constraints on IoT devices do not allow the use of heavy cryptographic algorithms. Lightweight cryptography is used for most of the IoT based applications which can be prone to attacks. Adding context to the cryptographic techniques can further enhance the security. Contextual information can be used to dynamically allocate the light cryptographic solutions to any IoT based smart applications.

In this chapter, a security framework has been proposed which considers context for managing the security policies of IoT based applications and IoT devices. Three context values associated with IoT devices are used which are when (time of record), where (location of the sensor), whom (surrounding sensor devices) for the security policies upgradations. Medical sensor recording heart rate, GSR values, and respiratory rate are used in the use case to test the proposed framework. Naïve Bayes algorithm which provides the probability-based selection of the security policy to be updated is used in the proposed framework.

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Cryptographic Security Solutions for the Internet of Things

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Section 1
Introduction

This section provides an overview of the Internet of Things including its applications, underlying technologies, and security challenges and reviews the literature and potential applications of cryptography to secure the internet of things.

Chapter 1
Security in Context of the Internet of Things: A Study 1
Mohammad Tariq Banday, University of Kashmir, India

The chapter discusses various security challenges in the design of the internet of things and their possible solutions. After presenting a precise introduction to the internet of things, its applications, and technologies enabling it, the chapter discusses its various architectures and models which follow with an introduction of development kits, boards, platforms, hardware, software, and devices used in the internet of things. A concise explanation and discussion on the internet of things standards and protocols with emphasis on their security is presented. Next, various possible security threats and attacks to the internet of things are presented. The subsequent sections of the chapter discuss identified security challenges at individual layers of various models along with their possible solutions. It further presents cryptographic and lightweight cryptographic primitives for the internet of things, existing use of cryptography in the internet of things protocols, security challenges, and its prospectus.

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Section 2
Encryption and Cryptography

This section presents encryption principles and discusses various cryptographic algorithms including lightweight cryptography that are applicable for the security of the Internet of Things.

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Encryption Principles and Techniques for the Internet of Things 42
Kundankumar Rameshwar Saraf, Dr. D. Y. Patil College of Engineering Lohegaon, India
Malathi P. Jesudason, Dr. D. Y. Patil College of Engineering Akurdi, India

This chapter explores the encryption techniques used for the internet of things (IoT). The security algorithm used for IoT should follow many constraints of an embedded system. Hence, lightweight cryptography is an optimum security solution for IoT devices. This chapter mainly describes the need for security in IoT, the concept of lightweight cryptography, and various cryptographic algorithms along with their shortcomings given IoT. This chapter also describes the principle of operation of all the above algorithms along with their security analysis. Moreover, based on the algorithm size (i.e., the required number of gate equivalent, block size, key size, throughput, and execution speed of the algorithm), the chapter reports the comparative analysis of their performance. The chapter discusses the merits and demerits of these algorithms along with their use in the IoT system.

Chapter 3
A Review of Cryptographic Algorithms for the Internet of Things 67
Issmat Shah Masoodi, University of Kashmir, India
Bisma Javid, University of Kashmir, India

There are various emerging areas in which profoundly constrained interconnected devices connect to accomplish specific tasks. Nowadays, internet of things (IoT) enables many low-resource and constrained devices to communicate, do computations, and make smarter decisions within a short period. However, there are many challenges and issues in such devices like power consumption, limited battery, memory space, performance, cost, and security. This chapter presents the security issues in such a constrained environment, where the traditional cryptographic algorithms cannot be used and, thus, discusses various lightweight cryptographic algorithms in detail and present a comparison between these algorithms. Further, the chapter also discusses the power awakening scheme and reference architecture in IoT for constrained device environment with a focus on research challenges, issues, and their solutions.

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Section 3
Security Protocols

This section discusses some schemes and protocols for securing Internet of Things. These include physically unclonable functions that promise cryptographic security enablers for resource-constrained IoT devices and hardware primitive-based security protocols. It also discusses gateway discovery protocol using ECC for MANET, scheme for node localization, security framework based on contextual information, and secure computation of private set intersection cardinality with linear complexity.

Chapter 4
Addressing Security Issues of the Internet of Things Using Physically Unclonable Functions 95
Ishfaq Sultan, University of Kashmir, India
Mohammad Tariq Banday, University of Kashmir, India

The spatial ubiquity and the huge number of employed nodes monitoring the surroundings, individuals, and devices makes security a key challenge in IoT. Serious security apprehensions are evolving in terms of data authenticity, integrity, and confidentiality. Consequently, IoT requires security to be assured down to the hardware level, as the authenticity and the integrity need to be guaranteed in terms of the hardware implementation of each IoT node. Physically unclonable functions recreate the keys only while the chip is being powered on, replacing the conventional key storage which requires storing information. Compared to extrinsic key storage, they are able to generate intrinsic keys and are far less susceptible against physical attacks. Physically unclonable functions have drawn considerable attention due to their ability to economically introduce hardware-level security into individual silicon dice. This chapter introduces the notion of physically unclonable functions, their scenarios for hardware security in IoT devices, and their interaction with traditional cryptography.

Chapter 5
Hardware Primitives-Based Security Protocols for the Internet of Things 117
Muhammad Naveed Aman, National University of Singapore, Singapore
Kee Chaing Chua, National University of Singapore, Singapore
Biplab Sikdar, National University of Singapore, Singapore

IoT is the enabling technology for a variety of new exciting services in a wide range of application areas including environmental monitoring, healthcare systems, energy management, transportation, and home and commercial automation. However, the low-cost and straightforward nature of IoT devices producing vast amounts of sensitive data raises many security concerns. Among the cyber threats, hardware-level threats are especially crucial for IoT systems. In particular, IoT devices are not physically

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protected and can easily be captured by an adversary to launch physical and side-channel attacks. This chapter introduces security protocols for IoT devices based on hardware security primitives called physically unclonable functions (PUFs). The protocols are discussed for the following major security principles: authentication and confidentiality, data provenance, and anonymity. The security analysis shows that security protocols based on hardware security primitives are not only secure against network-level threats but are also resilient against physical and side-channel attacks.

Chapter 6
Secure Computation of Private Set Intersection Cardinality With Linear Complexity 142
Sumit Kumar Debnath, National Institute of Technology Jamshedpur, India

PSI and its variants play a major role when the participants want to perform secret operations on their private data sets. The importance of this chapter is twofold. In the first phase, the author presents a size-hiding PSI-CA protocol followed by its authorized variant, APSI-CA, utilizing Bloom filter. All these constructions are proven to be secure in standard model with linear complexity. In the second phase, the author employs Bloom filter to design an efficient mPSI-CA protocol. It achieves fairness using offline semi-trusted third party (arbiter) unlike the most efficient existing protocols. The arbiter is semi-trusted in the sense that he does not have access to the private information of the entities while he will follow the protocol honestly. Proposed mPSI-CA is proven to be secure against malicious adversaries in the random oracle model (ROM) under the decisional Diffie-Hellman (DDH) assumption. It achieves linear complexity.

Chapter 7
A Secure Gateway Discovery Protocol Using Elliptic Curve Cryptography for Internet-Integrated MANET 181
Pooja Verma, Madan Mohan Malaviya University of Technology, India

Integration procedures are employed to increase and enhance computing networks and their application domain. Extensive studies towards the integration of MANET with the internet have been studied and worked towards addressing various challenges for such integration. Some idyllic mechanisms always fail due to the presence of some nasty node or other problems such as face alteration and eavesdropping. The focus of this chapter is on the design and discovery of secure gateway scheme in MANET employing trust-based security factors such as route trust and load ability. Over these, the elliptic curve cryptography is applied to achieve confidentiality, integrity, and authentication while selecting optimum gateway node that has less bandwidth, key storage space, and faster computational time. Simulation results of the security protocol through SPAN for AVISPA tool have shown encouraging results over two model checkers namely OFMC and CL-AtSe.

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Chapter 8
Preserving Security of Mobile Anchors Against Physical Layer Attacks: A Resilient Scheme for Wireless Node Localization.....211
Rathindra Nath Biswas, A. J. C. Bose Polytechnic, India
Swarup Kumar Mitra, MCKV Institute of Engineering, India
Mrinal Kanti Naskar, Jadavpur University, India

This chapter introduces a new security scheme for mobile anchors avoiding the physical layer attacks towards localization in wireless sensor networks (WSNs). In a network, anchors are made location-aware equipping them with GPS (global positioning system) receivers. Direction finding capabilities are also incorporated with smart antennas. The proposed algorithm is based on adaptive beamforming of smart array that always minimizes the probabilities of successful attacks, keeping the adversaries beyond its beam coverage. Particle swarm optimization (PSO) technique is used to compute array excitation coefficients, generating the desired pattern. Thus, anchors remain secured through pattern irregularities, deteriorating the information retrieval process even though chances of occurring adequate RSS (received signal strength)/AoA (angle of arrival) measurements may exist. Moreover, anchors are assumed to send pseudo references towards stationary nodes over private links, preserving data integrity for localization. Simulation results validate its effectiveness over the existing methods.

Chapter 9
An Adaptive Security Framework for the Internet of Things Applications Based on the Contextual Information 244
Harsuminder Kaur Gill, Jaypee University of Information Technology, India
Anil Kumar Verma, Thapar University, India
Rajinder Sandhu, Jaypee University of Information Technology, India

With the growth of Internet of Things and user demand for personalized applications, context-aware applications are gaining popularity in current IT cyberspace. Personalized content, which can be a notification, recommendation, etc., are generated based on the contextual information such as location, temperature, and nearby objects. Furthermore, contextual information can also play an important role in security management of user or device in real time. When the context of a user or device changes, the security mechanisms should also be updated in real time for better performance and quality of service. Access to a specific resource may also be dependent upon user's/device's current context. In this chapter, the role of contextual information for IoT application security is discussed and a framework is provided which auto-updates security policy of the device based on its current context. Proposed framework makes use of machine learning algorithm to update the security policies based on the current context of the IoT device(s).

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Section 4
Social/Legal Issues and Forensics

This section illustrates various concerns regarding the social and legal aspects of the internet of things through a case study. It also discusses the importance of digital forensics for the Internet of Things and its underlying challenges.

Chapter 10
Emerging Social and Legal Issues of the Internet of Things: A Case Study 269
Valentina Amenta, National Research Council, Italy
Adriana Lazzaroni, National Research Council, Italy
Laura Abba, National Research Council, Italy

The advent of internet represents a revolution for the contemporary era, having brought about a striking series of changes in social, institutional, political, and economic life. This ongoing revolution has spread and absorbed within itself all the problems related to its own development. Objects become recognizable and acquire intelligence in that they are able to communicate data regarding themselves and also access other information aggregated by other devices. They are able to participate in a dialogue and interact among themselves within electronic communication networks without human intervention. All objects can acquire an active role thanks to connection with the web. The associated problems, which can no longer be ignored, draw attention above all to the lack of data control, which is to the vast extent of the data collected and more generally to the security of these data. This chapter has the aim of analyzing the ways in which European legislators, and consequently also Italian representatives, have intervened in order to stem the tide of emerging issues.

Chapter 11
Digital Forensics in the Context of the Internet of Things 296
Mariya Shafat Kirmani, University of Kashmir, India
Mohammad Tariq Banday, University of Kashmir, India

The pervasive nature of IoT, envisioned with the characteristics of diversity, heterogeneity, and complexity, is diluting the boundaries between the physical and digital worlds. IoT being widely distributed qualifies it as the breeding ground for cyber-attacks. Although remarkable work is being done to ensure security in IoT infrastructure, security vulnerabilities persist. The IoT infrastructure can either be used as a direct target in a cyber-attack or exploited as a tool to carry a cyber-attack. In either case, the security measures in IoT infrastructure is compromised. The enormous IoT data is sensitive that can act as a gold mine to both the criminals for illicit exploitation or investigators to act as digital witness. IoT forensics help the investigators to acquire intelligence from this smart infrastructure to reconstruct the historical events occurred. However, due to sophisticated IoT architecture,

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the digital investigators face myriad challenges in IoT-related investigations using existing investigation methodologies and, hence, demand a separate dedicated forensic framework.

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MOHINDRU

UNMANNED AERIAL VEHICLES

UNMANNED AERIAL VEHICLES FOR INTERNET OF THINGS

CONCEPTS, TECHNIQUES, AND APPLICATIONS



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Concepts, Techniques, and Applications

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Vandana Mohindru,
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and
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Preface

Unmanned aerial vehicles (UAVs) have become one of the rapidly growing areas of technology, with widespread applications covering various domains. UAVs play a very important role in delivering Internet of Things (IoT) services in small and low-power devices such as sensors, cameras, GPS receivers, etc. These devices are energy-constrained and are unable to communicate over long distances. The UAVs work dynamically for IoT applications in which they collect data and transmit it to other devices that are out of the communication range. Furthermore, the benefits of the UAV include deployment at remote locations, the ability to carry flexible payloads, reprogrammability during tasks, and the ability to sense for anything from anywhere. Using IoT technologies, a UAV may be observed as a terminal device connected in the ubiquitous network, where many other UAVs are communicating, navigating, controlling, and surveilling in real time and beyond line-of-sight.

However, many significant research challenges should be addressed before bringing such UAV capabilities into practice. The aim of this book is to explore the theoretical as well as technical research outcomes of all aspects of UAVs. The UAV has drastically altered the perspectives of users, practitioners, and researchers in many fields of application such as disaster management, structural inspection, goods delivery, transportation, localization, mapping, pollution and radiation monitoring, search and rescue, farming, etc. The advancements introduced by UAVs are countless and have led the way for the full integration of UAVs as intelligent objects in the IoT.

This book helps to realize the full potential of the UAV for the IoT by addressing its numerous concepts, issues and challenges, and develops conceptual and technological solutions for handling them. It is comprised of 15 chapters authored by various renowned experts in the UAV and IoT fields. The book is organized as follows:

Chapter 1 presents a comprehensive survey of UAVs. The communication standards, workings, and various technologies of UAV are presented.

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Also, platforms of different types of drones in various categories, their working, types, sizes, and other technology employed in making them are explored. Furthermore, the latest ongoing technology used in drones and their recent advancements are discussed.

Chapter 2 highlights the state-of-the-art, challenges encountered and the open research issues in designing UAV-aided wireless communication networks. A few of the challenges identified and presented include the best methods of 3D deployment of drones, allocation of resources, optimization of the flight time and trajectory of UAVs, handover management, channel modeling of highly dynamic UAV channels in various scenarios of UAV-assisted networks, interference management, effects of higher Doppler shifts in mmWave networks, on-board energy availability of UAV devices, etc.

Chapter 3 focuses on the techniques available for effective battery and energy management in UAV-based communication networks. The mechanisms for the optimal utilization of energy resources by UAVs to maximize their lifespan or deployment in a network are critically examined. This helps to significantly reduce the usage of network energy that results in a prolonged network lifetime. Furthermore, potentially promising areas for future research in energy management are also explored.

Chapter 4 emphasizes the most used communication techniques in UAVs. The state-of-the-art literature regarding UAV communication techniques and a summary of the same in the form of challenges and issues that arise when developing communication methods for UAVs are presented. A comprehensive performance comparison of UAV communication techniques is provided at the end of this chapter.

Chapter 5 discusses different challenges and threats posed by UAVs such as hijacking, privacy, cybersecurity, and physical safety. Also discussed are different solutions for avoiding these issues with current technologies.

Chapter 6 bridges the landscape between the IoT and the UAV by identifying the technical and nontechnical issues facing integration. Also presented are various applications, architecture, and technologies of the UAV-enabled IoT. This chapter answers the question regarding the proximity between IoT and UAV by exploiting the mobility of UAVs.

Chapter 7 introduces the practice of using UAVs for security and intelligence and also relates how drones are employed in different domains and for different purposes, including mischievous ones. Also, new experiments are presented related to security, safety, and privacy concerns when UAV drones are engaged in dangerous activities.

Chapter 8 explores blockchain-based solutions for various security issues in UAV-enabled IoT. Though the fusion of UAVs and IoT proves disruptive,

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it is needed to address increased security issues. Identity management, authentication, UAV hijacking, secured and trustworthy data sharing in intra-UAV communications, and UAV signal jamming are explored in this chapter. Since blockchain is a decentralized technology, a distributed ledger offers solutions to some of these UAV issues presented here.

Chapter 9 introduces the efficient energy management systems in UAV-based IoT networks. The major constraint envisaged is the limited battery capacity of UAVs, proving them to be energy-constrained devices. The methods described here either harvest energy from RF signals or mmWaves, charge wirelessly from the charging station, or change the flight conditions for efficient energy utilization.

Chapter 10 contains an inclusive survey on the challenges and opportunities of IoE-enabled UAVs. There is a review of technologies enabling these opportunities, such as battery constraint, security issues, computing, and coverage constraints; and there is also an overview of UAVs. Finally, IoE-enabled UAV technology is presented that uses UAV deployment and mobility with IoE's intelligence, scalability, and diversity.

Chapter 11 provides a comprehensive survey of research for exploring applications of AI in UAV-enabled IoT systems with a specific focus on the research being conducted in the field of convergence of three disruptive technologies—namely, AI, UAVs, and the IoT—for improving the quality of life. The importance of AI in realizing an autonomous and intelligent flying IoT is emphasized.

Chapter 12 aims to follow a modular design approach to provide better functionality and a wide range of applications in all sorts of fields. It also incorporates the IoT in the UAV with all the sensor data of the surrounding environment with a UAV position that can be transmitted to a remote server and analyzed in real time.

Chapter 13 focuses on a mind-controlled UAV using brain-computer interface (BCI), which is a connection between the human brain and computers. The scope of this chapter is concentrated on the development boards which permit wireless communications.

Chapter 14 analyzes the new era farming system and the role of UAV technologies which help to improve the agricultural area to enable farmers to make cost-effective decisions while also preserving the ecosystem and changing how food is generated.

Chapter 15 explores the IoT-based UAV platform revolutionizing smart healthcare. The mobile phone industry and the IoT networks that are making robust data collection possible are rapidly being used in medical tools and software. This chapter discusses healthcare IoT technologies and their advantages for society.

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In closing, we would like to thank our contributing authors for their valuable work, without which it would have been impossible to complete this book. We would also like to express our deepest appreciation to our reviewers for submitting their valuable comments in a timely manner. Last but not least, we thank GOD for giving us the strength and wisdom to carry out this work successfully even during tough circumstances due to the COVID-19 pandemic.

We hope that the quality research work published in the 15 chapters of this book will serve the needs of those in the academic, research, science and technology communities along with all of humanity.

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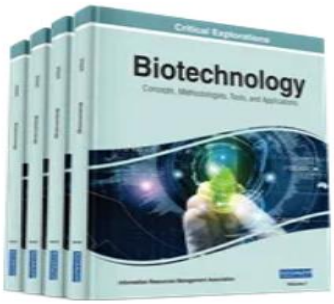

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Environmental Pollution pp 225–232

Biomedical Waste Generation and Management in Public Sector Hospital in Shimla City

Prachi Vasistha, Rajiv Ganguly & Ashok Kumar Gupta

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1285 Accesses | **6** Citations

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Abstract

Biomedical waste disposal is very important due to its infectious nature. Proper management of biomedical waste is necessary for maintaining good human health and environment. Biomedical Waste (Management and Handling) rules 1998 under the Environmental Protection Act, 1986 have been passed by government of India which is to be followed strictly to avoid menace. The purpose of the article is to differentiate between the Biomedical Waste Management practices such as collection, storage, transportation, and disposal along with the generation of biomedical waste undertaken in major public and private sector hospitals in Shimla city. A cross-sectional study and semi-structured interview considering the various biomedical waste management practices and

personnel handling of the biomedical waste undertaken in the major public and private sector hospitals in Shimla city through detailed analysis and questionnaire prepared will be used for the purpose of study. The study will quantify the actual values and unveil the difference that lie in management procedures followed by these hospitals in Shimla. The present paper presents some initial findings of the questionnaire analysis carried out in a major public hospital in Shimla.

Lecture Notes in Electrical Engineering 698

Amit Kumar
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Challenges and Opportunities with ECC and Noncommutative Cryptography: A Survey Perspective

Gautam Kumar , Sheo Kumar & Hemraj Saini

Conference paper | First Online: 12 October 2020

944 Accesses

Part of the Lecture Notes in Electrical Engineering book series (LNEE,volume 698)

Abstract

Due rapid growth in technological tools and techniques, there are various required considerations to take in the field of information security. The buzzwords of security and privacy are always being important observations in that regards. If consider the overall scenario Elliptic Curve Cryptography (ECC) is releasing one of the most powerful algorithm in relation to better performance and security related concerns than RSA algorithm. It is working as light-weight cryptography due to following reasons such as low computation costs, use of shorter key sizes, and the discrete logarithmic problem is nearly is hard to achieve on computational complexities. With ECC algorithm, to implement the same with noncommutative cryptography assumptions, which is one of the possible generalizations on noncommutative properties, that adds valuable research contributions in perfect secrecy. The prospective thoughts are considered in relation to the same.

Keywords

ECC Noncommutative cryptography Computational complexity Security PKC

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Chebyshev Polynomials-Based Pulse Compression Waveform for Modern Microwave Radars

Ankur Thakur, Salman Raju Talluri & P. K. Verma

Conference paper | First Online: 20 December 2019

1210 Accesses

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Abstract

This paper portrays the Chebyshev polynomial-based waveform for the improvement in peak side lobe levels (PSL), time–bandwidth (TB) product, and ambiguity function (AF). In the radar system, PSL and relative main lobe width are the main parameters to indicate the suitability of the waveform. Using the matched filter, the transmitted waveform's ambiguities in range and velocity can be examined at the radar receiver. Here, two cases have been considered to analyses these parameters. In the first case, different orders of ordinary Chebyshev polynomials are analyzed, whereas in the second case, alteration in the cycles of Chebyshev polynomial of different orders is assimilated. This modified signal is obtained by changing the polarities of the cycles depending on zero crossing. From the simulation, it is perceived that the half-cycle-modified polynomials have better results for the pulse compression and also their AF are analyzed to examine the resolution property. The entire stated method is applied with the aid of simulation verification and mathematical equations.

Keywords

Ambiguity function **Chebyshev polynomial** **Matched filter** **Peak side lobe level** **Pulse compression**

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Advances in Sugarcane Biorefinery

Technologies, Commercialization, Policy Issues and Paradigm Shift for Bioethanol and By-Products

Edited by Anuj Chandel and Marcos Henrique Luciano Silveira

In *Advances in Sugarcane Biorefinery*, Chandel and Silveira compile the basic and applied information covering sugarcane and biomass processing for sugar and ethanol production and by-products utilization for improving the economy of sugarcane biorefineries. In this unique collection of 14 chapters, specialists in their field present critical insights, review of current research, and discussions of future progress in this research area.

It presents the most current advances in sugarcane biorefinery starting from the sugarcane crop cultivation, new sugarcane varieties, mechanization of biomass collection, technical aspects of first- and second-generation ethanol production, economic analysis, life-cycle assessment, biomass logistics and storage, cogeneration of heat and electricity, process intensification, and alternative by-products utilization. It also explores the business ecosystem of sugarcane biorefineries, marketing analysis of ethanol demand, and price dwindling pattern aiming for a futuristic scenario.

This book will be especially useful for scientists, researchers, and engineers who are working in the area of biomass-based biorefineries, as well as professionals in the sugar and alcohol industry. It also brings relevant content for policy makers, market analysts, agricultural scientists, and managers.

KEY FEATURES

- Presents technological updates on sugarcane biomass processing, system biology, microbial fermentation, biochemicals, and ethanol business.
- Includes topics on techno-economic analysis, life-cycle assessment, sustainability, markets, and policy issues.
- Explores the future potential of biorefineries with zero or near zero waste and the valorization of by-products, including alternatives to current applications and the biomass management.

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Technologies, Commercialization, Policy Issues and Paradigm Shift for Bioethanol and By-Products

2018, Pages 241-252

Chapter 12 - Comparative Account of Carbon Footprints of Burning Gasoline and Ethanol

Rajiv Ganguly, Vijay Kumar Garlapati

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Abstract

Now days, climate change is one of the tangible issues that have to be solved to avoid major environmental consequences in the near future. Melting of glaciers, rising of sea levels, occurrence of drastic storm and drought conditions, and annual increase in global temperatures are some of the examples of climate change consequences due to the Greenhouse Gas (GHG) emissions by vehicles. The transportation sector is one of the major contributors of GHG emissions from man-made activities which accounts for approximately 14% of emissions globally. Ethanol is one of the transportation fuels as an alternative to the exhausting fossil fuel, gasoline. In view of growing concern about climate change, the analysts analyzing the potential impact of new transportation fuels on climate change for long-term usage are framing certain recommendations to combat the deleterious effects of climate change. This chapter provides an overview of carbon footprints, GHG emissions, climate change, and IPCC recommendations on gasoline and ethanol usage as a transportation fuel.

Previous Next

Keywords

Burning; climate change; ethanol; gasoline; GHG emission; IPCC

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Scalable technologies for lignocellulosic biomass processing into cellulosic ethanol

2019, Horizons in Bioprocess Engineering

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Nagamani Balagurusamy
Anuj Kumar Chandel *Editors*

Biogas Production

From Anaerobic Digestion to a Sustainable Bioenergy Industry

Springer

Comparative Analysis of Biogas with Renewable Fuels and Energy: Physicochemical Properties and Carbon Footprints

Edith Mier-Alba, Salvador Sánchez-Muñoz, Fernanda Gonçalves Barbosa, Vijay Kumar Garlapati, Nagamani Balagurusamy, Silvio Silvério da Silva, Júlio César dos Santos & Anuj Kumar Chandel

Chapter | First Online: 12 January 2021

591 Accesses

Abstract

Industrialization, infrastructure development, energy production, and their use are the engines of the economic growth of any country. These growth drivers permanently require the uninterrupted supply of energy and fuels. Currently, gasoline and its products are a primary source which is fulfilling the energy requirement. However, their excessive usage as an energy source is generating the greenhouse gasses (GHGs), which deteriorate the environment and eventually cause negative impact on the climate. Currently, more than 85% of the world's total energy needs are being fulfilled by crude petroleum resources. Therefore, it is necessary to look out for alternative fuels that are renewable and cause a low impact on the environment. Because of environmental concerns, there is a strong push to implement renewable energy sources. Renewable fuels and energies can play a crucial role in lowering GHG emissions and thus keeping the environment clean and green, which eventually meets the sustainability goals. Cellulosic ethanol in the USA and Brazil, biodiesel and biogas in Brazil and some European countries, and solar energy in India have shown promising growth. The carbon emissions of renewable fuels are very low compared to crude petroleum. This chapter compares the current scenario of biofuel implementation in various countries. Particular emphasis is placed on the current status of biogas development and commercialization. The carbon footprints of various biofuels/energies are also discussed.

Keywords

Biogas **Bioethanol** **Biodiesel** **Carbon footprints** **Carbon emissions** **Sustainability**



Innovations in Information and Communication Technologies (IICT-2020) pp 329–334

Comparative Analysis of Transform Domain Watermarking System Based on Performance Measures

Namita Agarwal , Amit Kumar & Pradeep Kumar Singh

Conference paper | First Online: 16 July 2021

383 Accesses

Part of the Advances in Science, Technology & Innovation book series (ASTI)

Abstract

In last few decades, data security has been a challenging issue to protect the copyright information and integrity of digital products. So digital watermarking is founded as one of the talented methods to defend digitized media. This paper defines functioning of major transform domain methods such as discrete cosine transform (DCT), quaternion Hadamard transform (QHT), discrete wavelet transform (DWT), discrete contourlet transform (DCT), and many more are discussed. Comparison of these techniques based on peak signal-to-noise ratio (PSNR) and normalized correlation (NC) is discussed in this paper. Various types of attacks are also evaluated on these techniques.

Keywords

Discrete wavelet transform (DWT)

Watermarking

Quaternion hadamard transform (QHT)

Discrete contourlet transform (DCT)

Peak signal-to-noise ratio (PSNR)

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Computational Network Approaches and Their Applications for Complex Diseases

Ankita Shukla & Tiratha Raj Singh

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Abstract

Network biology has been widely used for the interaction studies and analysis in modern era. Studies associated with biological networks, their modeling, analysis, and visualization are imperative to the biological world. The advancements in network biology have helped us better understand the biomolecular complexities which in earlier times were difficult to study in vivo. High-throughput technologies have revolutionized the genomic-sequencing procedures for the generation of tremendous data that need to be analyzed and interpreted rigorously. However it has still been difficult to construe biological networks completely due to the complexity of the interactions that exist between its components. Great efforts have been made to disclose the maximum possible interactions that are significant to maintain the potential mechanisms with the help of network biology. With improvement in the analysis process, network biology has thought to be playing a key role in understanding the complex biological behavior of the networks. In this chapter we will cover the basics of network biology and its expansion in various disciplines and its implementations in complex diseases and disorders, current resources, and tools available for studying diverse forms of pathways (transcriptional regulation, protein–protein interaction, signal transduction, and metabolism). This chapter therefore deals with the core of network biology, its role in various disease studies, and the advancements introduced so far in this field.

Keywords

Interactome **Cancers** **Autis m** **Network motif** **Cardiovascula r** **Agin g** **Diabete s**

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Sanket Saxena, Shivam Sinha & Shruti Jain

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Abstract

An ongoing advancement in the condition of craftsmanship innovation assumes an imperative job in the picture handling applications, like biomedical, satellite picture preparing, artificial intelligence, object recognizable proof, diabetic retinopathy (DR), etc. DR is an eye disease found in people having high blood sugar. It can lead to loss of vision, if it is not treated properly. There is an increase in number of patients in comparison with ophthalmologists. The seriousness of the DR depends upon nearness of microaneurysms, hemorrhages, exudates and neovascularization. Specialists arrange diabetic retinopathy into five stages, namely ordinary, gentle, moderate, non-proliferative DR (NPDR) or proliferative DR (PDR). Convolutional neural network (CNN) results in high accuracy in classifying these diseases by spatial analysis. A CNN is progressively mind-boggling engineering construed more from the human visual perspective. A previous study done on DR suggests the use of CNN but with a different approach. Among other managed calculations involved, the proposed arrangement is to locate a superior and advanced way to classify the fundus picture with little pre-preparing techniques. Different fundus image databases available have been discussed. In this paper, different parameters used for the evaluation of developed systems have been presented.

Keywords

Deep learning CNN Regularization Cost function Non-proliferative Kaggle

Rajesh K. Sani
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Extremophilic Microbial Processing of Lignocellulosic Feedstocks to Biofuels, Value-Added Products, and Usable Power

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Conversion of Lignocellulosic Feedstocks into Biogas

Ritika Verma, Abhilash Kumar Tripathi & Sudhir Kumar

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Abstract

This chapter will discuss in detail about the different processes involved in conversion of lignocellulosic feedstocks into biogas and the shortcomings of the conventional processes. The different methods of physical, chemical, and biological pretreatment for the lignocellulose will be discussed. The chapter also addresses methods of biogas production, analysis, and the different biogas reactors.

Keywords

Biogas **AD** **Lignocellulosic feedstock** **Extremophiles** **Biomethane** **Bioreactors** **Methanogens**

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Handbook of Research on

Machine Learning Techniques for Pattern Recognition and Information Security



Mohit Dua and Ankit Kumar Jain

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Handbook of Environmental Materials Management

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Critical Assessment of Existing Environmental Legislation and Policies in India, Its Benefits, Limitation, and Enforcement

Anirban Dhulia and Rajiv Ganguly

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Abstract

The problem of environmental pollution has attained international dimension due to rapid industrialization and urbanization, increased population growth, and overexploitation of natural resources leading to disruption of ecological balances. The problem is more pronounced and significant for developing countries like India. In this context, a regulatory framework is necessary for protection of existing enriched environmental system and integration of environmental realities while making decisions on economic issues and activities related to urban growth. Development of a comprehensive environmental policy in India poses

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several challenges including regulatory framework covering all aspects of environmental protection, modification of existing legislation for better achievement of its objectives, and establishment of governing boards for implementation of the framed and modified legislation. Other concerns involve political, social, and economic compromises made for development of infrastructure utilizing eco-friendly technology, implementing our international obligations through national legislation and creating awareness on other environmental issues. The Indian Government introduced two articles 48A and 51A in the Constitution of India in 1976 to tackle the issues of environmental pollution. While article 48A empowers the state to protect forest and wildlife of the country Article 51A gives powers to the citizens of the country for improvement and protection of the environment. Hence, the powers of the two articles combined as per the constitutional guidelines give sufficient power to both state and citizens for protection of the environment. In this context, the Environmental Protection Act was envisioned which subsequently led to enactment of different acts including Water (Prevention and Control of Pollution) Act, 1974; the Water (Prevention and Control of Pollution) Cess Act, 1977; the Air (Prevention and Control of Pollution) Act, 1981; the Environment (Protection) Act, 1986; Public Liability Insurance Act, 1991; the National Environment Tribunal Act, 1995; the Wildlife (Protection) Act, 1972; and the Forest (Conservation) Act, 1980. The enactments of the acts show that India had taken a definitive approach for environmental protection but the biggest lacunae observed was the enforcement of these acts strictly in case of reported violations. Hence, there is an immediate need to ensure proper enforcement of the constitutional mandate and other environmental laws as the effectiveness of those policies is diluted due to nonenforcement. The book chapter discusses the existing Indian environmental legislation and policies, their suitability and drawbacks in the present context, proposed changes to such policy, and methods on effective implementation of these legislation.

Keywords
Water (Prevention and Control of Pollution) Act · Water (Prevention and Control of Pollution) Cess Act · Air (Prevention and Control of Pollution) Act · Environment (Protection) Act · Public Liability Insurance Act · National Environment Tribunal Act · Wildlife (Protection) Act · Forest (Conservation) Act

Introduction

The need for conservation and sustainable use of natural resources to protect the environment and preserve the natural resources of the country had been introduced in the constitutional, legislative, and policy framework with active intervention of judiciary in the earlier decades. After the UN conference on the human environment at Stockholm in 1992, a structured framework of environmental legislation was developed relating to environmental protection (Environmental Protection Authority 2016; Environmental Law & Practice Review 2011; Jayakumar 1987). In this

context, the National Council for Environmental Policy and Planning was established as an authority for environmental protection under the Department of Science and Technology in 1972, which is presently known as the Ministry of Environment and Forest (MoEF) (Jayakumar 1987). MoEF acts as an advisory body in all matters relating to protection of environment and its improvement, but the responsibility for execution remains with the various ministries and government agencies. The Government of India declared the Policy Statement for Abatement of Pollution in 1992 which states "This statement declares the objective of the government to integrate environmental considerations into decision-making at all levels."

Recent Legislative Measures

In the last two decades, the Central Ministry of Environment has undertaken several steps to provide legal and institutional empowerment for protection of environment by making legislative guidelines, notification of standards, and delegation of powers, for hazardous chemical management, identification of agencies, and setting up of environmental councils in few states. In the delegated legislation areas, effluent and emission standards for 24 industries were specified and under the environment act general standards for effluent discharge and for noise pollution were prescribed. To check that the effluents met the prescribed standards, about 70 environmental laboratories were established across the country for the analysis of the effluent water and air samples. A gazette notification on environmental audit was issued, whereby under the Water Act, 1974, and the Air Act, 1981, carrying out an environment audit was made compulsory for all industries requiring environmental clearance. Further, in 1996, the Central Government framed the Chemical Accidents (Emergency, Planning, Preparedness, and Response) Rules to Supplement the Hazardous Chemical Rules of 1989 and in 1998 Bio-Medical Waste (Management and Handling) Rules were issued for biomedical waste regulation.

In particular, for establishment of an industry within the state and to obtain consent from the State Pollution Control Board, the Central Government enacted the Prevention and Control of Pollution Rules, 1999, requiring for all industries to be listed in the Environment Act, 1986. Further, the Government of India established the Recycled Plastic Manufacture and Usage Rules in 1999 prohibiting vendors packing foodstuff in recycled plastic bags or containers; instead foodstuff is directed to be sold in plastic bags which must be made of virgin plastic. It was mandated that municipal authority will be responsible for collection, segregations, storage, transportation, processing, and disposal of municipal solid wastes following Municipal Solid Wastes (Management and Handling) Rules, 2000, which has been updated in 2016. The State Pollution Control Boards have been made responsible for monitoring the compliance of the standards regarding groundwater, ambient air quality, and quality of compost within their state boundary premises. Further, the Noise Pollution (Regulation and Control) Rules, under 1986 Environment Protection Act, was established by the Central Government in the year 2000 prescribing the ambient air quality standards for different zones (residential, commercial, industrial, and

silence). Similarly, the Ozone Depleting Substances (Regulation and Control) Rules, 2000, was enacted by the Central Government under the Environment Protection Act. The rule focused on mandatory registration of manufacturers, dealers, and users of ozone-depleting products like halons, radons, CFCs, carbon tetrachloride (CCl_4), and similar other compounds. Establishment of such legislation effectively covers a diverse field including noise, hazardous waste, hazardous microorganisms, environment impact assessment, and others. Such legislation also improve the functioning of the existing monitoring agencies and formation of new regulatory bodies wherein required.

The Environment Protection Act, 1986

In India though many of legislation are meant to protect the environment from pollution, the enforcement of such legislations has not so far been considered in totality. Under Article 253 of the Indian Constitution, the Environment (Protection) Act, 1986, was enacted to implement the decisions made at the United Nations Conference on Human Environment held at Stockholm, 1972, and was expected to provide a blueprint for a progressive policy for protecting the ecosystem. The Environment (Protection) Act, 1986, was enacted to provide the protection and improvement of the quality of environment in order to prevent, control, and abate environmental pollution. As a direct consequence of the Bhopal Gas Tragedy, the Act came into existence and seeks to supplement the laws existing on control of pollution by enacting a general legislation for environmental protection and to fill the gaps in regulations of major environmental hazards. However, the Act has been invoked in very few cases. The Act is a special law and extends to the whole of India. The term "environment" has been defined to include water, air, and land, and the interrelationship existing amongst water, air, and land and human beings, other living creatures, plants, microorganism, and property. The definition is wide enough to include within its purview all living creatures including plants and microorganism and their relationship with biosphere. The Act has given vast powers to the Central Government to take measures with respect to planning and execution of a nationwide program for prevention, control, and abatement of environmental pollution. It empowers the government to lay standards for the quality of environment, emission, or discharge of environmental pollutants; for regulation of industrial locations; to prescribe procedure for managing hazardous substances, to establish safeguards for preventing accidents; and to collect and disseminate information regarding environmental pollution. The Act can be said to be an "umbrella" legislation designed to provide a framework for Central Government, and coordination of the activities of various central and state authorities established under previous laws, such as the Water Act and the Air Act. Thus, as regards air pollution, apart from the preventive or controlling measures under the Air Act, the residue protection of air would come within the Environment Act. According to the Preamble, the objective of the Environment Act is ". . . to provide for the protection and improvement of environment and for matters connected therewith."

Environment (Protection) Rules, 1986

The rule-making powers envisaged under the Environment Protection Act are quite exhaustive and have wide coverage and varied dimensions. The general rule-making power is conferred on the Central Government for carrying out the provision of the Act. The Department of Environment, Forests and Wildlife of Central Ministry of Environment and Forests has been entrusted with the responsibility for making these rules for implementation within the Environment Act. The Department has adopted specific industry standards for effluent discharge and has prescribed general effluent standards for other water polluters. Certain central and state officials are designated to carry out specific duties under the Act and for testing the samples of air or emissions obtained specific laboratories are also designated.

Under the Environment Act, the Central Government is empowered to establish standards for the quality of the environment in its various aspects that include maximum allowable concentration of various environmental pollutants for different areas and could be based on ambient levels of pollutants sufficiently low to protect the public health and welfare. To ensure that ambient levels are achieved emission or discharge standards for particular industries could be adjusted as per the requirement. The Environmental (Protection) Rules, 1986, do allow the state or central authorities to establish stricter emission/discharge standards, based on the recipient system quality than the present uniform and existing standards.

Further, the rules state the factors, which the Central Government should consider while it prohibits or restricts the location of any industry or carries on processes and operations in different areas. The climatic features, topography of the area and the biological diversity, as opined by the Central Government needs to be preserved and should be compatible environmentally within useful proximity to human settlement are some of the important factors to be considered. However, for areas that are not notified, the public has no provision to challenge the location of an industry. The provided safeguards for taking and sending samples for analysis are in recognition of the right of a fair process of law. The function of environmental laboratories, government analyst's qualification, and the manner of giving notices are also laid down by the rules. The Environment Act and Rules give powers to the Central Government which can be used to implement newer concepts like Environment Audit, EcoMark, Environment Impact Assessment, and other such suitable measures.

National Environment Appellate Authority Act, 1997

The National Environment Appellate Authority (NEAA) Act was established in 1997 under Article 123 wherein it has the power to hear appeals in respect to those restricted areas in which an industry was situated and is governed by the Environment (Protection) Act, 1986, and it came into existence on January 1998. This replaced the above-mentioned legislation. The inaugural chairman of NEAA was Justice J.S. Verma who mentioned that it was a very sound decision of the

government and its implementation will bring the expected results within a very short timeframe. It was promulgated that from the date of its establishment no civil court or other higher authority shall have the right to consider an appeal in any respect of the matter of authority under the purview of this act. The main office of the Appellate is located in Delhi but the appeal process can be made and heard at any location in India. The hearing authority shall be comprised of Chairperson, a Vice-Chairperson, and such other members (appointed by President) not exceeding three as the Central Government may deem fit as per Section 4. It was framed that the Chairperson should have served as judge of the Supreme Court, or the Chief Justice of a High Court. Further, a person to be appointed as Vice-Chairperson should have held the post of a Secretary to the Government of India for a minimum of 2 years, and must have sufficient expertise in administrative, legal, managerial, or technical aspects of environment-related problems. Under Section 5, an appointed member must possess sufficient professional knowledge or practical experience in the areas pertaining to conservation, environment management, law, or planning and development. The Vice-Chairperson should not be a bureaucrat as it may influence his or her decision regarding environmental concerns. Under the aegis of the Act an appeal can be launched by the aggrieved personnel if it is believed that no operating unit or industry should be set up in protected areas but environmental clearance has been provided in such cases that may file their appeal within 30 days of the order. However, there remain provisions in the Act to consider special circumstances if the appeal is filed after the mandatory 30-day period. Once the concern petition or appeal has been filed, the NEAA must resolve the issue within 90 days of the filing of the initial petition date. A further 30 days' extension may be taken under special circumstances under the provisions of Section 11 of the Act. It is important to note that the decision of NEAA is independent of the regulations of Code of Civil Procedure 1908 but should abide by natural justice system, and follow specifically the rules of the NEAA and any other similar rules enacted by the Government of India. Further, the NEAA has the provisions of acting as its own regulatory body. Though the NEAA is independent of Code of Civil Procedure it has equivalent powers (Section 12) with guilty party being punishable by maximum of 7 years in prison with affine of INR one lakh or both (Section 19). If the misdeed has been conducted by a company or a manufacturing unit then all personnel involved in running the company or the unit will be deemed guilty and will be punished as per the offence. Nonetheless an executive shall not be held liable if he or she can sufficiently prove that the offence was carried out without his or her prior knowledge and information and thereby may be freed from any prosecutable action.

The establishment of NEAA has been well received by both the people and the industrial community. It is expected that related to environmental concerns and disputes the Authority will act swiftly, unbiased, and deliver its judgement within the mandated timeframe. Further, in certain states like Andhra Pradesh, the State Pollution Control Board has also designated the Authority to play an advisory role for those judgements passed to the government from High Court or Supreme Court related to environmental issues. The term "person" in the provision of the Act has a wide scope of its application. Finally, it is the duty of the committee to ensure its

independent working and provide confidence amongst all parties of its unbiasedness regarding the appeal. Importantly, it can delegate matters wherein the environmental clearance has already been mandated and not for those wherein the EC is under consideration or directly refused.

Water (Protection and Control of Pollution) Act, 1974

India's profound deterioration in water quality has resulted due to rapid industrialization urbanization and green revolution. India's Water (Protection and Control of Pollution) Act, 1974, was the first major water legislation, passed by the Parliament to provide legislative support for prevention of water pollution. The prevention and control of water pollution and maintaining or restoring of wholesomeness of water (in the streams of well or on land) are the major objectives of this Act. The Act vests regulatory authority in the state boards empowering establishment and enforcement of effluent standards for factories that discharge pollutants directly into water bodies. A central board performs the same functions for union territories and coordinates activities amongst the different states (Agarwal 2005). Sewage and industrial effluent discharges are controlled by the board for approval, rejection, or conditioning applications for consent to discharge. By advising state governments on appropriate sites for new industry the state boards take steps to minimize water pollution. Power is granted to the board to ensure compliance with the Act by including the power of entry for examination, testing of equipment, and other purposes and power to take the sample for the purpose of analysis of water from any stream or well or sample of any sewage or trade effluents. Prior to its amendment in 1988, enforcement under the Water Act was achieved through criminal prosecutions initiated by the boards and through applications to magistrates for inculcations to restrain polluters. The amendment made on the year 1988 strengthened the implementation of the provisions in the Act. Now, a board may shut a default industrial plant or withdraw its power or water supply by an order from administration; the penalties are even more stringent, and a citizen's suit provision supports the enforcement machinery.

The Water (Prevention and Control of Pollution) Cess Act, 1977

The Water Cess Act was passed to meet the expenses of the Central and State Water Boards. The Water (Prevention and Control of Pollution) Cess Act, 1977, aims to provide levy and collection of a cess on water consumption by persons carrying certain industries and local authorities to augment the resources of the central board and the state boards constituted for the prevention and control of water pollution. The objective is to repay money for the activities which lead to pollution and thereby the polluter must bear the expenses of the remediation of the pollution such caused. The economic incentives are created for pollution control and require local authorities and certain designated industries to pay a cess (tax) for water consumption. These revenues are used for implementation of the Water Act. After deducting the

expenses of collection the Central Government pays the central board and the states such sums, as it deems necessary to enforce the provisions of Water Act. A rebate of about 70% is given to a polluter on the applicable cess upon installing effluent treatment equipment in order to encourage capital investment in pollution control. Furthermore 1974 Water Act also prohibits the use of any stream or well (the expression "stream" includes rivers) for disposal of polluting matter, etc.

Air (Prevention and Control of Pollution) Act, 1981

Air (Prevention and Control of Pollution) Act, 1981, referred to as Air Act, 1981, was enacted to provide legislative support for prevention and control of air pollution. The Act aims to prevent, control, and reduce air pollution; besides this, Environmental (Protection) Act, 1986, also covers some other aspects of air pollution. The United Nations Conference on the Human Environment held at Stockholm in June 1972 laid the platform for the drafting of the Air Act in India. Subsequently, the Parliament enacted the nationwide Air Act named as The Air (Prevention and Control of Pollution) Act of 1981. The Act was further amended in 1987. The main objectives of this Act are to improve the quality of air and to prevent, control, and abate air pollution in the country.

The Air Act's framework is similar to the one created by its predecessor, the Water Act of 1974. To enable an integrated approach to environmental problems, the Air Act expanded the authority of the central and state boards established under the Water Act to include air pollution control. States not having water pollution boards were required to set up air pollution boards. Under the Act, all industries operating within designated air pollution control areas need to obtain consent from the state boards. After consulting the central board the states are required to prescribe standards for industry and automobile emission and its ambient air quality standards. The Air Act granted power to the board to ensure compliance with the provisions of the Act for which powers were bestowed to the board including the power of entry for examination, testing of equipment and other purposes like analysis of air or emission from any chimney, flyash or dust from any other outlet in such manner as may be prescribed.

The Air Act has been designed to prevent, control, and abate air pollution. Industries, automobiles, domestic fires, and others are the major sources of air pollution. The polluted air adversely affects heart and lung and actively reacts with blood's hemoglobin. According to Roggar Mustress, the American scientist, air pollution causes mental tension which leads to increase in crimes in the society. The Air Act defines an air pollutant as any "solid, liquid or gaseous substance including noise present in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment." The Act provides that no person shall without the previous consent of the state board establish or operate any industrial plant in an air pollution control area. The Central Pollution Control Board and the State Pollution Control Board constituted under the Water Act shall also perform the power and functions under the

Air Act. The main functions of the Boards under the Air Act are to improve the quality of air and to prevent, control, and abate air pollution in the country. The permission granted by the Board may be a conditional one wherein stipulations are made in respect of raising of stack height and providing various control and monitoring equipment. It is expressly provided that persons carrying an industry shall not be allowed to emit air pollutants in excess of laid-down standards by the Board.

Noise has been taken as an air pollutant within the meaning of the Air Act. Sound becomes noise when it causes annoyance or irritates. Many sources of noise pollution are there like noise from factories, vehicles, and use of loudspeakers recklessly in marriages, religious ceremonies, and religious places. Crackers on festivals, winning of teams in the games, and other such occasions cause not only noise pollution but also air pollution. The Air Act helps in prevention and control of these pollutions. Though the Air Act is comprehensive in its contents relating to prevention and control of air pollution from industrial pollutants, its defined scope even after major amendments in 1987 remained inadequate, as it doesn't include in its complete range the pollution through the medium of air. Hence, noxious odors emitted by some industries (e.g., breweries and leather industries) are not covered under the Act; however, noise pollution through medium of air is covered.

The constitution of Boards is not free from drawbacks under the Act. Air pollution prevention and control has been given as an additional or secondary duty of the (Water) Pollution Boards. The importance of control of air pollution is underrated, as there remains a tendency to provide greater importance to primary function. Further, the Air Act similar to Water Act does not provide for an integrated approach to check pollution, as the local and municipal bodies which are armed with statutory powers for ensuring environmental purity have not been integrated into the national- and state-level enforcement machinery. Each state government is granted discretion to designate particular areas as "air pollution control areas" within which the provision relating to regulations of pollutant discharges through permit system is to be applicable. It seems that polluters located outside such air pollution control areas cannot be subjected to regulations of pollution or be prosecuted for violations of standards laid by the state boards. The improvement on implementation of the Act has to be looked upon. Rules have been framed under the Air Act, 1981, viz. the Air (Prevention and Control of Pollution) Rules, 1982, provided for the procedure on transaction of business of the Board and its committees; temporary association of persons with the central board (for assistance or advice); and budget, account, and annual report of the central board. Rules in other areas (viz. taking of samples of emissions or air) are required to be framed in order to overcome the subjective satisfaction of the board. Thus, the Air Act is a good piece of legislation and has shown the right path to be pursued in the direction of prevention and control of air pollution.

Forest and Wildlife Acts, 1972

India is one of the few countries, which had a forest policy since 1894. In 1972, the Wildlife (Protection) Act was enacted by the Parliament. The Act was enacted with a view to provide for the protection of wild animals, birds, and plants. The Act prohibits hunting of animals and birds as mentioned in the schedules. The Act also prohibits picking, uprooting, damaging, destroying, etc. any specified plant from any forest. The Act provides for State Wildlife Advisory Board to advise the state government in formulation of the policy for protection and conservation of the wildlife and specified plants, and in selection of areas to be declared as sanctuaries, national parks, etc. Director of Wildlife Preservation with Assistant Directors and a Chief Wildlife Warden with other wardens and their staff administer the Act.

The Wildlife Act provides for state wildlife advisory boards, regulating wild animal and bird hunting; establishing sanctuaries and national parks; regulating trade in wild animals, animal products, and trophies; and judicially imposing penalties for violating the Act. Harming endangered species is prohibited throughout India. Hunting species, like those requiring special protection, big game, is regulated only through licensing. A few species classified as vermin may be hunted without restrictions. In 1982, an amendment to the Act introduced a provision of permitting the capture and transportation of wild animals for the scientific management of animal population. India is also a signatory to the Convention of International Trade in Endangered Species of Fauna and Flora (CITES, 1976). Under this, export or import of endangered species and their products is governed by the conditions and stipulations laid down therein.

The Forest (Conservation) Act, 1980

Forest Act, 1927, is one of the many surviving colonial legislation. It was enacted to consolidate the law related to forest, the transit of forest produce, and the duty to be levied on timber and other forest produce. The Forest (Conservation) Act, 1980, provides that no forest destruction or forestland usage for non-forest purposes can be permitted without the previous approval of the Central Government. The conservation of forests includes preservation and protection of existing forests along with reafforestation. A continuous and integrated process to replace the vanishing forest reafforestation should be done regularly. The Act is enforced strictly for the benefit of the general public and intended to save a laudable purpose. Though there are several legislation on environment protection in India, the enforcement of these legislation has been far from satisfactory. What is exactly needed is the effective and efficient enforcement of the constitutional mandate and the other environmental legislation.

To make certain reforms, the Forest (Conservation) Act was promulgated in 1980 over the preceding Act of 1927. The 1927 Act deals with the four forest categories, namely reserved forests, village forests, protected forests, and private forests. A forest land or waste land may be declared as reserved forest by state and may sell the

produce from these forests. Any unauthorized felling of trees, quarrying, grazing, and hunting in reserved forests are punishable with a fine or imprisonment, or both. Village forests are reserved forests assigned to a village community. The state governments are empowered to designate protected forests and may prohibit the felling of trees, quarrying, and removal of forest produce from these forests. The enforcement of preservation of protected forests is done through rules, licenses, and criminal prosecutions.

Public Liability Insurance Act, 1991 (Jayakumar 1987)

The Public Liability Insurance Act was passed by an ordinance in the Parliament in 1991 to provide relief to those personnel involved in any casualty due to handling of hazardous substances and thereby are within the provisions of the Act.

In particular, the Act provides a definitive public liability insurance scheme for manufacturing units involved in management of hazardous substances and provides assistance to victims by using a collective decision principle. The scheme will be based on "no-fault" liability and will deal with providing relief and safeguard to victims of casualties and also providing cover and assistance to the industry to fulfil its liability for any such claims arising out of major mishaps. However, the victims of the mishap can claim for compensation separately by going to courts.

National Environment Tribunal Act, 1995

The National Environment Tribunal Act was enacted in 1995 to provide for any damages due to any accidents which occur due to handling of any hazardous substance. The Act was set up in effective and expeditious settlements of such cases. For cases arising of injuries and deaths of any person it imposes entire liability on the owner of the manufacturing unit or the industry to pay the entire compensation. The affected victim may also claim for compensation under the provisions of the Public Liability Insurance Act, 1991.

Conclusion

The book chapter highlights and explains in great details the existing legislation related to environmental concerns in India, including their establishment, formation, members, power associated with them, and in some cases their eventual limitations and drawbacks.

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Chapter 6
Data Mining, Big Data, Data Analytics:
Big Data Analytics in Bioinformatics

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ABSTRACT

In this digital and computing world, data formation and collection rate are growing very rapidly. With these improved proficiencies of data storage and fast computation along with the real-time distribution of data through the internet, the usual everyday ingestion of data is mounting exponentially. With the continuous advancement in data storage and accessibility of smart devices, the impact of big data will continue to develop. This chapter provides the fundamental concepts of big data, its benefits, probable pitfalls, big data analytics and its impact in Bioinformatics. With the generation of the deluge of biological data through next generation sequencing projects, there is a need to handle this data trough big data techniques. The chapter also presents a discussion of the tools for analytics, development of a novel data life cycle on big data, details of the problems and challenges connected with big data with special relevance to bioinformatics.

INTRODUCTION

Big data has undoubtedly gained much attention in every sector like science, IT, social media, etc., in the 21st century. Myriad technological revolutions are pouring the intensification of data and data gathering. In recent years we have observed a histrionic growth in data availability. For example; the number of web pages indexed by Google, which was nearly one million in 1999, have exceeded at 4.73 billion pages in 2015, and its enlargement is speeded up by the existence of the social networks (Che *et al.*, 2013, Grobelnik, 2012, Worldometers, 2014).

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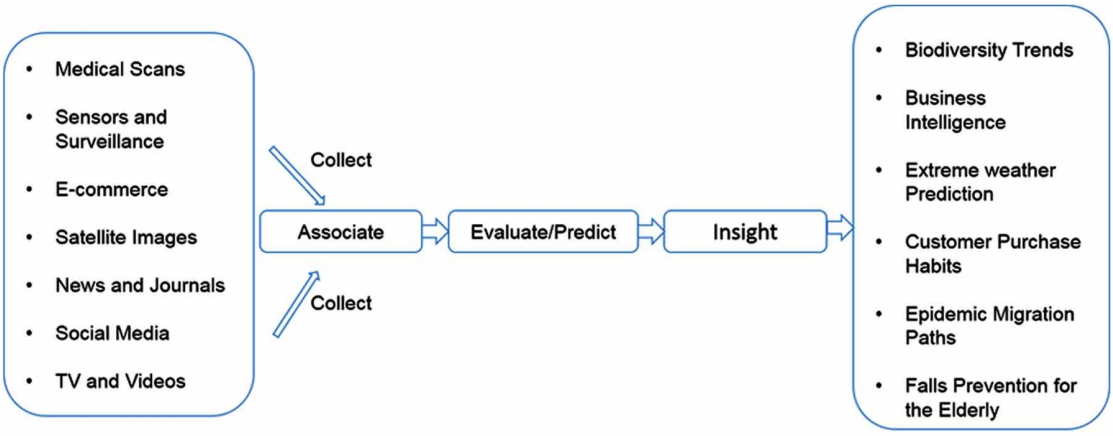
Why 'Big Data' Is Essential

- Numerous diverse big data programs launched.
- Increased use of sensors in all sectors like traffic patterns, purchasing behaviors, real-time inventory management, etc.
- Supermarkets handle approximately 1 million consumer transactions every single hour, which is imported into databases estimated to have nearly three petabytes of data.
- 72 hours of video are added to YouTube every minute.
- There are approximately 217 new mobile internet users every minute.
- Facebook handles 40 to 50 billion photographs from its user base.
- Twitter users send more than 150 million tweets per day.
- Biomedical computation decoding human Genome and personalized medicine.
- Social science revolution, etc. (Shaw, 2014).

As a result of this huge amount of data 'big data' has become a modern area of potential investment. According to The McKinsey Global Institute (2012), "Big data refers to data sets whose dimension is beyond the capability of usual database software tools to capture, store, manage and analyze" (Manyika, *et al.*, 2012). In Gartner June 2012 issue, Beyer and Laney stated: "Big data are high volume, high velocity, and high variety information resources that necessitate innovative procedures to enable heightened outcomes, insight discovery, and process optimization" (Beyer & Laney, 2012). Therefore, big data needs different methods, tools, and architectures to decipher novel problems and deep-rooted problems in an improved way. Some crucial factors for the evolution of big data are; accessibility of data, enlargement of storage capabilities, and enlargement of processing power, etc. Firms in most sectors have a minimum of 100 terabytes of stored data, and several have more than a petabyte. The size of big data is so vast and multifaceted that ordinary data handling applications are insufficient. The challenges comprise search, capture, data curation, exploration, storing, allocation, conception, and data privacy (Khan *et al.*, 2014). Figure 1 describes the basic workflow of big data architecture. Precision in big data can lead to more poised results and ultimately improved decisions that lead to better operational competence, cost

Figure 1. Big data facilitates institutions to collect, accumulate, and manipulate massive quantity of data at the right speed and right time



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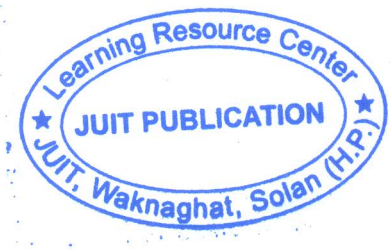

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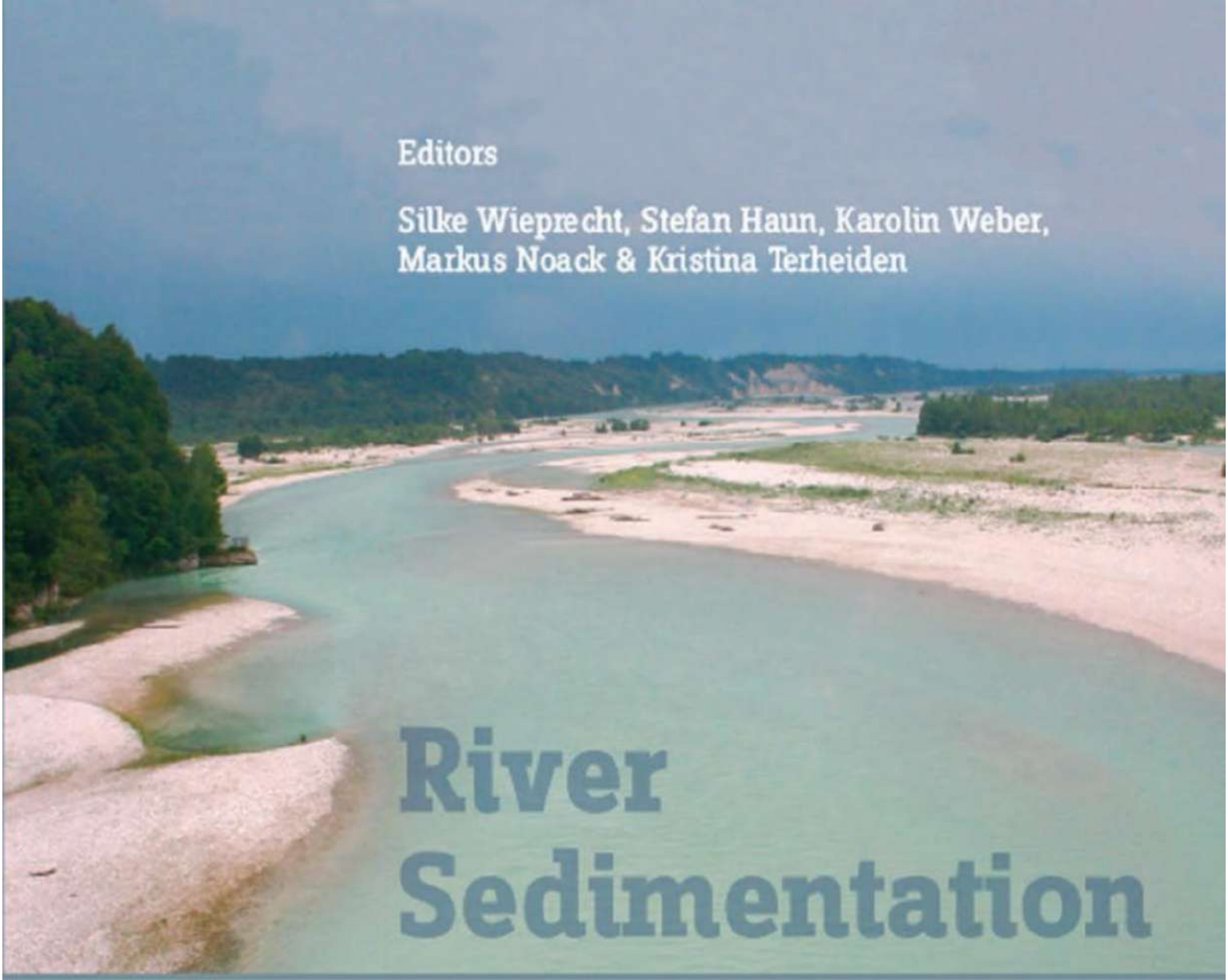

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Silke Wieprecht, Stefan Haun, Karolin Weber,
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River Sedimentation

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River Sedimentation

Editors

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Preface

Worldwide the majority of water bodies (rivers, reservoirs and lakes) are no longer in a natural morphodynamic status due to anthropogenic interventions in the catchment area as well as in the river itself. Alterations in the catchment, e.g. uprooting, may lead to high sediment intrusions in river systems even during relatively short precipitation events. The effect of high suspended load concentration and the intrusion of fine sediments (clogging) result in a reduction of habitat quality for many aquatic species. Furthermore, the low water quality can negatively affect both macroinvertebrates as well as microbial organisms on the sediment bed due to increased turbidity as well as sediment smothering that alter the light climate and oxygen penetration, respectively. Thus, in the long term, fine material intrusion also provokes a reduction of biodiversity. Consequently, rivers lose their capability to provide several ecosystem functions and services. Additionally, river modifications due to hydraulic engineering disturb the sediment continuity and natural sediment transport dynamics. The construction of dams and reservoirs, e.g. for drinking water purposes, flood mitigation or energy production results worldwide in a reduction of sediment availability in rivers of 20×10^9 ty^{-1}. This discontinuity reduces the storage potential of the reservoirs and thus causes economic losses but also impairs the whole aquatic ecosystem sustainably. As a result, ongoing river bed erosion downstream of dams and thus so called 'hungry rivers' can be observed which coincide mostly with a reduction of the groundwater level and with local bank erosion and bridge foundation scour. From an ecological perspective, the uncontrolled and diffusive inflow of nutrients and pollutants into rivers also changes the environmental conditions and severely impacts the natural system. For instance, an additional input of nutrients and phosphate might stimulate the growth of cyanobacteria and increase the secretion of harmful toxins. As a consequence affected rivers and lakes can no longer provide drinking or irrigation water or serve for recreation purposes.

In the context of the growing number of hydraulic mega projects and the associated effects on the sediment transport and budget of concerned river systems, in 1980 the first time the International Symposium on River Sedimentation (ISRS) was organized and established as a triennial event. Under the auspices of UNESCO-IRTCES (International Research and Training Centre on Erosion and Sedimentation), the ISRS symposia have been successfully held in Beijing, China (1980), Nanjing, China (1983), Jackson, USA (1986), Beijing, China (1989), Karlsruhe, Germany (1992), New Delhi, India (1995), Hong Kong, China (1998), Cairo, Egypt (2001), Yichang, China (2004), Moscow, Russia (2007), Stellenbosch, South-Africa (2010) and Kyoto, Japan (2013). Since the foundation of the "World Association for Sedimentation and Erosion Research" (WASER) during the ninth symposium in 2004 the ISRS serves as official symposia series of WASER.

The symposium aims at providing a platform for scientists, engineers and opinion leaders for an in-depth and stimulating exchange of information. The objectives are to develop sustainable revitalization and management strategies that address the ongoing negative effects of anthropogenic activities whilst improving river systems towards a healthy ecological status. The fundamental research and understanding of interactive processes between water and sediments is as important as the sharing and exchange of knowledge in applied projects.

Topics of nature-orientated use of water bodies with a focus on the connection between ecological needs and the structural and hydraulic requirements are a main theme of the symposium. Besides the spatial scale (from the initiation of motion of single grains to processes occurring at the catchment scale), the temporal scale plays an important role. While typical morphological structures are formed over years, hydrodynamic considerations may concentrate on processes occurring at short timescales (seconds). For example, eddy structures can be defined in very high-resolutions, which is one pre-condition for a detailed description of the interaction between water and sediments.

During the ISRS2016 six main topics are addressed:

A. Integrated sediment management at the river basin scale
B. Sediment transport
C. River morphodynamics
D. Hydromorphology meets Ecology
E. Reservoir sustainability
F. Social, economic and political aspects of sediment management

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Furthermore, special topics are discussed which are in the focus of research in Germany as well as worldwide:

SS 1 Hydropower and sediment management
SS 2 Navigation and river morphology
SS 3 Innovative measurement techniques
SS 4 SEDITRANS – sediment transport in fluvial, estuarine and coastal environment
SS 5 Sustainable land management

The Local Organizing Committee of ISRS2016 received 303 abstracts from 51 countries and regions, of which 269 full papers were requested after the first round of peer review by 70 members of the Review Board. The full papers submissions were subsequently subjected to a second peer review by 67 experts from around the world. Based on the comments of the reviewers, the Board finally selected 185 papers to be included in this book. The accepted contributions cover the broad spectrum of river sediment related issues. All papers included in this book are presented by the corresponding authors during the four day symposium either in oral or poster presentations.

We are proud to also introduce three keynote lectures representing the wide spectrum of sediment transport. Worldwide leading experts in their field report about their actual scientific results. Bruce W. Melville from New Zealand talks about "Local scour at hydraulic structures", David M. Paterson from Great Britain gives an insight in "Form, function and physics" and Weiming Wu from United Stated of America shares his knowledge about "Advances and challenges in mixed cohesive/non-cohesive sediment transport research".

A special "Workshop on International Sediment Advancements" (WISA) is launched on the second day of the symposium. The workshop, under the headline of "Hydraulic, morphological and biological interactions in sediment management", is proposed by Prof. Giampaolo Di Silvio. He is the current president of WASER and full of enthusiasm and ideas to promote the topic of sediment transport and its related processes. He puts great effort in the international exchange and is a major contributor to the success of this Symposium. This inter-organizational workshop, under the auspices of UNESCO-IHP-ISI is devoted to disseminate beyond the limits of each membership the most significant progress attained by several scientific associations operating in the field of sediment research and management. We are pleased that Manfred Spreafico (ISI-UNESCO) talks about "Material fluxes in river eco-systems with special attention to reservoirs", Zhaoyin Wang (IAHR) discusses "Eco-sedimentology. A new area in sediment studies", Desmond Walling (IAHS) refers to "Changing perspectives on the suspended sediment load of rivers", Ildefonso Pla Sentis (CONSOWA) speaks about "Hydrological processes in soils of sloping lands as a basis for sediment production and sediment yield", Silke Wieprecht (LOC) shares ideas about "Influence of morphological changes on ecology: a cascade of scales" and finally Giampaolo Di Silvio (WASER) addresses the subject of "A hydro-, morpho-, bio-dynamic model for long-term, basin-scale river simulations".

We would like to express our sincere gratitude to our colleagues who submitted abstracts and papers to ISRS2016, the paper reviewers who made in-depth reviews amidst their busy schedule, the advisory, scientific and local organizing committee members who significantly promoted this event and the secretariat members who were kept busy with the preparation and arrangements of all kinds of detailed matters and always had an open ear for all kinds of requests and desires. We express our gratitude to our collaborating publisher, CRC Press/Balkema (Taylor and Francis Group) who made our proceedings more visible and professional.

Editors
Stuttgart, September 2016

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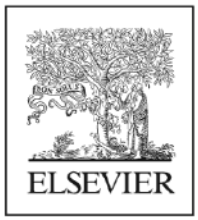



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Preface

Medical informatics, also known as healthcare analytics, is a useful tool that can assess and monitor health-related behavior and conditions of individuals outside the clinic. The benefits of medical informatics are significant, including improving life expectancy, disease diagnosis, and quality of life. In many individual situations, a patient requires continuous monitoring to identify the onset of possible life-threatening conditions or to diagnose potentially dangerous diseases. Traditional healthcare systems fall short in this regard.

Meanwhile, rapid growth and advances have occurred in the digitization of information, retrieval systems, and wearable devices and sensors. Our times demand the design and development of new effective prediction systems using machine learning approaches, big data, and the Internet of Things (IoT) to meet health and life quality expectations. Furthermore, there is a need for monitoring systems that can monitor the health issues of elderly and remotely located people. In recent times, big data and IoT have played a vital role in health-related applications, mainly in disease identification and diagnosis. These techniques can provide possible solutions for healthcare analytics, in which both structured and unstructured data are collected through IoT-based devices and sensors. Machine learning and big data techniques can be applied to collected data for predictive diagnostic systems. However, designing and developing an effective diagnostic system is still challenging due to various issues like security, usability, scalability, privacy, development standards, and technologies. Therefore machine learning, big data, and IoT for medical informatics are becoming emerging research areas for the healthcare community.

Outline of the book and chapter synopses

This book presents state-of-the-art intelligent techniques and approaches, design, development, and innovative uses of machine learning, big data, and IoT for demanding applications of medical informatics. This book also focuses on different data collection methods from IoT-based systems and sensors, as well as preprocessing and privacy preservation of medical data. We have provided potential thoughts and methodologies to help senior undergraduate and graduate students, researchers, programmers, and healthcare industry professionals create new knowledge for the future to develop intelligent machine learning, big data, and IoT-based novel approaches for medical informatics applications. Further, the key roles and great importance of machine learning, big data, and IoT techniques as mathematical tools are elaborated in the book. A brief and orderly introduction to the chapters is provided in the following paragraphs. The book contains 23 chapters.

Chapter 1 presents a survey of machine learning and predictive analytics methods for medical informatics. This chapter focuses on deep neural networks with typical use cases in computational medicine, including self-supervised learning scenarios: these include convolutional neural networks for image analysis, recurrent neural networks for time series, and generative adversarial models for correction of class imbalance in differential diagnosis and anomaly detection. The authors then continue by assessing salient connections between the current state of machine learning research and data-centric healthcare analytics, focusing specifically on diagnostic imaging and multisensor integration as crucial research topics within predictive analytics. Finally, they conclude by relating open problems

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of machine learning for prediction-based medical informatics surveyed in this article to the impact of big data and its associated challenges, trends, and limitations of current work, including privacy and security of sensitive patient data.

Chapter 2 presents a proposed model for geolocation aware healthcare facility with IoT, Fog, and Cloud-based diagnosis in emergency cases. An end-to-end infrastructure has been modeled for the healthcare system using geolocation-enabled IoT, fog, and cloud computing technology to identify the nearest hospital or medical facility available to the patient. It has also achieved 25%–27% less delay and 27%–29% less power consumption than the cloud-only environment.

Chapter 3 aims to capture the status of medical computer vision threats and the recent defensive techniques proposed by researchers. This chapter intends to shed light on the vulnerability of machine learning models in medical image analysis, e.g., disease diagnosis, and to become a guide for any researcher working in medical image analysis toward the development of more secure machine learning-based computer-aided diagnosis systems.

Chapter 4 demonstrates a model for skull stripping and tumor detection from brain images using 3D U-Net. The demonstrated model has been tested over 373 MRIs of the LCG Segmentation Dataset, showing good standard performance over metrics of dice coefficient, and the accuracy results are competitive with the existing methods.

Chapter 5 addresses the issue of corrupted laparoscopy video by haze, noise, oversaturated illumination, etc., in minimally invasive surgery. To effectively address the issue, the authors have proposed a novel algorithm to ensure the enhancement of video with faster performance. The proposed C^2D^2A (Cross Color Dominant Deep Autoencoder) uses the strength of (a) a bilateral filter, which addresses the one-shot filtering of images both in the spatial neighborhood domain and psycho-visual range; and (b) a deep autoencoder, which can learn salient patterns. The domain-based color sparseness has further improved the performance, modulating the classical deep autoencoder to a color dominant deep autoencoder. The work has shown promise toward providing a generic framework of quality enhancement of video streams and addressing performance. This, in turn, improves the image/video analytics like segmentation, detection, and tracking the objects or regions of interest.

Chapter 6 presents an alternative way of estimating respiratory rate from ECG and PPG by using machine learning to improve estimation accuracy. The proposed methods are based on respiratory signals extracted from raw signals and use a support vector machine (SVM) and neural network (NN) to estimate respiratory rate. The proposed methods achieve comparable accuracy to current methods when the number of classes is low. Once the number of classes increases, the accuracy drops significantly.

Chapter 7 serves as an introductory guideline to address the challenges and opportunities while designing machine learning-enabled Healthcare Internet of Things (H-IoT) networks. It provides a discussion on traditional H-IoT, challenges, and opportunities in the Network 2030 paradigm. It also discusses potential machine learning techniques compatible with H-IoT and points out open issues and future research directions.

Chapter 8 presents a skin lesion segmentation approach based on the Elitist-Jaya optimization algorithm. The proposed method contains two stages: image preprocessing and edge detection. The experimental sample consists of a set of 320 images from the skin lesion dataset. The outcomes proved that the proposed approach improved the segmentation accuracy of the affected skin lesion area and outperformed the compared methods.

Chapter 9 provides its readers with an all-encompassing review that will enable a clear understanding of the current trends in glove-based gesture classification and provide new ideas for further research. The

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authors have analyzed deep learning approaches in terms of their current performance, advantages over classical machine learning algorithms, and limitations in specific classification scenarios. Furthermore, they present other deep learning approaches that may outperform current algorithms in glove-based gesture classification.

Chapter 10 presents an ensemble approach for evaluating the cognitive performance of the human population at high altitude. The authors identify the key multidomain cognitive screening test (MDCST) and clinical features among the lowlander ($\leq$350 m) and highlander ($\geq$1500 but $<$4300 m) populations, staying at an altitude $\geq$4300 m for a prolonged duration. A goodness-of-fit test was applied to the two population cohorts for identifying significant independent measures. Rule-based mining was followed to discover associative rules between the clinical, behavioral, and cognitive screening parameters. Conclusively, a unique set of association rules have been identified with at least 30% support and more than 60% confidence in behavioral and clinical features associated with the cognitive parameters.

Chapter 11 presents the role of machine learning in expert systems for disease diagnostics in human healthcare. The authors discuss essential existing expert systems for human disease diagnosis in detail. They also provide a brief evaluation of various techniques used for the development of expert systems.

Chapter 12 presents an entropy-based hybrid feature selection approach for medical datasets. A stable linear-time entropy-based ensembled feature selection approach is introduced, mainly focusing on medical datasets of several sizes. The suggested approach is validated using three state-of-the-art classifiers, namely C4.5, naïve Bayes, and JRIP, over 14 benchmark medical datasets (drawn from the UCI machine learning repository). The empirical results achieved from the datasets demonstrate that the proposed ensemble model outperforms the selected learners.

Chapter 13 shows how to utilize machine learning algorithms to create models that can predict healthcare systems' critical issues. The chapter's discussion relates to the COVID-19 pandemic and highlights the solutions offered by machine learning in such scenarios. The chapter also highlights the significance of feature engineering and its impact on machine learning models' accuracy. The chapter ends with two case studies. The first case study shows how to build a prediction model that can predict the number of diabetic patients who will visit certain hospitals in a specific geographic location in future years. The second case study analyzes health records during the COVID-19 pandemic.

Chapter 14 presents an interpretable semisupervised classifier for predicting cancer stages. Authors illustrate the self-labeling gray-box applications on the omics and clinical datasets from the cancer genome atlas. They show that the self-labeling gray-box is accurate in predicting cancer stages of rare cancers by leveraging the unlabeled instances from more common cancer types. They discuss insights, the features influencing prediction, and a global representation of the knowledge through decision trees or rule lists, which can aid clinicians and researchers.

Chapter 15 presents an overview of applications of blockchain technology in smart healthcare. The authors overviewed the fundamental blockchain concepts and applications to be used for different aspects of the smart healthcare industry and proposed a live patient monitoring system by deploying blockchain technology in the model. Keeping an eye on recent technologies in connected healthcare, they finally presented various research factors and potential challenges where blockchain technologies can play an outstanding role in realizing the concept of smart optimization in the healthcare industry.

Chapter 16 focuses on clustering and classification techniques for the prediction of leukemia. The proposed work consists of Phase I, which will be dealing with the collection of datasets and visualization of datasets, whereas Phase II will be dealing with the machine learning and data mining

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techniques for the prediction of leukemia disease. The authors claim that the proposed techniques would give higher performance than the existing techniques.

Chapter 17 presents a performance evaluation of fractal features toward seizure detection from electroencephalogram signals. The authors have evaluated the ability of three well-known fractal dimension feature extraction methods (the Katz fractal dimension, Higuchi fractal dimension, and Petrosian fractal dimension) to classify epileptic and nonepileptic electroencephalogram signals. The features are fed to an SVM classifier for the classification of epileptic and nonepileptic electroencephalogram signals. The SVM classifier results show that the fractal features are good measures to characterize the complex information of epileptic signals.

Chapter 18 presents an integer period discrete Fourier transform-based algorithm to identify tandem repeats in the DNA sequences. The authors have discussed the importance of tandem repeats in diverse applications. They proposed an integer period discrete Fourier transform (IPDFT)-based algorithm to detect the tandem repeats in DNA sequences. A comparison of the proposed algorithm's performance has also been made with existing methods.

Chapter 19 discusses the scope, applicability, and usage of blockchain technology to preserve patients' sensitive medical data. A framework is also proposed that allows patients and hospitals to store medical records. The framework allows patients to share the information by providing access to their data and by invoking smart contracts for automatic payments for their medical claims.

Chapter 20 presents a novel approach to securing e-health applications in the cloud environment. The authors provide an algorithm to secure data in e-health applications in the cloud environment. A new architecture for e-health applications in the cloud environment is proposed, which will provide application-level security and server-level security using certificates.

Chapter 21 presents different ensemble learning algorithms and explains how these algorithms can be used to classify health disorders. The authors have discussed an ensemble classifier approach for thyroid disease diagnosis using the AdaBoostM algorithm.

Chapter 22 presents a review of the latest artificial intelligence research in this immense medical science field, including various architectures and approaches, with special attention given to brain tumor analysis. The authors discuss various deep learning architectures used to diagnose brain tumors and compare results with existing architectures. They have examined case studies from basic clustering techniques such as K-means clustering to fuzzy and neurotrophic C-means clustering techniques and kernel graph cuts (KGC) to advanced artificial intelligence techniques such as deep convolution neural networks (DCNs), atrous convolution neural networks (ACNs), and unit architectures to find the area of interest in the coherent/incoherent regions.

Finally, Chapter 23 focuses on machine learning in precision medicine. An overview of how machine learning is used in precision medicine and its potential use in the detection, diagnosis, prognosis, risk assessment, therapy response, and discovery of new biomarkers and drug candidates is presented in this chapter.

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Handbook of Research on Disease Prediction Through Data Analytics and Machine Learning

Geeta Rani
Manipal University Jaipur, India

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Vijaypal Singh Dhaka, Manipal University Jaipur, India

The increase in use of ICT tools and decrease in physical activities has increased the risk of disorders such as diabetes, hypertension, myopia, hypermetropia, etc. These disorders make the person more prone to eye disease such as glaucoma. The actual causes of glaucoma are still unknown. But the study of medical literature reveals that the factors such as intraocular pressure, thyroid, diabetics, eye injuries, eye surgeries, ethnic background, and myopia makes the person more prone to glaucoma. The difficulty in early detection make it an invisible thief of sight. Therefore, it is the demand of the day to design a system for its early detection. The aim of this chapter is to develop a convolutional neural network model "GlaucomaDetector" for detection of glaucoma at an early stage. The evaluation of the model on the publicly available dataset reports the accuracy of 99% for prediction of glaucoma from the input images of retina. This may prove a useful tool for doctors for quick prediction of glaucoma at an early stage. Thus, it can minimize the risk of blindness in patients.

Chapter 2
Pre-Processing Highly Sparse and Frequently Evolving Standardized Electronic Health Records for Mining 8
Shivani Batra, KIET Group of Institutions, Delhi-NCR, India
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EHRs aid in maintaining longitudinal (lifelong) health records constituting a multitude of representations in order to make health related information accessible. However, storing EHRs data is non-trivial due to the issues of semantic interoperability, sparseness, and frequent evolution. Standard-based EHRs are recommended to attain semantic interoperability. However, standard-based EHRs possess challenges (in terms of sparseness and frequent evolution) that need to be handled through a suitable data model. The traditional RDBMS is not well-suited for standardized EHRs (due to sparseness and frequent evolution).

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Thus, modifications to the existing relational model is required. One such widely adopted data model for EHRs is entity attribute value (EAV) model. However, EAV representation is not compatible with mining tools available in the market. To style the representation of EAV, as per the requirement of mining tools, pivoting is required. The chapter explains the architecture to organize EAV for the purpose of preparing the dataset for use by existing mining tools.

Chapter 3

Image Classification Techniques 22
Eugenio Vocaturo, Università della Calabria, Italy

The image processing task, aimed at interpreting and classifying the contents of the images, has attracted the attention of researchers since the early days of computers. With the advancement of computing system technology, image categorization has found increasingly broader applications, covering new generation disciplines such as image analysis, object recognition, and computer vision, with applications quite general both in scientific and humanistic fields. The automatic recognition, description, and classification of the structures contained in the images are of fundamental importance in a vast set of scientific and engineering fields that require the acquisition, processing, and transmission of information in visual form. Classification tasks also include those related to the categorization of images, such as the construction of a recognition system, the representation of patterns, the selection and extraction of features, and the definition of automatic recognition methods. Image analysis is of collective interest and it is a hot topics of current research.

Chapter 4

Prediction Models 50
Amit Kumar Tyagi, Vellore Institute of Technology, Chennai, India

Having/living convenient life through smart devices, people are more interested or more dependent on to predict something for future (i.e., with respect to their health, business, etc.). For that, many prediction models by several researchers are being used in many applications. Due to a vast (rapid) change in lifestyle, people are more prone to a number of life-threatening diseases when it comes to their well-being. Many of these diseases start developing their symptoms in their early stages. But, still many of these diseases like cancer, kidney damages remain unidentified in their developing stages. The earlier a disease is predicted, the easier it becomes to cure it and even prevent it. Predictive modeling provides a huge step forward in medical science in preventing the risk among patients. Prediction modeling is the process of analyzing current conditions to predict future results.

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Healthcare is always a sensitive issue for all of us, and it will always remain. Predicting various types of health issues in advance can lead us to a better life. Various types of health problems are there like cancer, heart diseases, diabetes, arthritis, pneumonia, lungs disease, liver disease, and brain disease, which all are at high risk. To reduce the risk of health issues, some suitable models are needed for prediction.

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Thus, it became as a motivational factor for the authors to survey the existing literature on this topic thoroughly and have consequently to identify suitable machine learning techniques so that improvement can be possible while selecting a prediction model. In this chapter, concept of survey is used to provide the prediction models for healthcare issues along with the challenges associated with each model. This chapter will broadly cover the following: machine learning algorithms used in health industry, study various prediction models for Cancer, Heart diseases, Diabetes and Brain diseases, comparative study of various machine learning algorithms used for prediction.

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Chronic Kidney Disease Prediction Using Data Mining Algorithms 92
Devesh Kumar Srivastava, Manipal University Jaipur, India
Pradeep Kumar Tiwari, Manipal University Jaipur, India

In today's contemporary world, it is important to know about the odds of having a disease because of changing living standards of the population overall in the continent. The disease on which the authors are working is chronic kidney disease. Once the person gets chronic kidney disease (CKD), his working capability decreases along with other adverse effects. It is possible to get rid of diseases like CKD with new methodologies that will help us to predict the stage of kidney disease at an early stage. Under big data analytics, data may be structured, unstructured, quasi- or semi-structured. The CKD detected and predicted by applying classification models: support vector machine (SVM), K-nearest neighbor (KNN), and logistic regression algorithm. It helps in predicting the likelihood of occurrence of disease on various different features. The two algorithms KNN and SVM are compared to find the algorithm that gives better accuracy. Further regression technique has been used to detect the disease based on, which the stages are classified by using GFR (glomerular filtration rate) formula.

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A Machine Learning Approach to Prevent Cancer 112
Ahan Chatterjee, The Neotia University, India
Swagatam Roy, The Neotia University, India
Rupali Shrivastava, The Neotia University, India

One of the most talked about diseases of the 21st century is none other than cancer. In this chapter, the authors take a closer look to prevent cancer through machine learning approach. At first, they ran their classifier models (e.g., decision tree, K-mean, SVM, etc.) to check which algorithm gives the best result in terms of choosing right features for further treatment. The classified results are compared, and then various feature reduction algorithm is being used to identify exactly which features affects the most. Various data mining algorithms are being used, namely rough-based theory, graph-based clustering, to extract the most important features which influence the results. In the next section they take a look in the cancer analytics part. A simulation model has been designed that can easily manage the patient flow in OPDs and a bed rotation model also have been designed to give patients an insight that how much time they will spend in the queue. Further they analyzed a risk analysis model for chemotherapy treatment, and finally, an econometric discussion has been drawn in how it affects the treatment.

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Machine Learning Perspective in Cancer Research 142
Aman Sharma, IT Department, Jaypee University of Information Technology, Solan, India
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Advancement in genome sequencing technology has empowered researchers to think beyond their imagination. Researchers are trying their hard to fight against various genetic diseases like cancer. Artificial intelligence has empowered research in the healthcare sector. Moreover, the availability of opensource healthcare datasets has motivated the researchers to develop applications which can help in early diagnosis and prognosis of diseases. Further, next-generation sequencing (NGS) has helped to look into detailed intricacies of biological systems. It has provided an efficient and cost-effective approach with higher accuracy. The advent of microRNAs also known as small noncoding genes has begun the paradigm shift in oncological research. We are now able to profile expression profiles of RNAs using RNA-seq data. microRNA profiling has helped in uncovering their relationship in various genetic and biological processes. Here in this chapter, the authors present a review of the machine learning perspective in cancer research.

Chapter 9

A Pathway to Differential Modelling of Nipah Virus 164
Dheva Rajan S., Almusanna College of Technology, Oman

This chapter is devoted to the study of mathematical modelling part of infectious diseases, especially the nipah virus. In the past few decades, one cannot deny that enormous new unanticipated diseases have been the cause of serious concern among the human community and that so many viruses have begun emerging and re-emerging though people are trying all means to get rid of diseases. It can even be said that diseases of all sorts are ruling the world. Early prediction of diseases that spread in humans plays a vital role to protect living beings. Most of such diseases are highly infectious, get transmitted from human to human or through some other vectors. Several research and developments take place in the pharma industry notably after the Second World War. Hence, the predictions are not just for theoretical purposes as quite a number of pharma industries use mathematical models for their findings in new medicines and even to decide the quantity of medicine production. This chapter gives an overview of the different researches conducted in mathematical modelling of nipah virus.

Chapter 10

Application of AI for Computer-Aided Diagnosis System to Detect Brain Tumors 185
Poulomi Das, OmDayal Group of Institutions, India & Maulana Abul Kalam Azad University of Technology, India
Rahul Rajak, University of Calcutta, India
Arpita Das, University of Calcutta, India

Early detection and proper treatment of brain tumors are imperative to prevent permanent damage to the brain even patient death. The present study proposed an AI-based computer-aided diagnosis (CAD) system that refers to the process of automated contrast enhancement followed by identifying the region of interest (ROI) and then classify ROI into benign/malignant classes using significant morphological feature selection. This tool automates the detection procedure and also reduces the manual efforts required in widespread screening of brain MRI. Simple power law transformation technique based on different performance metrics is used to automate the contrast enhancement procedure. Finally, benignancy/malignancy of brain tumor is examined by neural network classifier and its performance is assessed by well-known receiver operating characteristic method. The result of the proposed method is enterprising with very low computational time and accuracy of 87.8%. Hence, the proposed method of CAD procedure may encourage the medical practitioners to get alternative opinion.

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Chapter 11
Application of Machine Learning to Analyse Biomedical Signals for Medical Diagnosis 205
Upendra Kumar, Institute of Engineering and Technology, Lucknow, India
Shashank Yadav, Institute of Engineering and Technology, Lucknow, India

Interest in research involving health-medical information analysis based on artificial intelligence has recently been increasing. Most of the research in this field has been focused on searching for new knowledge for predicting and diagnosing disease by revealing the relation between disease and various information features of data. However, still needed are more research and interest in applying the latest advanced artificial intelligence-based data analysis techniques to bio-signal data, which are continuous physiological records, such as EEG (electroencephalography) and ECG (electrocardiogram). This study presents a survey of ECG classification into arrhythmia types. Early and accurate detection of arrhythmia types is important in detecting heart diseases and choosing appropriate treatment for a patient.

Chapter 12
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Data mining is likely to explore hidden patterns from the huge quantity of data and provides a way of analyzing and categorizing the data. Associative classification (AC) is an integration of two data mining tasks, association rule mining, and classification which is used to classify the unknown data. Though association rule mining techniques are successfully utilized to construct classifiers, it lacks in generating a small set of significant class association rules (CARs) to build an accurate associative classifier. In this work, an attempt is made to generate significant CARs using Artificial Bee Colony (ABC) algorithm, an optimization technique to construct an efficient associative classifier. Associative classifier, thus built using ABC discovered CARs achieve high prognostic accurateness and interestingness value. Promising results were provided by the ABC based AC when experiments were conducted using health care datasets from the UCI machine learning repository.

Chapter 13
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Abhranil Gupta, Auctus Solutions, India

This chapter gives a brief overview of the state of the art of machine learning approaches in detection of the neurodegenerative disease from medical records (brain scans, etc.). It starts with an understanding of the sub-field of artificial intelligence, machine learning, then goes to understand neurodegenerative disease, with a focus on four major diseases and then goes on to giving an overview of how such diseases are detected using machine learning. In the end, it discusses the future areas of research that needs to be done in order to improve the field of research.

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Chapter 14
Clinical Decision Support Systems: Decision-Making System for Clinical Data 268
Diviya Prabha V., Periyar University, India
Rathipriya R., Periyar University, India

Clinical data is increasing day-by-day mainly in hospitals by an ageing of the human population. Patients discharged from hospitals are readmitted due to health issues. As the number of patients increases, there are a smaller number of hospitals and an increase in healthcare costs. This results in ineffective decision making that minimizes the healthcare. Machine learning techniques score better for solving this kind of problem. The proposed work, minimum entropy feature selection with logistic regression (MELR), is performing better for the readmission rates. Decision cannot be based on the clinical knowledge and personal data about the patient. It must be precise in choosing the future patient outcomes. This chapter produces promising results for clinical data.

Chapter 15
Diagnosis and Prognosis of Ultrasound Fetal Growth Analysis Using Neuro-Fuzzy Based on Genetic Algorithms 281
Parminder Kaur, Guru Nanak Dev University, Amritsar, India
Prabhpreet Kaur, Guru Nanak Dev University, Amritsar, India
Gurvinder Singh, Guru Nanak Dev University, Amritsar, India

Acquisition of the standard plane is the prerequisite of biometric measurement and diagnosis during the ultrasound (US) examination. Based upon the analysis of existing algorithms for the automatic fetal development measurement, a new algorithm known as neuro-fuzzy based on genetic algorithm is developed. Firstly, the fetal ultrasound benchmark image is auto-pre-processed using normal shrink homomorphic technique. Secondly, the features are extracted using gray level co-occurrence matrix (GLCM), grey level run length matrix (GLRLM), intensity histogram (IH), and rotation invariant moments (IM). Thirdly, neuro-fuzzy using genetic approach is used to distinguish among the fetus growth as abnormal or normal. Experimental results using benchmark and live dataset demonstrate that the developed method achieves an accuracy of 97% as compared to the state-of-the-art methods in terms of parameters such as sensitivity, specificity, recall, f-measure, and precision rate.

Chapter 16
ECG Image Classification Using Deep Learning Approach 343
Pratik Kanani, Dwarkadas J. Sanghvi College of Engineering, India
Mamta Chandraprakash Padole, The Maharaja Sayajirao University of Baroda, India

Cardiovascular diseases are a major cause of death worldwide. Cardiologists detect arrhythmias (i.e., abnormal heart beat) with the help of an ECG graph, which serves as an important tool to recognize and detect any erratic heart activity along with important insights like skipping a beat, a flutter in a wave, and a fast beat. The proposed methodology does ECG arrhythmias classification by CNN, trained on grayscale images of R-R interval of ECG signals. Outputs are strictly in the terms of a label that classify the beat as normal or abnormal with which abnormality. For training purpose, around one lakh ECG signals are plotted for different categories, and out of these signal images, noisy signal images are removed, then deep learning model is trained. An image-based classification is done which makes the ECG arrhythmia system independent of recording device types and sampling frequency. A novel idea is proposed that helps cardiologists worldwide, although a lot of improvements can be done which would foster a "wearable ECG Arrhythmia Detection device" and can be used by a common man.

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Chapter 17
Genetic Data Analysis 358
M. Shamila, Malla Reddy Engineering College, India
Amit Kumar Tyagi, Vellore Institute of Technology, Chennai, India

Genome-wide association studies (GWAS) or genetic data analysis is used to discover common genetic factors which influence the health of human beings and become a part of a disease. The concept of using genomics has increased in recent years, especially in e-healthcare. Today there is huge improvement required in this field or genomics. Note that the terms genomics and genetics are not similar terms here. Basically, the human genome is made up of DNA, which consists of four different chemical building blocks (called bases and abbreviated A, T, C, and G). Based on this, we differentiate each and every human being living on earth. The term 'genetics' originated from the Greek word 'genetikos'. It means 'origin'. In simple terms, genetics can be defined as a branch of biology, which deals with the study of the functionalities and composition of a single gene in an organism. There are mainly three branches of genetics, which include classical genetics, molecular genetics, and population genetics.

Chapter 18
Heart Disease Prediction Using Machine Learning 373
Shiva Shanta Mani B., Indian Institute of Information Technology, Kottayam, India
Manikandan V. M., SRM University AP, Andhra Pradesh, India

Heart disease is one of the most common and serious health issues in all the age groups. The food habits, mental stress, smoking, etc. are a few reasons for heart diseases. Diagnosing heart issues at an early stage is very much important to take proper treatment. The treatment of heart disease at the later stage is very expensive and risky. In this chapter, the authors discuss machine learning approaches to predict heart disease from a set of health parameters collected from a person. The heart disease dataset from the UCI machine learning repository is used for the study. This chapter discusses the heart disease prediction capability of four well-known machine learning approaches: naive Bayes classifier, KNN classifier, decision tree classifier, random forest classifier.

Chapter 19
Heuristic Approach Performances for Artificial Neural Networks Training 382
Kerim Kürşat Çevik, Akdeniz University, Turkey

This chapter aimed to evaluate heuristic approach performances for artificial neural networks (ANN) training. For this purpose, software that can perform ANN training application was developed using four different algorithms. First of all, training system was developed via back propagation (BP) algorithm, which is the most commonly used method for ANN training in the literature. Then, in order to compare the performance of this method with the heuristic methods, software that performs ANN training with genetic algorithm (GA), particle swarm optimization (PSO), and artificial immunity (AI) methods were designed. These designed software programs were tested on the breast cancer dataset taken from UCI (University of California, Irvine) database. When the test results were evaluated, it was seen that the most important difference between heuristic algorithms and BP algorithm occurred during the training period. When the training-test durations and performance rates were examined, the optimal algorithm for ANN training was determined as GA.

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Mental Health Through Biofeedback Is Important to Analyze: An App and Analysis 402
Rohit Rastogi, ABES Engineering College, India
Devendra Kumar Chaturvedi, Dayalbagh Educational Institute, Agra, India
Mayank Gupta, Tata Consultancy Services, India

Many apps and analyzers based on machine learning have been designed to help and cure the stress issue. This chapter is based on an experiment that the authors performed at Research Labs and Scientific Spirituality Centers of Dev Sanskriti VishwaVidyalaya, Haridwar and Patanjali Research Foundations, Uttarakhand. In the research work, the correctness and accuracy have been studied and compared for two biofeedback devices named as electromyography (EMG) and galvanic skin response (GSR), which can operate in three modes: audio, visual and audio-visual with the help of data set of tension type headache (TTH) patients. The authors used some data visualization techniques that EMG (electromyography) in audio mode is best among all other modes, and in this experiment, they have used a data set of SF-36 and successfully clustered them into three clusters (i.e., low, medium, and high) using K-means algorithm. After clustering, they used classification algorithm to classify a user (depending upon the sum of all the weights of questions he had answered) into one of these three class. They have also implemented various algorithms for classifications and compared their accuracy out of which decision tree algorithm has given the best accuracy.

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Pre-Clustering Techniques for Healthcare System: Evaluation Measures, Evaluation Metrics, Comparative Study of Existing vs. Proposed Approaches..... 424
Asadi Srinivasulu, Sree Vidyanikethan Engineering College, India

This chapter presents a comparative study of the proposed approaches (i.e., extended dark block extraction [EDBE], extended cluster count extraction [ECCE], and extended co-VAT approaches). This chapter evaluates pre-clustering and post-clustering algorithms on real-time data and synthetic datasets. Unlike traditional clustering algorithms, pre-clustering algorithms provide a prior clustering on different datasets. Simulation studies are carried out using datasets having both class-labeled and unlabeled information. Comparative studies are performed between results of existing pre-clustering and proposed pre-clustering approaches. A simulated RDI-based preprocessing method is also applied for data diversification. Extensive simulation on real and synthetic datasets shows that pre-clustering algorithms with simulated RDI-based pre-processing performs better compared to conventional post-clustering algorithms.

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Strategic Analysis in Prediction of Liver Disease Using Different Classification Algorithms..... 437
Binish Khan, University Institute of Technology, Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal, India
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Liver diseases avert the normal activity of the liver. Discovering the presence of liver disorder at an early stage is a complex task for the doctors. Predictive analysis of liver disease using classification algorithms is an efficacious task that can help the doctors to diagnose the disease within a short duration of time. The main motive of this study is to analyze the parameters of various classification algorithms and compare their predictive accuracies so as to find the best classifier for determining the liver disease. This chapter focuses on the related works of various authors on liver disease such that algorithms were implemented using Weka tool that is a machine learning software written in Java. Also, orange tool is utilized to compare several classification algorithms in terms of accuracy. In this chapter, random forest, logistic regression, and support vector machine were estimated with an aim to identify the best classifier. Based on this study, random forest with the highest accuracy outperformed the other algorithms.

Chapter 23
Texture Segmentation and Features of Medical Images 450
Ashwani Kumar Yadav, Amity University Rajasthan, Jaipur, India
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Texture analysis is one of the basic aspects of human visual system by which one can differentiate the objects and homogenous areas in an image. Manual diagnosis is not possible for huge database of images. Automatic diagnosis is required for greater accuracy in a shorter time. Texture analysis is required for effective diagnosis of medical images like functional MRI (magnetic resonance image) and diffusion tensor MRI, where only visualization is not sufficient to get the pathological information. This chapter explains the basic concepts of texture analysis and features available for analysis of medical images. Specifically, the intense review of texture segmentation and texture feature extraction and entropy measures of medical images have been done. The chapter also explores the available techniques for it. Common findings, comparative analysis, and gaps identified have also been mentioned on both issues.

Chapter 24
Towards Integrating Data Mining With Knowledge-Based System for Diagnosis of Human Eye Diseases: The Case of an African Hospital 470
Nilamadhab Mishra, School of Computing Science and Engineering, VIT Bhopal University, India
Johny Melese Samuel, Debre Berhan University, Ethiopia

The eye is the most important sensory organ of vision function. But some eye diseases can lead to vision loss, so it is important to identify and treat eye disease as early as possible. Eye care professionals can help protect their patients from vision loss or blindness by recognizing common eye diseases and recommending for an eye exam. Eye diseases with early detection, treatment, and appropriate follow-up care, vision loss, and blindness from eye disease can be prevented or delayed. In this study, rule-based eye disease identification and advising the knowledge-based system are projected. The projected system is targeting using hidden knowledge extracted by employing the extraction algorithm of data mining. To identify the best prediction model for the diagnosis of eye disease, four experiments for four classification algorithms were performed. Finally, the researchers decided to use the rules of the J48 pruned classification algorithm for further use in the development of a knowledge base of KBS because it exhibited better performance with a 98.5% evaluation result.

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Chapter 25
Use of IoT and Different Biofeedback to Measure TTH: An Approach for Healthcare 4.0 486
Rohit Rastogi, ABES Engineering College, India
Devendra Kumar Chaturvedi, Dayalbagh Educational Institute, Agra, India
Mayank Gupta, Tata Consultancy Services, India

This chapter applied the random sampling in selection of the subjects suffering with headache, and care was taken that they ensure to fulfill the International Headache Society criteria. Subjects under consideration were assigned the two groups of GSR-integrated audio-visual feedback, GSR (audio-visual)- and EMG (audio-visual)-integrated feedback groups. In 10 sessions, the subjects experienced the GSR and EMG BF therapy for 15 minutes. Twenty subjects were subjected to EEG therapy. The variables for stress (pain) and SF-36 (quality of life) scores were recorded at starting point, 30 days, and 90 days after the starting of GSR and EMG-BF therapy. To reduce the anxiety and depression in day-to-day routine, the present research work is shown as evidence in favor of the mindful meditation. The physical, mental, and total scores increased over the time duration of SF-36 scores after 30- and 90-days recordings ($p<0.05$). Intergroup analysis has demonstrated the improvement. EMG-audio visual biofeedback group also showed highest improvement in SF-36 scores at first and third month follow up. EEG measures the Alpha waves for the subjects after meditation. GSR, EMG, and EEG-integrated auditory-visual biofeedback are efficient in solution of stress due to TTH with most advantage seen.

Chapter 26
ACO_NB-Based Hybrid Prediction Model for Medical Disease Diagnosis 526
Amit Kumar, Sanaka Educational Trust's Group of Institutions, India
Manish Kumar, Vellore Institute of Technology, Chennai, India
Nidhya R., Madanapalle Institute of Technology & Science, India

In recent years, a huge increase in the demand of medically related data is reported. Due to this, research in medical disease diagnosis has emerged as one of the most demanding research domains. The research reported in this chapter is based on developing an ACO (ant colony optimization)-based Bayesian hybrid prediction model for medical disease diagnosis. The proposed model is presented in two phases. In the first phase, the authors deal with feature selection by using the application of a nature-inspired algorithm known as ACO. In the second phase, they use the obtained feature subset as input for the naïve Bayes (NB) classifier for enhancing the classification performances over medical domain data sets. They have considered 12 datasets from different organizations for experimental purpose. The experimental analysis advocates the superiority of the presented model in dealing with medical data for disease prediction and diagnosis.

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BIOVALORISATION OF WASTES TO RENEWABLE CHEMICALS AND BIOFUELS

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Application of Nanotechnology



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Artificial Intelligence for Accurate Analysis and Detection of Autism Spectrum Disorder

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assess ASD prediction in an artificial neural network (ANN). AQ-10 data collection was used to test the proposed pattern. The findings of the evaluation reveal that the proposed prediction model has improved results in terms of consistency, specificity, sensitivity, and dataset accuracy.

Chapter 7

Existing Assistive Techniques for Dyslexics: A Systematic Review 94
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Reading is an essential skill for literacy development in children. But it is a challenge for children with dyslexia because of phonological-core deficits. Poor reading skills have an impact on vocabulary development and to exposure to relevant background knowledge. It affects the ability to interpret what one sees and hears or the ability to link information from different parts of the brain. Dyslexic children face many challenges in their educational life due to reading difficulty. Support to dyslexic children include computer-based applications and multi-sensory methods like text-to-speech and character animation techniques. Some applications provide immediate reading intervention facility. Automatic speech recognition (ASR) is a new platform with immediate intervention for assisting dyslexic children to improve their reading ability. Findings contribute to develop a suitable approach to correct the reading mistakes of dyslexic children. Speech recognition technology provides the most interactive environment between human and machine.

Chapter 8

Mouse-Less Cursor Control for Quadriplegic and Autistic Patients Using Artificial Intelligence 105
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Artificial intelligence is a field within computer science that attempts to simulate and build enhanced human intelligence into computers, mobiles, and various other machines. It can be termed as a powerful tool that has the capability to process huge sums of information with ease and assess patterns created over a period of time to give significant results or suggestions. It has garnered focus from almost every field from education to healthcare. Broadly, AI applications in healthcare include early detection and diagnosis, suggesting treatments, evaluating progress, medical history, and predicting outcomes. This chapter discussed AI, ASD, and what role AI currently plays in advancing autistic lives including detection, analysis, and treatment of ASD and how AI has been improving healthcare and the existing medical and

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hypothesis that deep neural networks can train and move more reliable SMM sensing systems. The study shows the feasibility of embedded functionality learning. This work is an early attempt to improve SMM detectors in real time. A device can be built into a smartphone application for the omnipresent identification of SMM.

Chapter 5 narrates that Autism can be diagnosed as a behavioural condition, since signs generally occur within the first two years of life. The problem begins with puberty and goes on in adolescence and adulthood. In this paper, two machine learning approaches have been used for the diagnosis of Autism Spectrum Disorder (ASD). Diverse criteria have been used for success assessment in nonclinical data set analysis of ASD detection models. The CNN classifier has reached a high degree of precision and the results show that an autism-spectrum condition CNN model should be used instead of a conventional machine learning classification.

Chapter 6 explains that Autism can be expected at an early stage by the development of artificial intelligence and machine learning (ML). This paper is therefore intended to suggest an accurate MLASD predictive model based on the ML methodology to prevent ASD for people of all ages. AQ-10 data collection was used to test the proposed pattern. The findings of the evaluation reveal that the proposed prediction model has improved results in terms of consistency, specificity, sensitivity and dataset accuracy. Autism with 96.06%, 97.78%, and 93.54% for children, teenagers and adults, can be predicted by the proposed model, by using the AQ-10 dataset.

Chapter 7 discusses about Learning disabilities which are different type of neurologically based processing problems. Children face many difficulties such as writing, reading and mathematics. Dyslexia is most common type of learning disability. Children having dyslexia problems in language processing, decode the words, identifying the sound of letters and reading fluently. The most techniques are available in Arabic, Malay, English but not for Punjabi spoken dyslexic children. Lacks of assistive technologies are barriers for dyslexics in their learning. The chapter is focusing on available assistive techniques and developing an ASR application based on machine learning in Punjabi regional language. This technique will be very helpful for Punjabi spoken dyslexic children in their learning skills.

Chapter 8 discusses Artificial Intelligence which can be termed as a powerful tool that has the capability to process huge sums of information with ease and assess patterns created over a period of time to give significant results or suggestions. In this book chapter, is discussed about ASD, current role of AI in advancing autistic lives including detection, analysis and treatment of ASD. The chapter examines current and provides support for the future advancements, including the idea of the use of “Mouse-less Cursor Control” and “Brain- Computer Interface” based developments, for improving social abilities and reducing the communication & motor difficulties faced by people with ASD. The discussed utilities are already being used by many people including people dealing with Quadriplegia, Arthritis

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and more, but not much by autistic people. Hence, an attempt is made to highlight the lesser-explored technologies which can be exploited to add convenience to the autistic lives in manifold ways.

In Chapter 9, the authors presented several Machine Learning (ML) models based on Support Vector Machines (SVM), Naïve Bayes (NB), k-Nearest Neighbours (KNN) and Decision Trees (DT) algorithms to diagnose the autism in the individuals. The authors also improved the performance of the ML models with the help of optimal subset of features selected using various well-known evolutionary optimization algorithms like GA and BTLBO. The experimental setup and discussion of results on various ASD datasets (children, adolescent and adult) of UCI repository are specified in this chapter.

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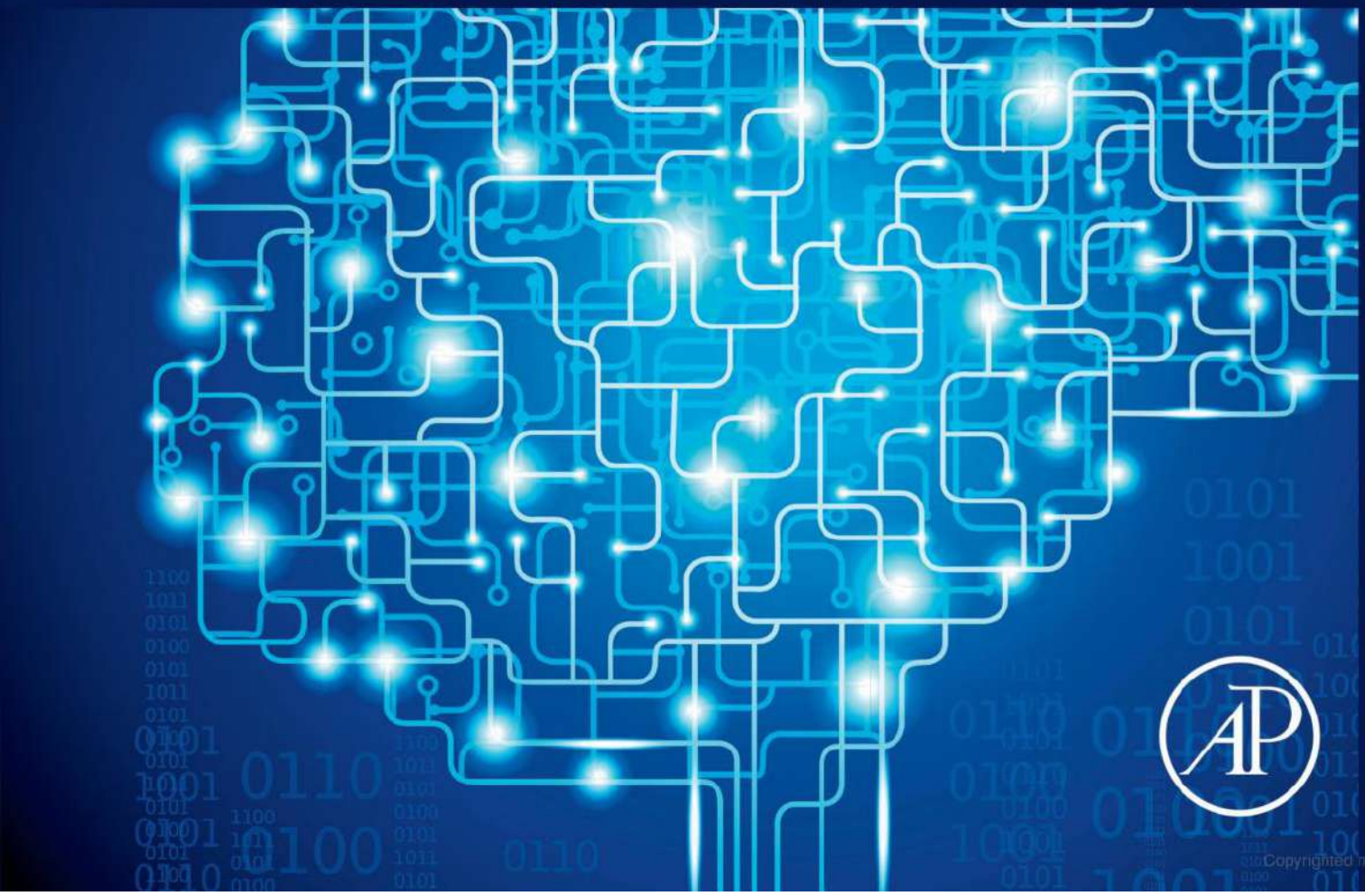
Techniques and Applications

Edited by Sanjay Kumar Singh, Ravi Shankar Singh, Anil Kumar Pandey, Sandeep S. Udmale, Ankit Chaudhary



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Preface

The Internet of things (IoT) is a new revolution of the Internet era that is rapidly discovering the research path in numerous academics and industrial domains, particularly in the healthcare industry. A remarkable proliferation of wearable devices, as well as smartphones, has assisted the IoT-enabled technology to evolve the healthcare industry for offering numerous and potentially innovative services to today's digital world. The smart healthcare industry improves the medical treatment process, efficiently manages the multiple resources, and eases the insurance claiming process, etc. The technology-enabled system identifies the current needs and presents future directions to medical organizations, manufacturers, service providers, and application developers. As a result, this is the most promising and demanding paradigm for providing the various medical services to a vast world population. Besides, it allows the medical facility providers to reach remote locations, correspond to experts, and understand the medicinal positions in a diversified environment. As an effect, it reduces the costs as well as saves time of patients and allows the doctors as well as supporting staff to attain more users in time.

The smart healthcare industry has a big market and provides ample opportunities for the business. The medical equipment manufacturers, Internet service providers, insurance companies, and software developers are the main stakeholder of the intelligent healthcare industry. The design, development, and deployment of a well-organized intelligent healthcare system require reliable hardware and software platforms with IoT-enabled technologies like communication networks. This healthcare system gets evolved over time for providing the new advantageous services to end-users, and thus, stakeholders must provide support for the scalability of the system. Nowadays, the healthcare industry has extended its services to agriculture, pet, and wild animals for tracking, monitoring, identifying diseases, etc. It presents the new challenges like designing a new device/sensor for providing the IoT-enabled solution to a specific animal.

Objective

The IoT-based healthcare industry provides a broad range of opportunities to identify and examine the new architectures and methods, theories and algorithms, intelligent analysis approaches, and construction of the practical application. Thus, this book aims to present a common platform to academicians as well as practitioners to observe the recent advances in the health industry through IoT, which consists of IoT architectures, platforms, data analysis methods, and health industry applications. The book introduces state-of-the-art-based approaches based on IoT and intelligent methods, challenges, opportunities, and future research directions. The book presents a potential thought and comprehensive review of emerging methodology for health IoT data analytics that provide valuable information for creating new knowledge for the future to develop novel prediction methods for the health industry.

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Organization of book

This book is organized into four sections. Each section helps to understand the importance of IoT in the health industry and various research as well as business opportunities. The summary of each section is as follows.

Section I reveals the history of IoT, the importance of IoT in healthcare with challenges for the implementation of IoT-based system and business opportunities. The personal and clinical smart architectures are described with a variety of sensors. The importance of a variety of sensors in designing the human healthcare system is explored along with different data types. The overview of data analysis methods is presented with challenges. Also, computational techniques are introduced as an arsenal tool to meet the continuously rising and demanding needs of the healthcare industry.

Section II presents the role of various services offered by the IoT-based healthcare system to patients, physicians, hospitals, and insurance companies. Also, there have been various decision-making tools, and methods are available for supporting healthcare decision making. However, multicriteria decision analysis techniques are exploited to provide effective services for a healthcare decision process. As a consequence, the analytic method requires analysis and mining of useful information from substantial medical data by handling the semantic interoperability issues in an electronic health record system. Besides, the extension of IoT services is discussed for offering the security and privacy to electronic health records as well as a smart healthcare system and assists the insurance companies to avoid fraud claims.

A potential roadmap for developing the healthcare applications by enabling seamless integration of IoT with existing healthcare infrastructure is focused in Section III. Smart healthcare systems designed for remote monitoring and personalized healthcare are highlighted with a challenge to the medical frontier. Thus, challenging applications such as critical heart monitoring and pain monitoring are discussed in detail. Further, an assistive solution for visually impaired is introduced to reduce the fraud cases and attacks by stray animals.

Finally, the potential of transforming the animal health paradigm through the rapid expansion of IoT in the animal sector is covered in the last section by introducing the Internet of animal health things. Smart animal farming and management methods are focused on providing the novel perspectives and opportunities for exploitation of the technology in the animal sector. As a result, the IoT provides a promising solution to livestock management, control, and prevention of infectious diseases like COVID-19, and developing the digital pathology.

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Versatile Applications for Materials Engineering

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Preface

In the present scenario of using thin films to realize miniature devices, multilayer thin films have become important for applications. Although the single layer is the ideal technology, the multilayer thin films are a more realistic technology, from the price index and the device dimensions point of view. Mechanical, electrical and electronic, magnetic, and optical devices have shown better performance with large scale integration thereby saving lots of space. Ultra-thin films with multilayer configurations can function more efficiently. If we consider the physics, chemistry, and engineering aspects, multilayer thin films can be controlled more precisely. It is also relatively easier to fabricate and study the multilayer films than the single layer films. With these views, technologists prefer multilayer thin films for recent applications in solar cells, sensors, and spintronic devices.

This edited book consists of thirteen chapters. The authors have presented different aspects of multilayer thin films. Repeated research has confirmed the vital use of multilayer thin films with optimal results. Except for some rigorously precise gadgets where single layer thin films are superior, the multilayer films are largely used and make miniature devices more popular. The chapters discuss the different materials and their thin films for various applications. Of late, solar cells and sensors technology have replaced many conventional textures of thin films and are using multilayer thin films. Especially in the sensor devices with graphene technology with multilayer structures shown as the most efficient detectors. The authors have described the use of multilayer graphene thin films as gas/vapor sensors for monitoring environmental pollution. The composite thin films with different combinations of nanomaterials have also been highlighted with a score of advantages.

The chapters are evenly distributed on different aspects of materials, devices, and the mechanism of ultrathin layers. With the development of multilayer thin films, a new type of binary and ternary composite sensors has been evaluated and been found to be quite efficient as multilayer devices. The material part is very relevant for the formation of nanolevel thin films. In this book, most of the chapters discuss the materials technology. The device configurations are also given importance. Finally, the applications have been elaborated on in some chapters. It is envisaged that this book will lead to more awareness of the multilayer thin films, its importance, and the advantages over the single layer films for uses in the modern technology.

Finally, it is expected that the book may act as a map for the scientists and technologists for carrying on more research and development work on multilayer thin films for varied applications. This development will show how a material with some intrinsic defects in the language of science and technology can have more advantages than the so-called more perfect materials. The successful technology does not only mean the theoretical perfections and available at much higher costs but it means the relatively low-cost materials with appreciably high output. In the present trend, the functional materials mean the upliftment of so-called inferior materials through different modifications such as thermal annealing, laser annealing, and chemical treatment of the multilayer thin films. In this book we aim to bring attention on these directions.

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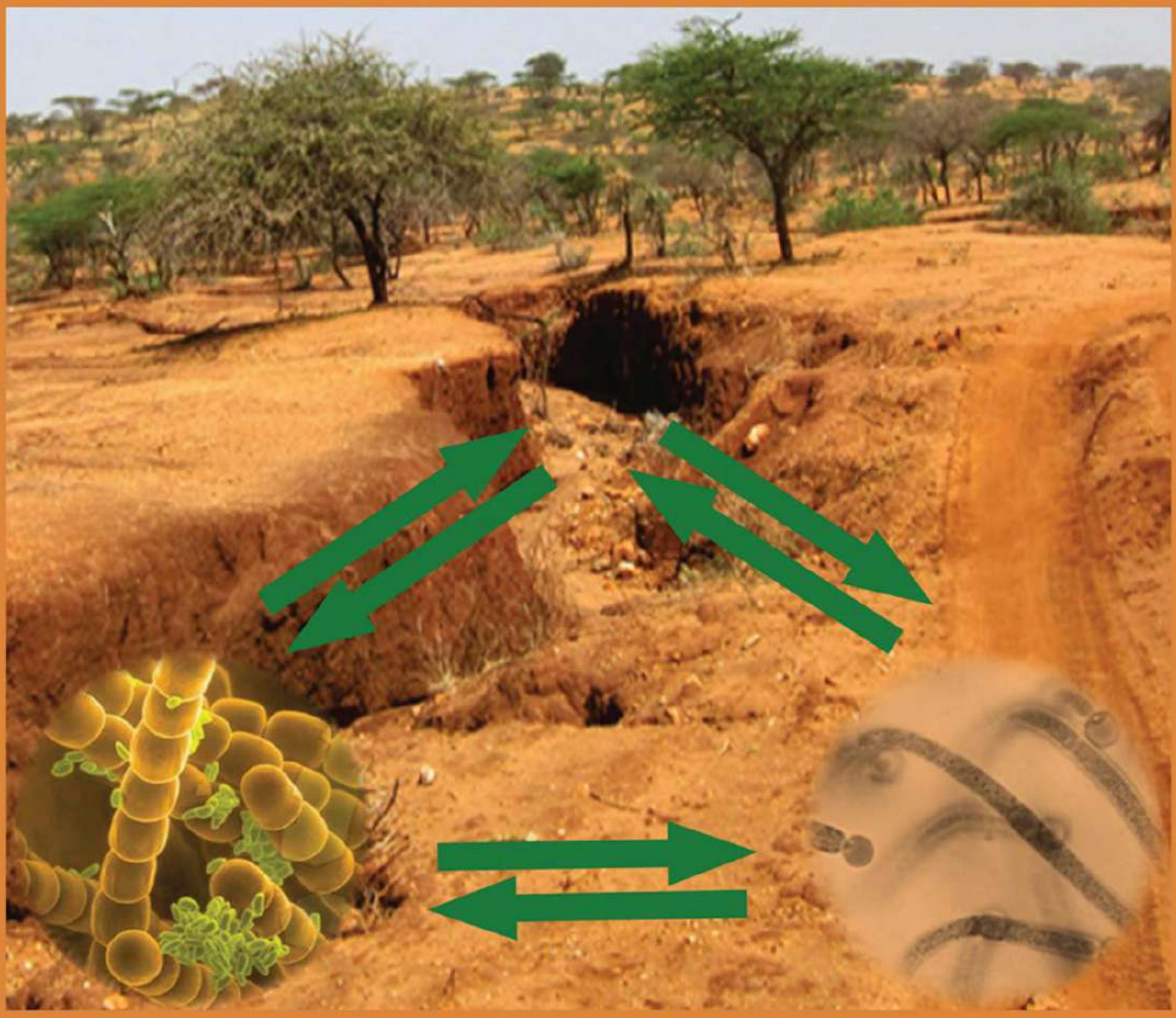

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Oil and petrochemical industries wastewater treatment in bioelectrochemical systems

7

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7.1 Introduction

Since the demand for energy resources is exponentially increasing, the concept of biofuel cells using microbes or enzymes as biocatalysts came into significance (Fig. 7.1). Here, we are discussing two categories of biofuel cells, namely, microbial fuel cells (MFCs) and enzymatic fuel cells (EFCs) which are well established for energy-saving waste disposal system. MFCs, as well as EFCs, are the new evolving technology not only for bioelectricity generation but also for wastewater treatments because of unique operating conditions (Sevda and Sreekrishnan, 2012, 2014; Quan et al., 2018). The current output in MFC is found to be low as compared to EFC. The conversion of fuel to electricity is more efficient in EFCs due to the absence of (1) cellular membrane, which inhibits electron transfer and (2) fuel-consuming microbial growth. But the commercialization of both the fuel cells still

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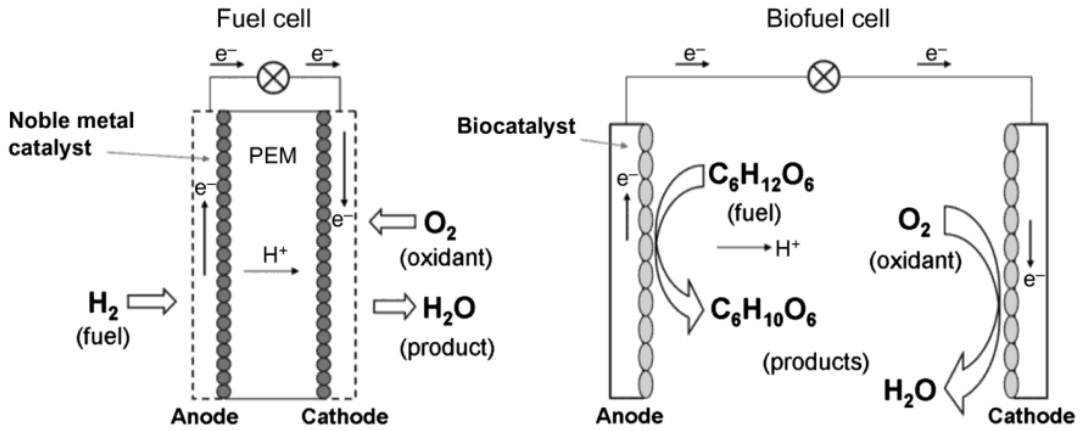

Figure 7.1 Diagrammatic depiction of a conventional fuel cell and a biofuel cell (Ivanov et al., 2010). A conventional fuel cell uses a metal catalyst in the anode, whereas biofuel cell uses microorganism or enzymes in the anode.

requires improvement for proper operations in the near future. Table 7.1 lists various MFCs and EFCs yield for various substrates.

In MFC, microorganisms, which are biocatalyst, catabolize the substrate and therefore generate power. Carbohydrates, proteins, fatty acids can be used as fuel in this system. MFC can be categorized into (1) MFCs with the mediator and (2) MFCs without a mediator

Current output in an MFC is attained by

1. catabolic activities of the microbes,
2. oxidation occurring at the anode,
3. reduction occurring at the cathode, and
4. anode chamber to cathode chamber proton transfer (Chaturvedi and Verma, 2016).

Fig. 7.2 shows a flowchart of the current generation in MFCs and EFCs.

MFCs can be used in the generation of electricity, production of biohydrogen, wastewater treatment, biosensor development for pollutant analysis, bioremediation of phenolic, and petroleum-based products (Rahimnejad et al., 2015; Sevda et al., 2016, 2017).

7.2 Oil field and petrochemical wastewater treatment in the conventional treatment process

Industrialization and urbanization simultaneously affect oil and petroleum resources worldwide. Petroleum and oil field resources generate a large amount of oily waste, which infects the water resources (Yu et al., 2017). The oil waste has a high amount of organic and inorganic pollutants, heavy oil complexes, surfactants and polymers, and their removal from the environment is the major concern facing by the oil refinery industries (Ji et al., 2002). The petroleum waste has aliphatic and aromatic hydrocarbon, and their presence enormously impacts every aspect of the

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Table 7.1 Advantages and disadvantages of different treatment techniques for oil and petrochemical industries.

Treatment	Advantages	Disadvantages	References
Oil effluents treatment techniques			
Flotation	A small amount of sludge formed Highly economical	Rely on various physical, chemical parameters	Rubio et al. (2002)
Coagulation/ flocculation	Decrease in oil concentration Elimination of suspended solids Poly-zinc silicates and anion polyacrylamide used as a coagulant	Reaction conditions vary with oil concentration	Zeng et al. (2007)
Coagulation	Hydroxypropyl guar gum of oil field wastewater degraded Decrease in the COD	Oil has a high amount of organic content, so it creates hurdles in flocculants formation	Zhang (2018)
Activated sludge process	Separate the petroleum hydrocarbon from the oil field wastewater	Mainly depend on solids retention time	Tellez et al. (2002)
Chemical coagulation	BOD, COD, ammoniacal nitrogen, and oil concentration reduced	Complex nature of effluent so alkaline, polymer flooding, and surfactant are used	Yan et al. (2014)
Micro-flocculation and filtration	Eliminate the suspended solids and oil	The little adsorption capacity of ceramsite filters	Si et al. (2018)
Electrocoagulation	Continuous flow of current density and consistent flow rate affect the turbidity and oil removal positively	Occupy huge space	Jiang et al. (2017)
Advanced oxidation	COD reduction Organic pollutants separated easily	Homogenous electron Fenton does not show that much efficiency for oil removal and reduction in COD	Boopathy and Das (2018)
Microfiltration	Excessive emulsifiers in oil can be segregated by the polytetrafluoroethylene membrane	Emulsion concentration affects retention efficiency	Kiss et al. (2013)

(*Continued*)

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Debashis Saha
Indian Institute of Management Calcutta, India

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A Demand Model for Mobile Data Traffic in the 5G Era: Case of Finland.....21
Michail Katsigiannis, Magister Solutions Ltd., Finland

This chapter examines how to estimate and forecast the market demand of mobile data traffic in the 5G era. The research objective is to develop a demand model for forecasting the market price and quantity of traffic in the Finnish mobile data communications market for the period between 2016 and 2020. The market price of traffic unit (GB/month), quantity, revenue, and profits are empirically estimated and forecast. The results show that the improvements of network performance, reflected by the user experienced data rate, cause a drop in the price from 0.8 to 0.27 € per GB/month between 2016 and 2020 (tenfold traffic growth). Also, a more than threefold increase is shown in mobile data revenues, whereas the profitability remains at a high level for the minimum marginal cost of 0.08 €.

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Oshin Sharma, Jaypee University of Information and Technology, India
Hemraj Saini, Jaypee University of Information and Technology, India

The most dominant service of cloud computing is infrastructure as a service (IaaS). Virtualization is the most important feature of IaaS and it is very important for the improvement of resource utilization; but along with this, it also degrades the system's performance and makes them overutilized. Therefore, to solve the problem of overutilization or underutilization of machines and performance improvement of machine, the VMs present inside the physical machine needs to be migrated to another physical machine using the process of VM consolidation, and the reduced set of physical machines after placement needs a lesser amount of power or energy consumption, which is the main aim of energy-aware VM placement. This chapter presents a decision-making VM placement system and compares it with other predefined VM placement techniques. This analysis contributes to a better understanding of the effects of the placement strategies over the overall performance of cloud environment and also shows how the one algorithm delivers better results for VM placement than another.

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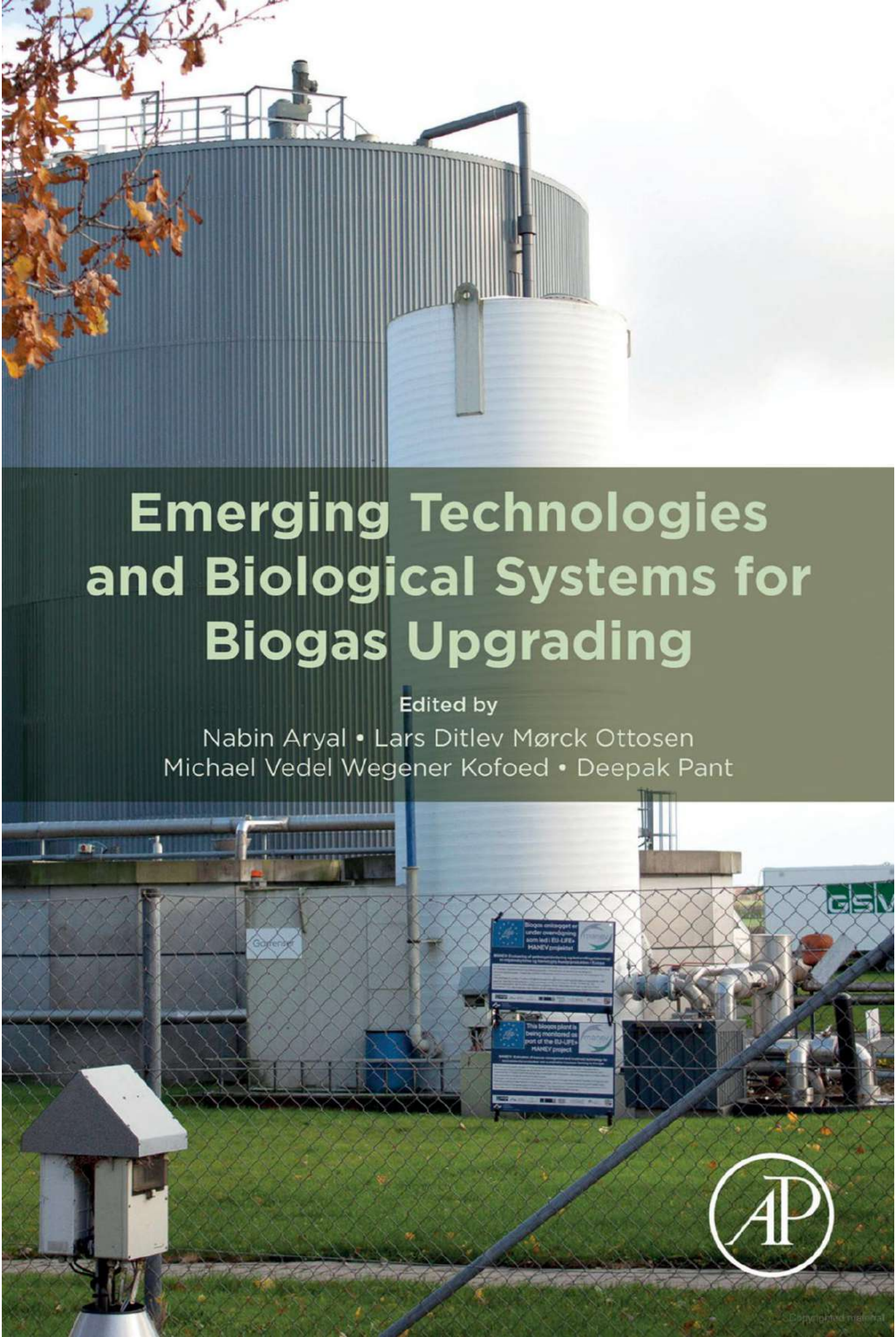

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Preface

Biogas is a methane-rich gas produced from biological degradation of biomass. The anaerobic digestion (AD) process has been commercially initiated to produce methane (CH_4) from organic waste degradation that significantly contributes to global renewable energy production and consumption. Biogas has an important role in the global carbon cycle and has traditionally been used as an alternative renewable energy source. Especially in developing countries, a large part of the rural population relies on decentralized small-scale biogas digestors for meeting their household energy needs and furthermore for utilizing the digestate from such plants as a source of nutrient-rich fertilizer for their soils. Worldwide uncontrolled solid waste production leads to greenhouse gas (GHG) emissions in the form of carbon dioxide (CO_2) and CH_4, contributing significantly to climate change. Hence, harvesting biogas from the organic waste stream results in an environmentally sustainable source of renewable energy while reducing GHG emissions. According to the World Biogas Association, the annual biogas production in 2018 exceeded 60.8 billion m^3, of which almost 54% was in Europe. The global production is projected to increase further worldwide, illustrating the worth of biogas, especially in a scenario with dramatic reductions in the consumption of fossil fuels.

Biogas predominantly consists of 40%−60% CH_4, 60%−40% CO_2, and traces of hydrogen sulfide (H_2S), ammonia (NH_3), hydrogen (H_2), oxygen (O_2), nitrogen (N_2), siloxanes, carbon monoxide (CO), hydrocarbons, and volatile organic compounds. Primarily, the CO_2 content in biogas lowers its heating value compared to natural gas, and the presence of other constituents may cause corrosion and salt accumulation on the associated appliances such as boilers, burners, and gas engines.

Biogas therefore has to be treated and conditioned to improve its gas heating value and downstream applicability. The gas can ultimately reach gas grid quality by upgrading it even further through removal or conversion of CO_2. Recently, biogas upgrading has gained intense attention due to national targets for renewable energy production, environmental concerns, and the need to replace fossil fuels with sustainable fuel alternatives. Several technologies are today commercially available and implemented for biogas upgrading at commercial biogas plants, including water scrubbing, amine scrubbing, pressure swing adsorption, and membrane-based technologies. Among the implemented

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biogas upgrading technologies, water scrubbing is a widely applied technology that accounts for almost 40% of the total upgrading. These scrubbers upgrade the biogas by removing CO_2 from biogas and emitting it to the atmosphere.

The focus on reducing emissions from the biogas industry and utilizing biogas as a source of CO_2 has spawned the development of alternative technologies for biological, bioelectrochemical, and chemical biogas upgrading. These technologies are at different technological readiness levels but all represent promising solutions for reducing the carbon footprint of the biogas industry and at the same time increasing its importance as a supplier of renewable energy and chemicals. As an example, biological methanation today constitutes a promising technology for converting biogas CO_2 to CH_4 by the use of electricity from renewable sources through a process that combines carbon capture and utilization with energy conversion (Power-to-X). The development and demonstration of new technologies is not only an academic exercise but also includes heavy industrial involvement. Nonetheless, comprehensive access to technical information on biogas upgrading technology remains limited. To overcome such a gap, this book intends to provide complete technical details on biogas upgrading. Each chapter of the book is designed to give a fully comprehensive and most recent state-of-the-art on different technologies currently in use or under development for biogas cleaning and upgrading.

In this book, fundamental principles, state-of-the-art, biogas cleaning, and upgrading technologies for CO_2, H_2S, and siloxane removal or conversion have been elaborated. The book begins by outlining the global scenario of biogas production and upgrading processes, followed by an insight into physicochemical upgrading systems that have been implemented at an industrial scale. The critical process parameter optimization of absorption/stripping technology, and optimization of cryogenic, membrane, and power-to-gas are discussed. The subsequent chapters describe biological cleaning and conversion of H_2S, H_2-mediated CO_2 conversion, bioelectrochemical conversion of CO_2 to CH_4, and algal-based photosynthetic biogas upgrading. Finally, the implications of policies for biogas upgrading are provided. In a nutshell, the information in this book brings insights into technologies and processes for biogas treatment and upgrading. This book is aimed at a broad audience, mainly researchers, biogas specialists, academics, entrepreneurs, industrialists, policymakers, and others who wish to know the latest developments and future perspectives of biogas upgradation approaches for the enhancement of the existing digestors, and also discusses the bottlenecks of the various technologies that currently limit scale-up and commercialization.

The chapters are written by experts in the field from all parts of the world. Consolidation of the most recent state-of-the-art into an independent chapter for each type of physical, chemical, or biotechnological upgrading system is the main aim of this book. A key point of the book is that it also provides guidance on which procedures should be followed under what

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conditions to get the best results in terms of upgrading. It is our sincere hope that this book will contribute to the necessary transition to environmentally benign and sustainable adoption of biogas in general and biogas upgrading approaches in particular. Though we have tried to be objective in our choice of topics to be covered in this book, some not so common themes which may become important in the future may have been missed out, we will try to cover them in the second edition of the book.

This book is intended to have three roles and to serve three associated audiences, namely, the students and research community who will benefit from the lucid explanation of the possible applications of biogas upgradation for the betterment of environment, the policymakers who will find it easier to identify the pros and cons of different upgradation systems, and finally, the industries involved, as it will give them a feeling about the current loopholes (technological possibilities and possibilities for optimization) and ways to fix them. Each chapter begins with a fundamental explanation for general readers and ends with in-depth scientific details suitable for expert readers. The text in all the chapters is supported by numerous clear, illustrative, and informative diagrams, flowcharts, and comprehensive tables detailing the scientific advancements, providing an opportunity to understand the process thoroughly and meticulously. Written in an eloquent style, the book comprehensively covers each point to give the reader a holistic picture of biogas treatment technologies and the future perspective of their use. The book may even be adopted as a textbook for university courses that deal with such courses related to both energy and the environment.

Despite the best efforts of the authors and editors, along with extensive checks conducted by many experts in the field of biogas and AD, mistakes may have crept in inadvertently. We would appreciate if readers could highlight these and make comments or suggestions to improve and update the book contents for future editions.

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MICROBIAL BIOTECHNOLOGY FOR FOOD, HEALTH, AND THE ENVIRONMENT

PLANT-MICROBIAL INTERACTIONS AND SMART AGRICULTURAL BIOTECHNOLOGY

EDITED BY

Swati Tyagi, Robin Kumar,
Baljeet Singh Saharan,
and Ashok Kumar Nadda

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Edited by
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Preface

Farmers have great potential to adapt to and accept climate change. The global economy has changed and has been able to develop sustainable agriculture with high rates of growth. This helped us to solve the problem of food shortage. In this age, climate change has brought new and complicated challenges. To combat these challenges, it is necessary to understand the root causes, after which proper implementation of the solutions is required. On the other hand, the overuse of chemical fertilizers and pesticides has caused many environmental problems, including water acidification, greenhouse effect, and depletion of the ozone layer. These problems can be addressed using biopesticides and biofertilizers, which are beneficial, environmentally friendly, natural, and easy to use. Microbial biofertilizers control soilborne diseases, maintain soil structure, and provide nutrients to plants. They play a vital role in sustainable agriculture. Arbuscular mycorrhizal fungi are important soil microbes that form symbiotic associations with most terrestrial plants and are mainly responsible for the uptake of phosphorus. Another group of microbes are biological nitrogen-fixing bacteria, which are universally potent bioinoculants used to promote plant growth. The use of *Rhizobium* in legume crops to support agricultural productivity is increasing day by day. Such types of bioinoculants are easily available to farmers. Moreover, the mass production of these biofertilizers is done in laboratories, and they can easily be stored as liquid or carrier-based bioformulations at room temperature. Phosphate-solubilizing bacteria are also extremely important, as they have been reported to increase P uptake by converting insoluble to soluble forms. *Azotobacter* and *Azospirillum* are two other very important bacteria. The response of these organisms is commonly seen in increasing yields. Apart from these microbes, cyanobacteria also contribute significantly to the nitrogen economy of sustainable agriculture. The tripartite relationship between legumes, rhizobia, and mycorrhiza is the most efficient combination to promote growth and achieve higher productivity in plants, trees, and vegetables. Cyanobacteria are excellent suppliers of nitrogen. Their importance for abundant crop production cannot be ignored and has been felt by farmers. They are easy to multiply and can now be obtained in bottles or packets throughout the year. In fact, the application of microbial bioinoculants is a very effective and natural method to increase and maintain the mineral economy of nature. Their use reduces the need for chemical fertilizers, making them the only effective alternative for self-sustaining farming.

Microbe–host or microbe–microbe interactions are important strategies for colonization and establishment in different agro-climatic conditions/regions. This communication/crosstalk covers all aspects of the microbial communities', e.g., signaling, chemotaxis, genetic exchange, metabolite conversion, intermediary metabolism, and physicochemical changes that lead to genotype selection. The survival rate of microbes in the environment depends on biodiversity because the high genetic variability increases the competitiveness and reduces the chances of intruders settling in the respective climatic conditions. Hence, these interactions are the result of

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a coordination that results in acclimatization and adroitness and enables the filling of various niches by limiting biological and abiotic stresses or exchanging growth factors and signals. Several mechanisms might be involved in this exchange, such as secondary metabolites, biofilm formation, cellular transduction signaling, quorum sensing system, and siderophores. The final unit of interaction is the expression of each organism's genes in response to environmental stimuli responsible for the production of the biomolecules involved in such associations. Hence, in this book, we focus on the molecular mechanisms involved in such interactions in the molecular strategy used by various microbes, which influence the constitution and structure of microbes.

The challenges are varied and unpredictable, but with the experience of farmers and expertise of our scientists, it is possible to make agriculture smarter. There has been great demand for a book on *Plant-Microbial Interactions and Smart Agricultural Biotechnology*, wherein different issues concerning microbial interactions and smart agriculture have been described.

This book will certainly provide useful information dealing with a diverse group of microbes, beneficial effects, and the bottlenecks in their implementation. Students, researchers, biotechnologists, microbiologists, botanists, soil biologists, industrialists involved in the mass production of biofertilizers, producers, environmentalists, and all other users should find this book extremely useful. The goal of this book is to provide essential information on the use of different microbes and their secondary metabolites for the treatment of various diseases affecting crops. This book also describes the potential of microbes (tiny factories) in improving crop yield, plant health, and the biomolecules' production efficiency for smart agriculture.

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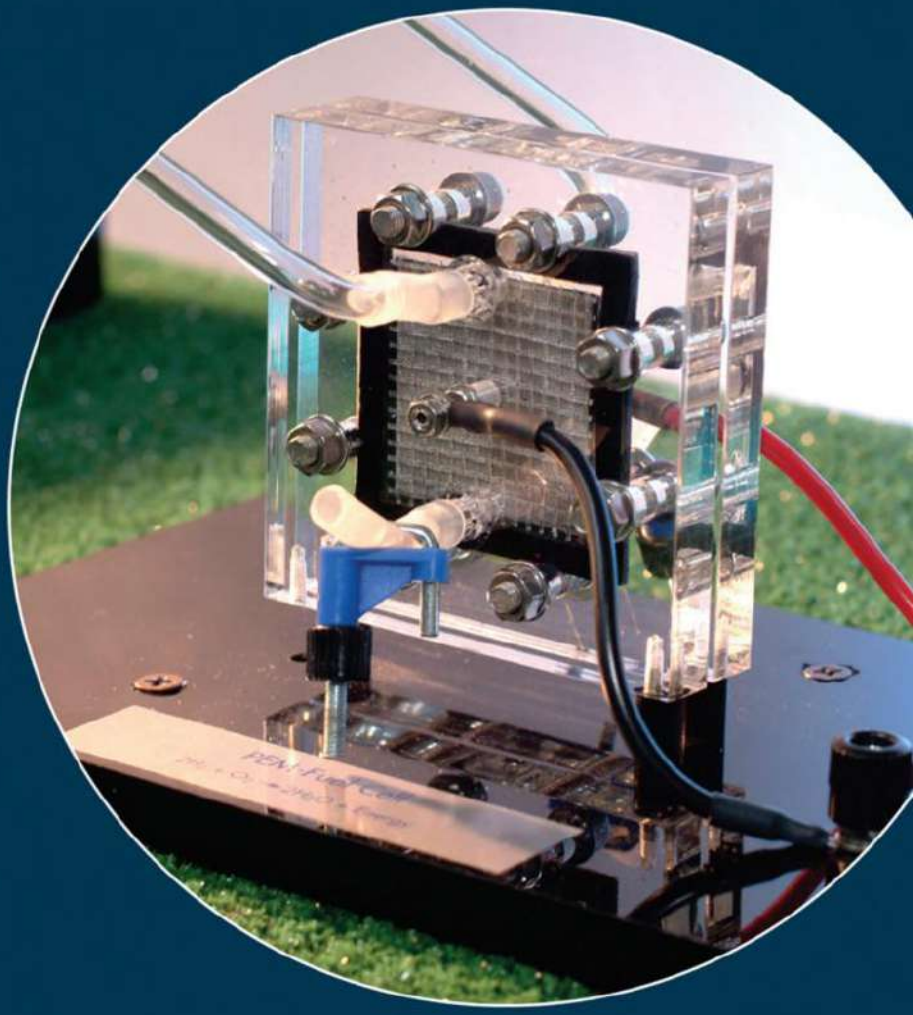
Bioelectrochemical Systems: The Way Forward

Volume I

Delivering Low-Carbon Biofuels with Bioproduct Recovery:

An Integrated Approach to Commercializing Bioelectrochemical Systems



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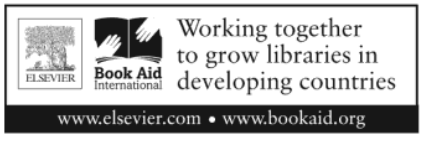

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Preface

Advancements in data science have created opportunities to sort, manage, and analyze large amounts of data more effectively and efficiently. In contemporary society, medical records and patient information have increasingly become more digitized, with patients required to use patient portals to access their medical information. Additionally, doctors, nurses, hospital staff, and specialists rely on electronic documents that are easy to access and share and that can follow patients that require multiple medical experts. Applying new data science technologies to the healthcare industry, which has vast quantities of patient and medical data and is increasingly becoming more data-reliant, is crucial for refining medical practices and patient care as well as maintaining efficient communication between departments and offices.

Staying informed of the most up-to-date research trends and findings is of the utmost importance. That is why IGI Global is pleased to offer this four-volume reference collection that will shed light on practical applications of healthcare analytics for improved patient care, resource allocation, and medical performance, as well as for diagnosing, predicting, and identifying at-risk populations by providing both broad and detailed perspectives on cutting-edge theories and developments. This reference is designed to act as a single reference source on conceptual, methodological, technical, and managerial issues and to provide insight into emerging trends and future opportunities on the connections between data analytics in the field of medicine.

Data Analytics in Medicine: Concepts, Methodologies, Tools, and Applications is organized into seven distinct sections that provide comprehensive coverage of important topics. The sections are:

1. Fundamental Concepts and Theories;
2. Development and Design Methodologies;
3. Tools and Technologies;
4. Utilization and Applications;
5. Organizational and Social Implications;
6. Critical Issues and Challenges; and
7. Emerging Trends.

The following paragraphs provide a summary of what to expect from this invaluable reference tool.

Section 1, "Fundamental Concepts and Theories," serves as a foundation for this extensive reference tool by addressing crucial theories essential to the understanding of data analytics in medicine. Introducing the book is "A Guideline to Use Activity Theory for Collaborative Healthcare Information Systems Design," by Prof. Carolin Durst (University of Bremen, Germany), Prof. Nilmini Wickramasinghe (Epworth HealthCare, Australia & Deakin University, Australia), and Prof. Jana Riechert (University

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of Erlangen-Nuremberg, Germany): a great foundation laying the groundwork for the basic concepts and theories that will be discussed throughout the rest of the book. Section 1 concludes and leads into the following portion of the book with a nice segue chapter, "Population Health Management and the Science of Individuality," by Prof. Anastasius Moumtzoglou (Hellenic Society for Quality and Safety in Healthcare, Greece, & P. & A. Kyriakou Children's Hospital, Ilion, Greece) and Prof. Abraham Pouliakis (2nd Department of Pathology, National and Kapodistrian University of Athens, Athens, Greece).

Section 2, "Development and Design Methodologies," presents in-depth coverage of the conceptual design and architecture of data analytics in medicine. Opening the section is "A Yes/No Answer Generator Based on Sentiment-Word Scores in Biomedical Question Answering," by Prof. Mourad Sarrouti (Laboratory of Computer Science and Modeling, FSDM, Sidi Mohammed Ben Abdellah University, Fez, Morocco) and Prof. Said Ouatik El Alaoui (Laboratory of Computer Science and Modeling, FSDM, Sidi Mohammed Ben Abdellah University, Fez, Morocco). Through case studies, this section lays excellent groundwork for later sections that explore present and future applications for data analytics in medicine. The section concludes with an excellent work by Prof. Basant Tiwari (Hawassa University, Awassa, Ethiopia) and Prof. Vivek Tiwari (IIIT-NR, Naya Raipur, India), "An Intelligent Multi-Objective Framework of Pervasive Information Computing."

Section 3, "Tools and Technologies," presents extensive coverage of the various tools and technologies used in the implementation of data analytics in medicine. The first chapter, "Detecting Human Diseases Relatedness: A Spreading Activation Approach Over Ontologies," by Prof. Said Fathalla (Bonn University, Bonn, Germany & Alexandria University, Alexandria, Egypt), lays a framework for the types of works that can be found in this section. The section concludes with "A Study on Lifetime Enhancement and Reliability in Wearable Wireless Body Area Networks," by Prof. Saranya Vasanthamani (Sri Krishna College of Engineering and Technology, Coimbatore, India). Where Section 3 described specific tools and technologies at the disposal of practitioners, Section 4 describes the use and applications of the tools and frameworks discussed in previous sections.

Section 4, "Utilization and Applications," describes how the broad range of data analytics in medicine efforts has been utilized and offers insight on and important lessons for their applications and impact. The first chapter in this section is "Pluralistic Tendencies in Healing Abantu Illness in the Contemporary South Africa," written by Prof. Kholekile Hazel Ngqila (Walter Sisulu University, South Africa). This section includes the widest range of topics because it describes case studies, research, methodologies, frameworks, architectures, theory, analysis, and guides for implementation. The breadth of topics covered in the section is also reflected in the diversity of its authors, from countries all over the globe. The section concludes with "Big Data and IoT-Allied Challenges Associated With Healthcare Applications in Smart and Automated Systems," by Prof. Mamata Rath (Department of IT, C.V. Raman College of Engineering, Bhubaneswar, India), a great transition chapter into the next section.

Section 5, "Organizational and Social Implications," includes chapters discussing the organizational and social impact of data analytics in medicine. The section opens with "Shared Electronic Health Records as Innovation: An Australian Case," by Prof. Troy Pullen (Queensland State Archives, Australia) and Latif Al-Hakim (University of South Australia, Australia). This section focuses exclusively on how these technologies affect human lives, either through the way they interact with each other or through how they affect behavioral/workplace situations. The section concludes with "Forensic Investigation of Digital Crimes in Healthcare Applications," by Prof. Nourhene Ellouze (University of Carthage, Tunisia), Prof. Slim Rekhis (University of Carthage, Tunisia), and Prof. Noureddine Boudriga (University of Carthage, Tunisia).

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Bioactive Compounds in Nutraceutical and Functional Food for Good Human Health

Edited by Kavita Sharma, Kanchan Mishra, Kula Kamal Senapati and Corina Danciu



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Preface

Bioactive compounds are widely used in the pharmaceutical industry, food processing, and drug, nutraceutical, and cosmetic manufacturing, among others. This book examines how to obtain bioactive compounds from different sources and their potential industrial uses. New and sophisticated techniques are used for obtaining bioactive compounds from different sources such as plants, marine life, and microorganisms. Currently, researchers are investigating the utilization of fruit and vegetable wastes as good and cheap sources of bioactive compounds. The bioactive compounds possess antioxidant, antimicrobial, anti-inflammatory, anticancer, and antidepressant properties. The biological activity of these compounds is based on the lead or privileged scaffolds present in their structure. These different scaffolds include indole, purine, chromone, coumarin, benzothiophene, lactone, and so on, and can be modified into multiple molecules for different bioactivities. Sesquiterpene lactones (SLs) are an example of containing lactone as a privileged scaffold. The γ-lactone ring, usually with an α-methylene group, is a significant characteristic of SLs. Their molecular structure may present hydroxyls, esterified hydroxyls, or epoxide groups. These bioactive molecules have direct potent effects on human health.

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Preface

Extinction and introduction of new taxa are two crucial biodiversity crises of the modern era. Taxa become endangered and eventually extinct due to the high death rate. There are a number of factors associated with this and many taxa are facing tremendous pressure and are on the verge of extinction throughout the world. Therefore, documentation of endangered species, as well as restoration work in certain landscapes, is very important. *Endangered Plants* presents an account of diversity, threats, restoration, and long-term conservation strategies of endangered plants worldwide. Section I describes endangered species and Section II discusses conservation strategies for these endangered plants.

I express my deep gratitude to the contributors of this book for sharing their valuable works and knowledge on endangered plants. I am also thankful to Mr. Josip Knapić and other staff at IntechOpen for their support in the publication of this book.

I hope this volume will be of use to researchers, scientists, academicians, biologists, and other interested readers.

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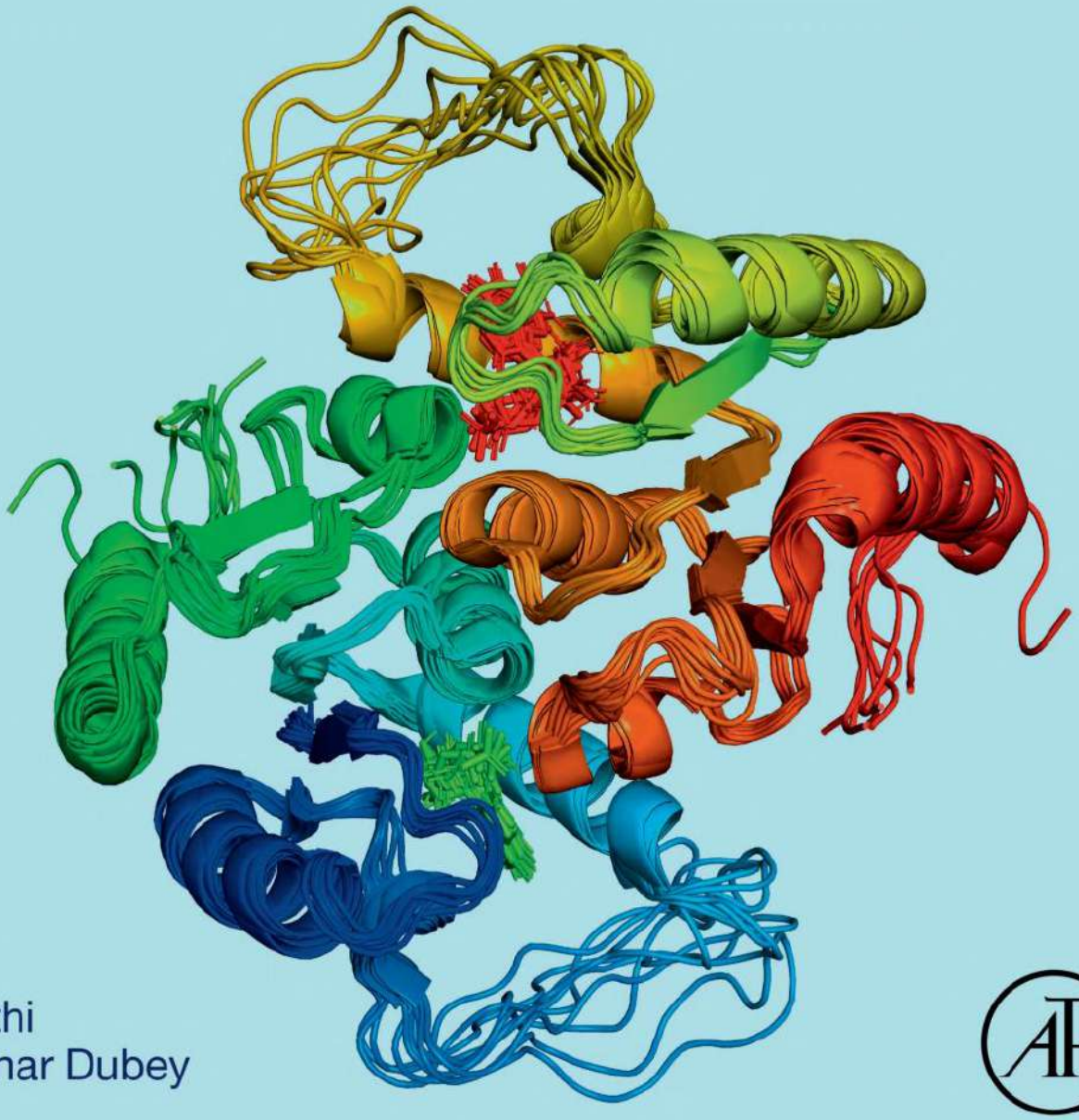
Advances in Protein Molecular and Structural Biology Methods



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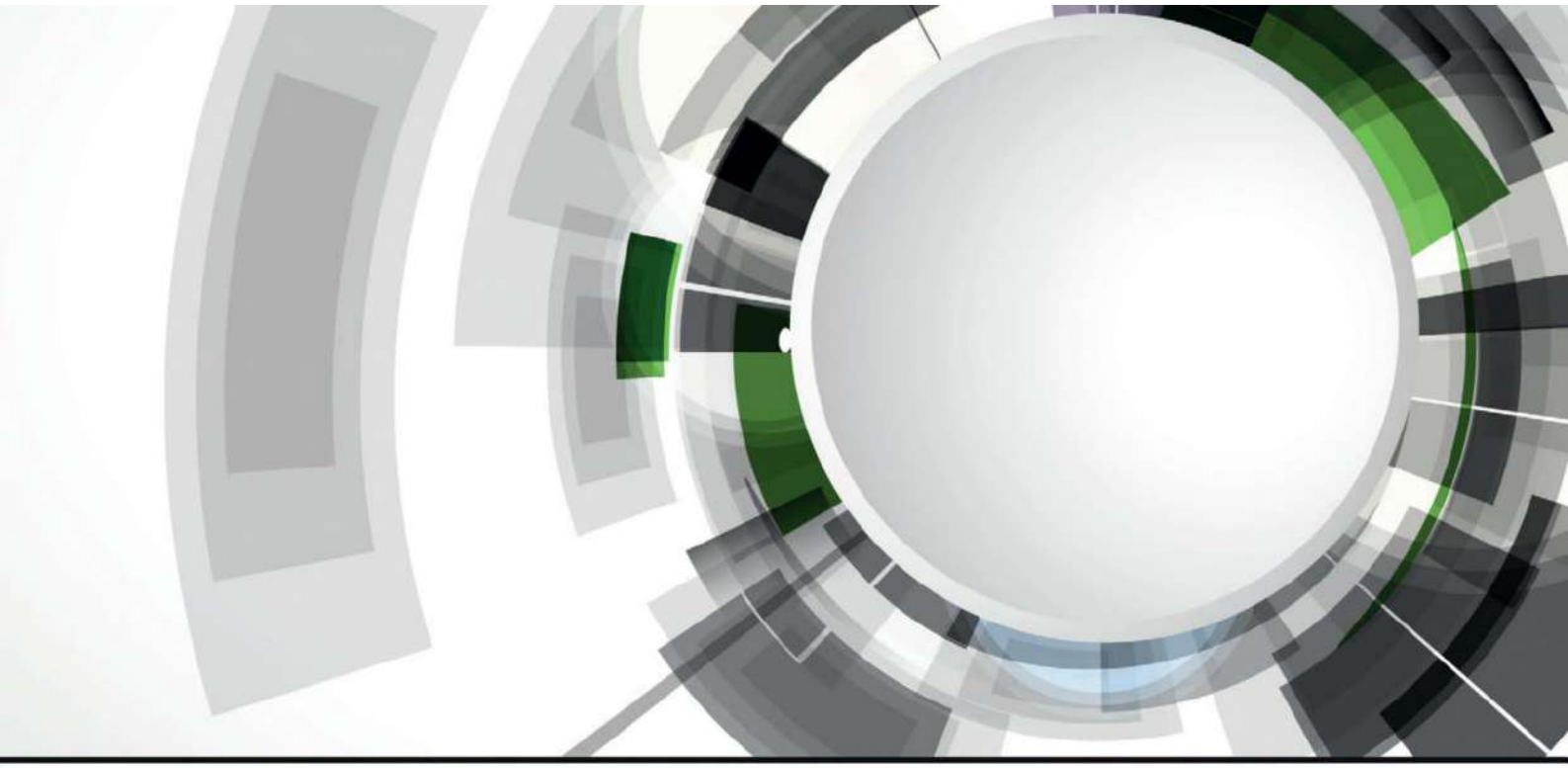

Himalayan Medicinal Plants

Advances in Botany, Production & Research

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Preface

Horizons in Bioprocess Engineering is intended to all those who make use of science and technology skills for applications pertaining to chemical and bioprocess engineering. The prospects of bioprocess engineering is unlimited. However, this book attempts to highlight a few key concepts by our distinguished authors. The book's objective is to help academia, researchers, and practitioners to use the principles and tools of chemical and bioprocess engineering in a pertinent way, while brainstorming novel concepts of bioprocess engineering.

The book is divided into **four parts** and each part branches out into different chapters. **Biomass and Bioenergy** comprises **five chapters** ("Studies on Esterification Optimization of High FFA Content Pongamia Oil Using Box–Behnken Design"–"Scalable Technologies for Lignocellulosic Biomass Processing into Cellulosic Ethanol") and addresses the significance of bioenergy and biomass and scalable technologies for greener processes and products. **Novel Technologies of Bioprocess Engineering** consists of **five chapters** ("Role of Biofilms in Bioprocesses: A Framework for Multidimensional IBM Modelling of Heterogeneous Biofilms"–"Furfural—A Promising Symbiotic Business Model for Integrated Biorefinery") and delves with an insight into science of nanoparticles in bioprocesses for protein separation, purification, and detection, conversion of glycerol to valuable products, optimization of Catalytic Cracking of Refined Rubber Seed Oil for Bio gasoline, Furfural Production, and a promising symbiotic business model for integrated biorefinery. **Applications of Biotechnology** comprises **four chapters** ("Role of White Biotechnology in 2G Biofuels: Biocatalytic Process Development for the Hydrolysis of Lignocellulosic Biomass"–"Biotechnology For Environmentally Benign Gold Production") with an emphasis on white biotechnology, gold biotechnology, metabolic engineering, and immobilized biocatalysis studies. Finally, **Bioreactor Engineering Transfer Learning and IP Rights** presents the biowaste treatment, transfer learning, and IP rights in **three chapters**

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("Bio Waste Treatment"–"Transfer Learning Combined with High-Throughput Experimentation Framework for Integrated BioRefinery") and explores new horizons on transfer learning and intellectual property(IP) rights.

Columbia, South Carolina, USA Ravindra Pogaku

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Computer-Aided Diagnostic System for Diabetic Retinopathy Using Convolutional Neural Network

Sanket Saxena, Shivam Sinha, and Shruti Jain

Abstract

An ongoing advancement in the condition of craftsmanship innovation assumes an imperative job in the picture handling applications, like biomedical, satellite picture preparing, artificial intelligence, object recognizable proof, diabetic retinopathy (DR), etc. DR is an eye disease found in people having high blood sugar. It can lead to loss of vision, if it is not treated properly. There is an increase in number of patients in comparison with ophthalmologists. The seriousness of the DR depends upon nearness of microaneurysms, hemorrhages, exudates and neovascularization. Specialists arrange diabetic retinopathy into five stages, namely ordinary, gentle, moderate, non-proliferative DR (NPDR) or proliferative DR (PDR). Convolutional neural network (CNN) results in high accuracy in classifying these diseases by spatial analysis. A CNN is progressively mind-boggling engineering construed more from the human visual perspective. A previous study done on DR suggests the use of CNN but with a different approach. Among other managed calculations involved, the proposed arrangement is to locate a superior and advanced way to classify the fundus picture with little pre-preparing techniques. Different fundus image databases available have been discussed. In this paper, different parameters used for the evaluation of developed systems have been presented.

Keywords

Deep learning • CNN • Regularization • Cost function • Non-proliferative • Kaggle

1 Introduction

Diabetic retinopathy is one of the most prominent diseases found in the human eye. The problem with DR is its detection which requires very highly skilled medical facility. The main reason for a person to get contracted with diabetic retinopathy is diabetes. Diabetes occurs when the body is either not capable of producing sufficient insulin (known as Type 1 diabetes) or cells that cannot utilize which is produced by pancreas (Type 2 diabetes). Factors that are responsible for the increase in diabetes are obesity, urbanization, diabetes is population growth, aging, and reduced physical activity. As per the statistics from the International Diabetic Federation (IDF), the number of people with diabetes over the world in 2015 was 415 million, and by 2040, it will be 642 million. For Southeast Asia, it was 78.3 million in 2015 and will be 140.2 million in 2040. In India alone, there are 69.18 million cases of diabetes (http://www.ubcieee.org/events/signal-processing-cup-2015). If proper care is not taken, diabetes will lead to complications in the eye, kidney, skin, heart, foot, etc. An eye is an essential part of the human visual system which operates as a receptor organ. The eye is an exceptionally perplexing and stunning organ. It is roughly one inch wide and profound, and 0.9 inches tall. Natural eyes permit people to value all the superiority of the world. The natural eye is enveloped by three layers of tissue. There are just about 80 million individuals in India living with sight misfortune, counting around 3,60,000 individuals who are enlisted as visually impaired or incompletely located. Sight undermining maladies, for example, macular degeneration and diabetic retinopathy (DR) have added to the 40% expansion in outpatient attendances in the most recent decade yet are agreeable to early location and checking. With right on time and proper mediation, visual impairment might be forestalled in numerous cases (https://www.mayoclinic.org/diseases-conditions/retinal-diseases/symptoms-causes/syc-20355825). The retinal ailment is getting basic in the creating scene.

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Treatment of retinal conditions is improving and might be financially savvy, even in eye clinics. One of the diabetes complexities is DR which harms the eye. It mainly harms the veins of light-touchy tissue which is at the back of the eye (retina). Ophthalmic training ought to plan eye laborers not just for the difficulties they will confront today, yet besides for future turns of events. This implies that we need all the more creating world ophthalmologists with sub-claim to fame preparing in retinal ailment who can prepare people in the future of eye workers (https://www.mayoclinic.org/diseases-conditions/diabetic-retinopathy/symptoms-causes/syc-20371611; https://www.eatonrapidseyecare.com/eye-health/diabetic-retinopathy/h). The standard eye tests, great control of our glucose and circulatory strain, and early intercession for vision issues can assist with forestalling extreme vision misfortune. The complications in the eye can be glaucoma, cataracts and DR. About 40% of diabetic people are affected by DR. About 10% of the DR patients have the chance of completely losing the vision (https://www.mayoclinic.org/diseases-conditions/retinal-diseases/symptoms-causes/syc-20355825). DR is the entanglement that affects the eyes. It mainly harms the veins of delicate tissues of the eye.

Diabetic retinopathy is an eye disease found in people having high blood sugar. It can lead to loss of vision if it is not treated properly. There is an increase in the number of patients in comparison with ophthalmologists. In this scenario, there is a need for a system to aid the ophthalmologists for faster and easy diagnosis. Among other existing managing calculations, the majority of them require more pre-handling or post-preparing stages for recognizing various phases of the DR. Likewise, different calculations obligatorily require manual element extraction stages to order the fundus pictures. DR is the intricacy of diabetes and a leading reason for blindness in the world. The layer that covers the eye is the retina (https://www.nature.com/articles/s41746-019-0172-3). The retina is profoundly sensitive to light. It changes over any light that hits the eye into signals that can be deciphered by the mind. Signal manages to examine and handle uncomplicated and computerized signals and helps in removing other signals (http://www.ubcieee.org/events/signal-processing-cup-2015). These signs incorporate transmission signals, sound or voice signals, picture signals and different signs. DR damages the tissue which is in the retina and further makes it to excrete liquid and misshape sight which is shown in Fig. 1 (https://expertsystem.com/machine-learning-definition/). DR may cause no side effects or just mellow vision issues, and it causes the loss of eyesight.

DR affects the blood vessels in the retina. The inner side of an eye opposite to the lens forms the *fundus* of the eye (https://machinelearningmastery.com/what-is-deep-learning/; https://verhaert.com/use-artificial-intelligence-valuable-new-solutions/value-add-strategies-verhaert-nl/). As the situation gradually increases, diabetic retinopathy indications have spots in our vision, unfocused vision, and vary vision, unpaired color vision, black or blank areas in vision loss. DR is categorized into two parts, namely proliferative DR (PDR) and non-proliferative DR (NPDR). NPDR is the first phase of the DR. The extra fluid and some amount of blood start leaking from the retina into the eye. Sometimes, deposits of fats or cholesterol from the blood might seep out into the retina (https://www.eatonrapidseyecare.com/eye-health/diabetic-retinopathy/h). PDR is an advanced stage of DR, thereby precluding the flow of blood leading to block the vision. In response, the retina grows new blood vessels. However, they do not supply blood flow (https://www.geeksforgeeks.org/python-language-introduction/; http://news.mit.edu/2017/explained-neural-networks-deep-learning-0414). Also, these sometimes have scar tissue that can cause the retina to wrinkle or detach. When the tiny blood vessels, leaking blood and other fluids, forming features such as *microaneurysms(MAs)*, *exudates*, *hemorrhages,* and *cotton wools* distorts vision as shown in Fig. 2. The presence of microaneurysms is an indication of mild NPDR. Moderate NPDR is identified by the presence of hemorrhages. Severe NPDR is depicted by the presence of exudates in the retina (https://www.kaggle.com/sid321axn/regularization-techniques-in-deep-learning; https://www.kaggle.com/sohaibanwaar1203/diabetic-rateinopathy-full). PDR can be in the form of vitreous hemorrhages. This blocks the light rays to arrive the retina. It can cause retinal detachment or neovascular glaucoma (https://modernod.com/articles/2019-june/the-four-stages-of-diabeticretinopathy?c4src=article:infinite-scroll; Santhakumar et al. 2016; Chandrakumar et al. 2016).

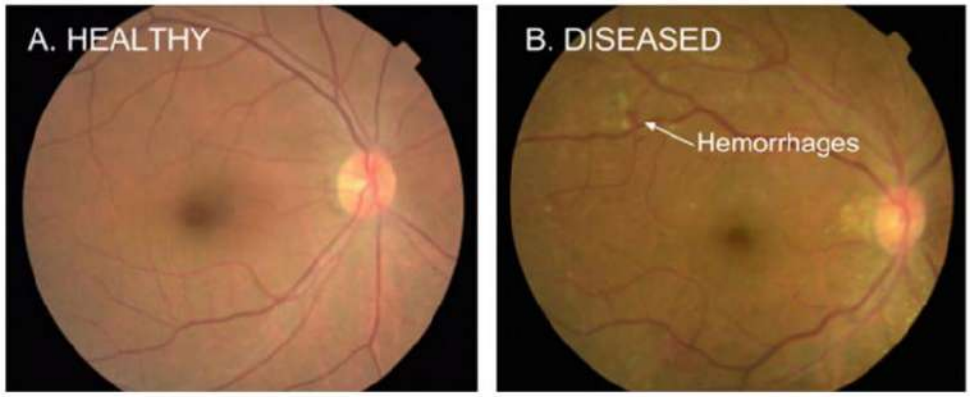

Fig. 1 Comparison between normal eye and diabetic eye. (https://expertsystem.com/machine-learning-definition/)

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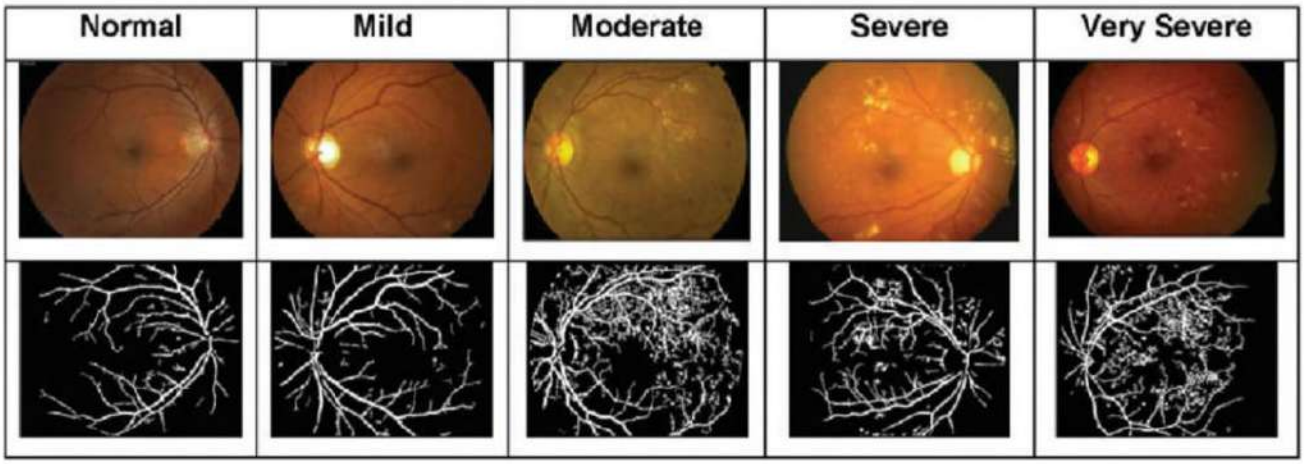

Fig. 2 Different DR stages

The patients with normal eyes have no findings in the eye images. The patients with only microaneurysm can be classified in the mild category, with at least one microaneurysm or retinal hemorrhage can be placed under moderate category and with greater than 20 microaneurysm are of severe type. Patients with neovascularization are of very severe category (Santhakumar et al. 2016). It has been realized that there are just about 80 million individuals in India who are experiencing sight loss or some other eye diseases. One of the significant tests is the forecast of the eye ailments accurately and by observing the statistical data points, and before expectation issues, it has been chosen to construct a program by which we can support the individuals and the specialists everywhere throughout the world to effectively and precisely foresee the retinal sicknesses (Chandrakumar and Kathirvel, 2016).

The objective of this paper is to develop software that can more accurately and efficiently predict diabetic retinopathy and help people and doctors all over the world to accurately predict retinal diseases. Initially, a basic neural network or algorithm requires a hand featured algorithm. In this paper, convolution neural networks which do not require hand-engineered features are used. Artificial intelligence (AI) intellectual advances can make it much progressively viable in preparing huge volumes of data that prompt profound learning. Profound learning, a subset of AI, uses various levels of counterfeit neural systems to do the procedure of AI. Machine learning revolves around the progress and improvement of PCs software and programs that can have the information and further use it to learn and grow (https://expertsystem.com/machine-learning-definition/).

This paper consists of the following: Sect. 2 explains the methodology for the images using CNN, Sect. 3 explains experimental results and discussion, of the proposed algorithm on images followed by a conclusion.

2 Proposed Methodology

In recent times, the majority of the picture handling specialists enjoyed the improvement of AI, particularly profound learning. Our proposed approach firmly developed dependent on the key parts of infection seriousness arrangement from the fundus pictures. To accomplish the most extreme exactness from the picture dataset, the proposed engineering of DCNN comprises various advances to be specific data augmentation, pre-handling, initialization of networks and *convolution neural network (CNN) classification* as shown in Fig. 3. The main reason for choosing CNN was that they have taken inspiration from animal's visual cortex. The CNN is considered over NN because fewer features are required in CNN which in turn helps in reducing overfitting problem in the proposed model.

Data augmentation: The fundus images are attained by different cameras and by changing its field of views, angles, clarity and ratio collected from different datasets. Data augmentation consists of different steps: flipping images, contrast adjustment and brightness adjustments which are made (Wang et al. 2019; https://www.flatworldsolutions.com/data-science/articles/7-applications-of-convolutional-neural-networks.php).

Pre-processing: Resizing is the primary step of the pre-processing. Before nourishing into the architecture for classification, the images are converted to gray scale and afterward to the L model. It is a monochrome image that is utilized to emphasize the MAs and vessels in the fundus images and helps in flattening the images in a single dimension for further dealing.

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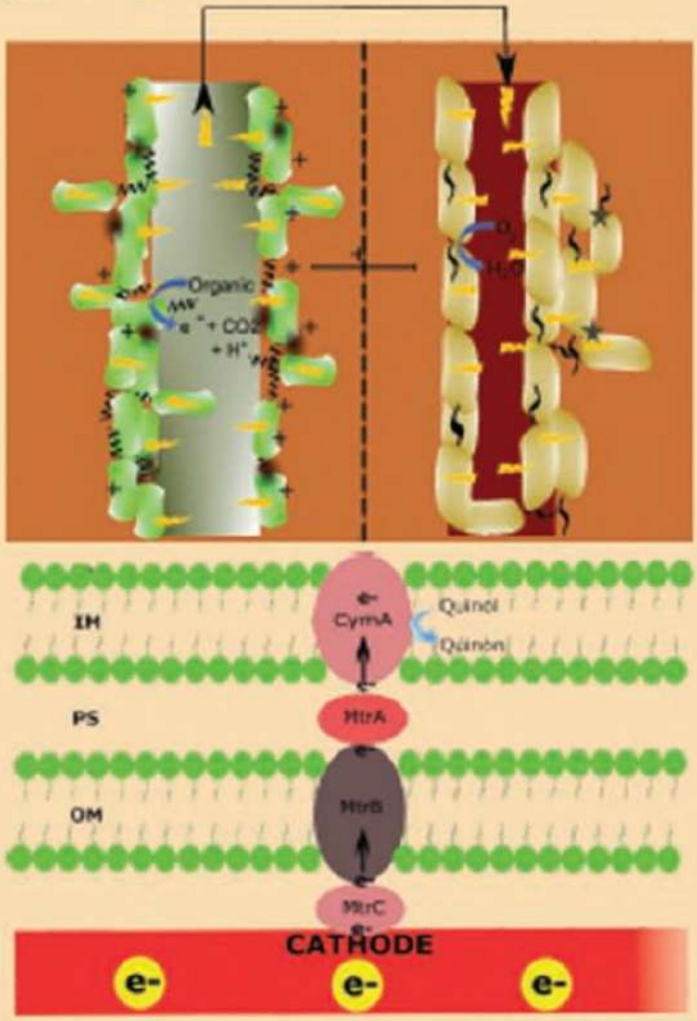

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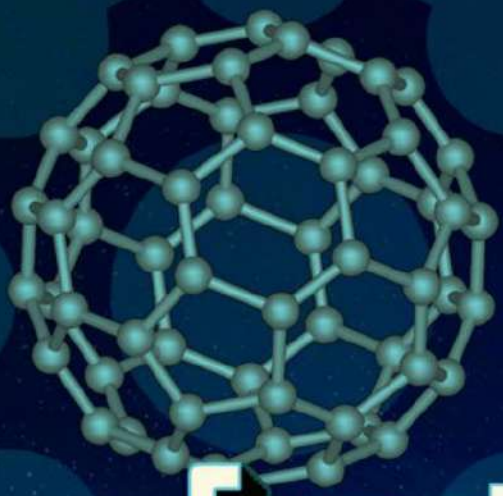

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Edited by
Chaudhery Mustansar Hussain
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Preface

With the rapid development in nanotechnology, it is now possible to modulate the physical and chemical properties of nanomaterials with molecular recognition and catalytic functional applications. Such research efforts have resulted in a huge number of catalytic platforms for a broad range of analytes ranging from metal ions, small molecules, ionic liquid and nucleic acids down to proteins. Functionalized nanomaterials (FNMs) have important applications in the environmental, energy and healthcare sectors. Strategies for the synthesis of FNMs have contributed immensely to the textile, construction, cosmetics, biomedical and environmental industries among others. These areas are considered a key platform for a wide range of applications, consequently becoming a top priority for science and technology policy development since they are already involved in the production of various modern products, especially in electronics, healthcare, chemicals, cosmetics, composites and energy. Due to their ultra-small size, nanostructured FNMs have extraordinary physical and chemical properties such as unique optical, electrical, thermal, magnetic and adsorption characteristics. The large specific surface area of FNMs can certainly improve their current application even at the industrial as well as academic scale. In addition, FNMs of various compositions and morphologies can provide powerful tools for advanced industrial techniques. Therefore, FNMs-based techniques can play a vital role in numerous industrial procedures such as, for example, by increasing sensitivity, magnifying precision and improving the production limit. Moreover, freedom to functionalize nanomaterials with various chemical groups can also increase their affinity toward respective counterpart analytes, which is very desirable for selective manufacturing of certain products.

This book highlights the design of functionalized nanomaterials with respect to recent progress in the industrial arena and their respective applications. It presents an inclusive overview encapsulating FNMs and their applications to give the reader a systematic and coherent picture of nearly all relevant up-to-date advancements. Herein, functionalization

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have revealed their potentialities in getting rid of biological, organic and/or inorganic toxicants from water bodies that might lead to painful health issues. Functionalized nanocatalytic materials for remediation of water resources will be mainly focused in the segments to come.

Keywords: Functionalization, nanomaterials, nanocatalyst, pollutants, remediation, water

Abbreviations Used:

	Organization		
WHO	World Health Organization	EPA	Environmental Protection Agency
	Technical		
NIR	Near Infra-Red	*ECMR*	Electrocatalytic Membrane Reactor
PL	Photoluminescence	LUMO	Lowest unoccupied molecular orbital
CB	Conduction Band	VB	Valence Band
e^-	Electron	h^+	Holes
	Functionals		
EC	Electrocatalyst	PC	Photocatalyst
EF	Electro-Fenton	P-EF	Photoelectro Fenton
F'bC	Fenton-based catalyst	H-EF	Hetero Electro-Fenton
HF	Heterogenous-Fentons	H-PF	Hetero Photo-Fenton
PF	Photo-Fentons	pF	Photo-Fenton–like
	Terminologies		
FNMs	Functionalized Nanomaterials	NM	Nanomaterials
NP	Nanoparticles	NT	Nanotubes
NS	Nanosheets	NR	Nanorods
NF	Nanofibers	NW	Nanowires
TP	Target Pollutant	OP	Organic Pollutant
TOC	Total Organic Carbon	DP	Degraded Products
CNT	Carbon nanotubes	MWCNT	Multiwalled Carbon nanotubes

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CNO	Carbon nano onion	CF	C Felt/Fiber
CFP	Carbon fiber paper	CP	Carbon paper
QDs	Quantum Dots	MNPs	Magnetic nanoparticles
CQDs	Carbon QDs	CDs	Carbon dots
	Materials		
R/r GO	Reduced GO	ACA	Activated C aerogel
GA	Graphene aerogels	GPCA	Graphene polyacrylamide carbonized aerogel
PC	Porous C	MPCMSs	Magnetic porous C micro-spheres
BDD	Boron doped diamond	Fe-HPAN	Fe-loaded hydrolyzed polyacrylonitrile
SS	Stainless steel	GMSA	Glycerol mediated self-assembly
HPC	Hollow porous C	MMTNS	Montmorillonite nanosheets
Fe-POM	Fe-polyoxometalates	PPy NTs	Polypyrole nano-tubes
CNQDs	Carbon nitride QDs	GCNQDs	Graphene-Carbon nitride QDs
		TCNCs	Tubular Carbon Nitride
	Nomenclature:		
PANI	Polyaniline	PTFE	Polytetrafluoroethylene
G	Graphene	CE	Cetyl Trimethyl Ammonium Bromide
GO	Graphene Oxide	EDTA	Ethylenediaminetetraacetic acid
PAN	Polyacrylonitrile	EDC	1-ethyl-3-(3-dimethylamino-propyl) carbodiimide
CS	Chitosan	PDVF	Polyvinylidene difluoride
PHB	Poly-hydroxyl butyrate	MUC	Melamine, Cyanuric acid, Urea
PEG	Poly-ethylene glycol	ABA	4-aminomethyl benzoic acid
O-TD	O-toluidine	TCPP	Tetrakis (4-carboxyphenyl) porphyrin
SA	Salicylic acid	L-Cys	L-Cystine
2-ME	2-mercaptoethanol	PAMAM	Poly(amidoamine)
Try	L-tryptophan	Glu	L-glutamic acid

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PUF	Polyurethane foam		
	Organic: Pollutant		
PCA	p-Chloroaniline	TCP	2,4,6-trichlorophenol
4-NP	p-nitrophenol (PNP)	4-CP	4-chlorophenol
2,4-DCP	2,4-Dichlorophenol	DMP	dimethyl phthalate
5-TBA	5-tolylbenzotriazole	2,4,5-PCB	2,4,5-trichlorobiphenyl
BPA	Bisphenol A		
	Dyes: Pollutant		
MO	Methyl Orange	MB	Methylene Blue
MG	Malachite Green	CR	Congo Red
Rh B	Rhodamine B	CB	Chlorazol black
BG	Brilliant Green	RR-120	Reactive red 120
EB	Evans blue	X-3B	Reactive Brilliant Red
CV	Crystal Violet	VBR	Victoria blue R
RO-16	Reactive Orange-16	TBAC-L	Texbrite BAC-L
TNFW-L	Texbrite NFW-L	TBBU-L	Texbrite BBU-L
	Drugs: Pollutant		
CIP	Ciprofloxacin	TC	Tetracycline
IBP	Ibuprofen	TCH	Tetracycline-Hydrochloride
CBZ	Carbamazepine	OTC	Oxytetracycline
DFC	Diclofenac	NPX	Naproxen
PCM	Paracetamol	KP	Ketoprofen
CEL	Cephalexin		
	Pesticides: Pollutant		
ATZ	Atrazine	IMI	Imidacloprid
ATP	Acetamiprid	TMX	Thiamethoxam
ALA	Alachor		
	Consumer Products		
TCS	Triclosan		

1.1 Introduction

Water, one of the essential elements in the nature, is under a great threat, with pollutants treasured in it. Noxious suffocations are generated with the raise in contaminants globally. It is time we wake up to take care of it, else

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Handbook of Research on Critical Examinations of Neurodegenerative Disorders

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A volume in the Advances in Medical Diagnosis, Treatment, and Care (AMDTC) Book Series



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Neurodegeneration is the progressive and gradual dysfunction and loss of axons in the central nervous system. It is the main pathological characteristic of chronic and acute neurodegenerative conditions like Alzheimer's disease (AD), Parkinson's disease (PD), and multiple sclerosis (MS). The usual aspects of pathogenesis of disease can be abridged with regards to the downstream implications of uncontrollable protein oligomerization and aggregation from postmitotic cells. The brain structure constantly changes in normal aging without any dysfunction accompanying the structural changes in brain. The decline in cognitive capabilities, for example, processing speed, memory, and functions related to decision making are the sign of healthy aging. The reduction in brain volume in healthy aging is possibly related to neuronal loss at some marginal extent. The following chapter discusses the structural and functional alterations in the brain in ageing and neurodegeneration.

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Neurons are the building units of the nervous system and are therefore critical units for the health of the brain and the spinal cord. This is necessitated by their inability to be either replaced or reproduced once lost. Their losses are implicated in a number of conditions which have been elaborated in this chapter. Oxidative stress has been strongly implicated in neurodegeneration through blockade of neuroprotection by a number of mechanisms including inhibitory effect on insulin-like growth factor I (IGF-1) via stimulation of the transcription factor, Forkhead box O3 (FOXO3). This chapter elaborates on these two phenomena which cannot be decoupled.

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Free Radicals in Oxidative Stress, Aging, and Neurodegenerative Disorders 48
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Free radicals are intricately woven into the fabric of oxidative stress and are significant in the development of neurodegenerative disorders (NDs). This chapter examines free radicals in the context of neurodegeneration and provides overview of the multiple roles they play in the pathophysiology and clinical progression of varying NDs including Pick's disease (PiD), Parkinson's disease (PD), Alzheimer's disease (AD), prion diseases (PrD), traumatic brain injury, and aging. The molecular mechanisms of degeneration in Huntington's disease (HD) are also examined with respect to free radicals. Different antioxidant systems and their mechanisms of action are briefly reviewed in addition to the role of diet in aging. The effectiveness of selected synthetic drugs and natural products used in oxidative stress is also reviewed. Lastly, the chapter examines challenges associated with the use of antioxidants and how promising future directions like the endocannabinoid system is being pursued in the race to effectively manage NDs.

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Mitochondria are a dynamic organelle of the cell involved in the various biological processes. Mitochondria are the site of the adenosine triphosphate (ATP) production, electron transport chain (ETC), oxidation of fatty acids, tricarboxylic acid (TCA), and cellular apoptosis. Besides these, mitochondria are the site of production of reactive oxygen species (ROS), which further disrupts the normal functioning of this organelle also making mitochondria itself as an important target of oxidative stress. Thus, mitochondria serve as an important target in the process of neurodegeneration. In the present chapter, the authors describe mitochondria and its functioning, dynamics, and the mitochondrial dysfunction in aging and neurodegenerative disorders (NDs).

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Neurodegenerative disorders (NDs) are characterized by dysfunction and loss of neurons associated with altered proteins that accumulate in the human brain and peripheral organs. Mitochondrial and Golgi apparatus (GA) dysfunctions are supposed to be responsible for various NDs. Damaged mitochondria do not produce sufficient adenosine triphosphate (ATP) and produce reactive oxygen species (ROS) and pro-apoptotic factors. Mitochondrial dysfunctions may be caused by various factors such as environmental causes, mutations in both nuclear or mitochondrial deoxyribonucleic acid (DNA), that code many mitochondrial components. Three factors that are mainly responsible for the morphological changes in GA are certain pathological conditions, drugs, and over expression of Golgi associated proteins. In this chapter, common aspects of mitochondrial and GA dysfunction concerned about NDs are summarized and described for Alzheimer's disease (AD), Parkinson's disease (PD), amyotrophic lateral sclerosis (ALS), and Huntington's disease (HD).

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Neurodegenerative Disorders Progression: From Synaptic Dysfunction to Transmission Failure..... 129
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Neurodegenerative disorders (NDs) are a diverse group of disorders characterized by selective and progressive loss of neural systems that cause dysfunction of the central nervous system (CNS). The examples of NDs include Alzheimer's disease (AD), amyotrophic lateral sclerosis (ALS), Parkinson's disease (PD), and Huntington's disease (HD). The aggregated proteins block or disrupt the normal proteosomal turnover, autophagy, and become abnormally modified with time, generating toxicity via pathways thereby resulting in neurodegeneration and neuron death. The chapter highlights the understanding in the areas of AD, PD, HD as illustrative of major research so as to define the key factors and events in the improvement of NDs. It defines the physiological functioning of neural transmission (presynaptic, postsynaptic activity) at neural signaling pathway, then the dynamics of neuronal dysfunctioning and its molecular mechanism. Further, it also discusses the progression from synaptic dysfunction to transmission failure followed by NDs.

Chapter 7
Stroke: A Potential Risk Factor of Neurodegenerative Disorders 153
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Mariana M. Canever, Federal University of Paraná, Brazil
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The brain relies on a specialized endothelial system, the blood brain barrier (BBB), which is capable of regulating the transfer of substances from the blood to the neurons. Stroke is the most frequent cause of disability in adulthood. Lesions of vascular origin also include asymptomatic small infarcts, microbleeds, dilated perivascular spaces, and atrophy. Vascular cognitive impairment (VCI) is the second most prevalent cause of dementia. Several mechanisms are implied, including strategic infarct dementia, post-stroke dementia, cerebral amyloid angiopathy, and subcortical vascular dementia. As there is no disease modifying therapies currently available, treatment of comorbidities and adequate control of the vascular risk factors remain the standard strategies to reduce the vascular contributions to neurodegeneration. This chapter represents the basic concepts of pathophysiology of cerebrovascular diseases, and describes the subtypes of VCI, as well as treatment and primary prevention strategies.

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Zinc and Neurodegenerative Disorders 176
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Omotade Ibidun Oloyede, Ekiti State University, Nigeria
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Zinc (Zn) is an essential trace element that is abundantly present in humans. Despite its importance in normal brain functions, alterations in zinc homeostasis cause various neurological pathologies such as dementia, Parkinson's disease, Prion's disease, etc. A growing body of evidence has shown that zinc might play a dual role: in which both zinc depletion and excess zinc cause severe damage and hence neurotoxicity develops. Homeostatic controls are put in place to avoid the accumulation of excess zinc or its deficiency. This cellular zinc homeostasis results from the actions of a coordinated regulation effected by different proteins involved in the uptake, excretion, and intracellular storage or trafficking of zinc. Further investigation has also shown the role of endogenous carnosine (beta-alanyl-L-histidine) in binding excess zinc. Hence, it has the ability to prevent neurotoxicity. Also, the role of a zinc-rich diet cannot be overemphasized. The authors of the chapter, however, provide an insight into the link between zinc homeostasis and neurodegenerative disorders (NDs).

Section 2
Imperious Neurodegenerative Disorders

Chapter 9
Neurodegenerative Disorders: An Introduction 195
Mohamed M. Amin, National Research Centre, Egypt

Neurodegenerative diseases (NDs) are characterized by specific dysfunction and damage of neurons related to pathologically changed proteins that deposit in the patient brain but also in peripheral organs. These proteins can be used for therapy or used as biomarkers. Except for a plethora of alterations revealed for dissimilar neurodegeneration-related proteins, amyloid-β, prion protein, TAR DNA-binding protein 43 (TDP-43, transactive response DNA binding protein 43 kDa), tau and α-synuclein, or fused in sarcoma protein (FUS), molecular classification of NDs depend on the full morphological assessment of protein deposits, their spreading in the brain, and their correspondence to clinical signs with specific genetic modifications. The current chapter represents the etiology of neurodegeneration, classification of NDs, concentrating on the maximum applicable biochemical and anatomical characteristics and most imperative NDs.

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Chapter 10
Tau Pathology: A Step Towards Understanding Neurodegenerative Disorders Network Complexity217
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A number of neurodegenerative disorders (NDs) are usually referred as tauopathies and characterized by the disappearance or disintegration of tau protein from microtubules. Alzheimer's disease (AD), Pick's disease (PiD), Parkinson's disease (PD) are directly or indirectly associated with tauopathy. Tau is a protein which is usually associated with microtubule. Microtubules are the backbone of neurons, and tau provides a support to microtubule stability. Hyperphosphorylation of tau leads to its separation from microtubule, consequently forming neurofibrillary tangles and resulting in a condition of dementia. Therapeutic implication on tauopathy is symptomatic as there is no exact regulation mechanism known till date. This chapter helps in the comprehensive study of biomarkers and pathways involved in tauopathy to decipher the complexity of the system, resulting in candidate drug target for the management of NDs.

Chapter 11
Amyloid Beta: The Foremost Protagonist in Alzheimer's Disease 235
Abhinav Anand, Lovely Professional University, India
Neha Sharma, Lovely Professional University, India
Monica Gulati, Lovely Professional University, India
Navneet Khurana, Lovely Professional University, India

Alzheimer's disease (AD), exhibiting accumulation of amyloid beta (Aβ) peptide as a foremost protagonist, is one of the top five causes of deaths. It is a neurodegenerative disorder (ND) that causes a progressive decline in memory and cognitive abilities. It is characterized by deposition of Aβ plaques and neurofibrillary tangles (NFTs) in the neurons, which in turn causes a decline in the brain acetylcholine levels. Aβ hypothesis is the most accepted hypothesis pertaining to the pathogenesis of AD. Amyloid Precursor Protein (APP) is constitutively present in brain and it is cleaved by three proteolytic enzymes (i.e., alpha, beta, and gamma secretases). Beta and gamma secretases cleave APP to form Aβ. Ubiquitin Proteasome System (UPS) is involved in the clearing of Aβ plaques. AD also involves impairment in UPS. The novel disease-modifying approaches involve inhibition of beta and gamma secretases. A number of clinical trials are going on worldwide with moieties targeting beta and gamma secretases. This chapter deals with an overview of APP and its enzymatic cleavage leading to AD.

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Parkinson's Disease: A Progressive Disorder of the Nervous System That Affects Movement..... 252
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Ashish Gakkhar, Maharshi Dayanand University, India
Munish Garg, Maharshi Dayanand University, India

Parkinson's disease (PD) is a neurodegenerative disorder in which a progressive loss of the dopaminergic neurons occurs. The loss of the neurons is most prominent in the substantia nigra region of the brain. The prevalence of PD is much greater among the older patients suggesting the risk of PD increases with the increase of age. The exact cause of the neurodegeneration in PD is not known. In this chapter, the authors introduce PD, demonstrate its history, pathogenesis, neurobiology, sign and symptoms, diagnosis, and pharmacotherapy.

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Chapter 13
Alpha-Synucleinopathies: Parkinson's Disease, Dementia With Lewy Bodies, and Multiple System Atrophy 274
Carlos Henrique Ferreira Camargo, Hospital Universitário dos Campos Gerais – UEPG, Brazil
Marcus Vinicius Della-Coletta, State University of Amazonas, Brazil
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Alpha-synuclein is a protein that forms a major component of abnormal neuronal aggregates known as Lewy bodies. A particular group of neurodegenerative disorders (NDs) is characterized by the abnormal accumulation of α-synuclein; termed the α-synucleinopathies, this group includes Parkinson's disease (PD), dementia with Lewy bodies (DLB), and multiple system atrophy (MSA). Lysosomal storage diseases have also been linked to α-synuclein toxicity. Several therapeutic targets have been chosen among steps of metabolism of α-synuclein. Reducing α-synuclein synthesis or expression and increasing the clearance can be achieved in many ways. The development of immunotherapeutic approaches targeting α-synuclein has received considerable attention in recent years. The aim of this chapter is to present the α-synucleinopathies, as well as to present the most recent researches about treatment of synucleinopathies based on knowledge of the pathophysiology of α-synuclein pathways.

Chapter 14
Lewy Body Disease: Point Towards Progressive Dementia 298
Vaibhav Walia, Maharshi Dayanand University, India
Munish Garg, Maharshi Dayanand University, India

Fritz Heinrich Lewy described the intracytoplasmic inclusions found in the neurons for the very first time. In 1919 these inclusions were termed as "LBs" by Tretiakoff. LBs were found in the brain of the patients suffering from Lewy body disease (LBD). LBD is characterized by the presence of Parkinsonian symptoms in the earlier stages and dementia in the later stages of the disease. LBs were classified on the basis of the region of the brain in which they are distributed and so is the case of the LBD means the type of the LBD depends on the anatomical areas of the brain involved. LBD is not a single disorder. It is a spectrum of disorders. This chapter addresses the entire profile of LBs, types, composition, formation, and various LB pathologies as well as diagnostic criteria and pharmacotherapy.

Chapter 15
Amyotrophic Lateral Sclerosis: A Predominant Form of Degenerative Disease of the Motor Neuron System 322
Newman Osafo, Kwame Nkrumah University of Science and Technology, Ghana
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Amyotrophic lateral sclerosis (ALS) is a progressive neurodegenerative disorder (ND) that primarily comprises the neurons responsible for controlling voluntary muscle movement. The unique neuropathologic findings include anterior horn cell degeneration producing muscle atrophy or amyotrophy, degeneration, and sclerosis of the corticospinal tracts. It is a common neuromuscular disease worldwide and has been

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identified in people of all races. There seems to be neither identified risk factors nor family history associated with most of the documented ALS cases. There exists no treatment for ALS that can prevent neither its progression nor reverse its development. However, there are treatments available that can help control symptoms, prevent unnecessary complications, and make living with the disease easier. This chapter extensively discusses this neurodegenerative disorder based on the currently available knowledge on the condition.

Chapter 16

Spectrum of Neurodegeneration in Autism Spectrum Disorder 347
Kirti Rani, Amity University Noida, India

Autism spectrum disorder (ASD) is neurodevelopmental disorder which is characterized by lack of social behaviors and impaired non-verbal interactions that start early in childhood. It can also lead to progressive neurodegeneration like schizophrenia disorder, Alzheimer's disease, Parkinson's disease, and dementia. Genetic studies of ASD have confirmed the mutations that interfere with neurodevelopment in mother's womb through childhood and these mutations are further involved in synaptogenesis and axon motility. Crucial role of amygdala is found to be deficit in ASD individuals whose association cognition with nucleus accumbens lead to impaired social behaviors and cognitive stimulus. Educational and behavioral treatments are considered the key steps used for its management along with pharmacological and interventional therapies. In this chapter, the author presents the etiology of ASD, proof of neurodegeneration in ASD, as well as the clinical feature and the management of ASD.

Chapter 17

Creutzfeldt-Jakob Disease: A Prion-Related Neurodegenerative Disorder 368
Sadeeq Muhammad Sheshe, COMSATS Institute of Information Technology, Pakistan

Creutzfeldt-Jakob disease (CJD) is a rare disease associated with neurodegeneration mostly characterized by damage to the neurons. CJD is caused by aggregation of misfolded proteins known as prions; thus, CJD is said to be a prion-related illness. CJD and other prion-related illnesses such as Kuru and Gerstmann-Sträussler-Scheinker disease (GSS) have been reported to have complex mechanisms due to their association with the brain and the nervous system in general. A lot of questions have been raised about the mechanism, diagnosis, and pathogenesis of this disease. The complexity of prion proteins themselves have contributed to more questions about the complications of CJD, whether misfolding of the prions are responsible for neurodegeneration or the misfolding are mere symptoms of the disease. This chapter attempts to explore some details about CJD and answers most related questions about the disease's mechanism. The author finally attempts to explore recent development in pathogenesis, diagnosis, and treatment of CJD.

Chapter 18

Childhood Neurodegenerative Disorders 385
Lal Devayanivasudevan Nair, Saveetha Medical College, India

Neurodegenerative disorders (NDs) are a group of disorders with the deterioration of attained skills often with no solutions, usually ending with death or crippling disabilities. This chapter contains a classification for childhood NDs as well as an algorithmic approach for easy management of these disorders. Genetic defects and pathophysiology of disorders like Canavan, Krabbe, subacute sclerosing panencephalitis (SSPE), etc. are written in detail. Suggestions regarding management of some of these conditions are

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described as a lifecycle approach, from birth to death, to enable those who are taking care of such kids. Allogeneic hematopoietic stem cell transplantation (HSCT), gene therapy, combination therapy, and other experimental therapies have enlarged the scope of diagnosis and treatment options for these disorders. The author aims to brush up the existing and latest possibilities in NDs, including those at the experimental stage, for an easy understanding and for further research, especially as treatment options.

Section 3
Therapeutic Interventions for Neurodegenerative Disorders

Chapter 19
Neurosurgical Treatments of Neurodegenerative Disorders 414
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Functional neurosurgery consists of procedures that either promotes judicious destruction or chronic stimulation of the nervous system in order to treat disordered behavior or aberrant function, as it is expected in neurodegenerative disorders ([NDs], e.g., movement disorders [Parkinson's disease, Tourette's syndrome, essential tremor, ballism, and dystonia]). Over the past 20 years, approximately 100,000 deep brain stimulation implant procedures have been performed worldwide. Neurosurgery is also a well-established therapeutic option for people with epilepsy whose seizures are not controlled by anti-epilepsy drugs. The most common pathological finding in patients with drug-resistant mesial temporal lobe epilepsy is hippocampal sclerosis. The aim of this chapter is to present the main NDs that can be treated through surgical procedures, and to describe the surgeries with a focus on the pathophysiology of diseases.

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Preface

Neurodegenerative disorders have become one of the most exciting and glowing researched areas of neuroscience. The Handbook of Research on Critical Examinations of Neurodegenerative Disorders accentuate on the diverse genres of diseases, comprising Alzheimer's disease, Parkinson's disease, Huntington´s disease, Lewy body disease, amyotrophic lateral sclerosis, autism spectrum disorder, Creutzfeldt-Jakob disease, and multiple system atrophy. This book introduces various factors such as aging, oxidative stress, pathogenic protein, dysfunction of mitochondria and Golgi apparatus, alpha-synuclein, stroke, and zinc that serve as protagonist to neurodegeneration. Furthermore, this book provides a diaphanous explanation of various neurodegenerative disorders based on existing studies to clarify etiology, pathological mechanisms, diagnosis, therapeutic interventions, as well as current status and future opportunities and challenges. This book also focuses on numerous childhood neurodegenerative disorders and neurosurgical treatments.

This book represents the copious set of specific research updates. All over the world numerous erudite, experienced and eminent academicians, researchers and scientists had participated to write the texts of this book to give a concise thorough understanding of neurodegenerative disorders at a more advanced level with excellent presentation.

This book is suitable for professionals, academicians, students, researchers, scientists and industrialists around the world. Biomedical, health, and life science departments can use this book as a crucial textbook. Researchers and scientist from research institutes can use this book as efficient research info. Pharmacists, physicians, and other healthcare professionals can use this book as a complete reference book. Furthermore, for interested readers, this book is a storehouse of knowledge to comprehend neurodegenerative disorders complexity. The organizations of this book provided a profound knowledge and also maintain the reader's interest.

This book contains 19 chapters divided into 3 sections. The contents of the book cover the peril factors that are likely to the development and propagation of neurodegenerative disorders, and concise thorough understanding of these disorders as well as existing and forthcoming prevention and treatment strategy of neurodegenerative disorders.

Section 1 represents the spectrum of ample factors that can initiate and propagate chronic neuronal dysfunction that leads to neurodegenerative disorders. This section consists of eight chapters. A description of each chapter follows.

Chapter 1 is "The Aging Brain: From Physiology to Neurodegeneration". This chapter explores the physiological functioning of the brain. Further, it discusses the process, mechanism and various factors that cause aging. The pathway and mechanism of neurodegeneration are also introduced. Lastly, it highlights the functional and structural changes in the brain in aging and neurodegeneration.

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Chapter 2 is "Oxidative Stress and Neurodegeneration". This chapter clarifies the precarious link between neurodegeneration and oxidative stress and how this could inform future research on the neurodegenerative disorders.

Chapter 3 is "Free Radicals in Oxidative Stress, Aging and Neurodegenerative Disorders". This chapter reviews the causes of susceptibility of the central nervous system to oxidative damage and the contribution of the aging in neurodegenerative disorders. Additionally, the role of free radicals in some neurodegenerative disorders as well as novel targets which are being explored to effectively manage these neurodegenerative disorders is presented.

Chapter 4 is "Mitochondrial Dysfunction in Aging and Neurodegeneration". This chapter explains the alteration in the mitochondrial dysfunction by aging and how this alteration is linked with the neuronal degeneration.

Chapter 5 is "Alternation of Mitochondrial and Golgi Apparatus in Neurodegenerative Disorders". This chapter focuses on that how mitochondria and Golgi apparatus get affected in neurodegenerative disorders. The target is to explain the factors that are mainly responsible for the morphological changes in these organelles.

Chapter 6 is "Neurodegenerative Disorders Progression: From Synaptic Dysfunction to Transmission Failure". This chapter describes the dynamics of neuronal dysfunction, the models that are used to study neurodegenerative disorders and the factors that cause the dysfunctioning. Further, it also highlights the progression of the pathological basis from synaptic deregulation to synaptic transmission deficits.

Chapter 7 is "Stroke: A Potential Risk Factor of Neurodegenerative Disorders". This chapter represents the relationship between stroke and neurodegenerative disorders, predominantly those related to cognitive impairment. Moreover, describes the pathophysiological mechanisms of vascular action on neurodegeneration reaching prevention and treatment suggestions.

Chapter 8 is "Zinc and Neurodegenerative Disorders". This chapter relates the significant role of zinc in relation to several biochemical and pathophysiologic activities in humans and its relation to neurological disarranges. The basic impact of zinc on homeostasis, oxidative stress, aging, and neurodegeneration is also stated.

Section 2 focuses on the clear explanation of the utmost imperative neurodegenerative disorders with a momentous impact on etiology, pathological mechanisms, disease management, current status, future opportunities, and challenges. This section consists of ten chapters. A description of each chapter follows.

Chapter 9 is "Neurodegenerative Disorders: An Introduction". This chapter portrays the causes and concepts of the classification of neurodegenerative disorders. Moreover, this chapter deals a concise depiction of the neuropathological features of numerous neurodegenerative disorders.

Chapter 10 is "Tau Pathology: A Step Towards Understanding Neurodegenerative Disorders Network Complexity". This chapter discusses various types of neurodegenerative disorders to understand the underlying mechanism of tauopathy. Additionally, presented a comprehensive study of biomarkers and pathways involved in pathological aggregation of tau protein in the human brain.

Chapter 11 is "Amyloid Beta: The Foremost Protagonist in Alzheimer's Disease". This chapter focuses on the amyloid beta hypothesis and the biomolecular targets, including the proteins and enzymes that contribute towards the development of Alzheimer's disease. A brief insight into the currently existing pipeline of potential drug candidates involving these targets has also been provided.

Chapter 12 is "Parkinson's Disease: A Progressive Disorder of the Nervous System that Affects Movement". This chapter provides a detailed overview of the Parkinson's disease from pathogenesis to therapeutics with existing challenges and the future directions.

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Chapter 13 is "Alpha-Synucleinopathies: Parkinson's Disease, Dementia with Lewy Bodies, and Multiple System Atrophy". This chapter presents the alpha-synucleinopathies and the most recent researches about the treatment of alpha-synucleinopathies based on knowledge of the pathophysiology of alpha-synuclein pathways.

Chapter 14 is "Lewy Body Disease: Point Towards Progressive Dementia". This chapter represents the different pathologies, characterized by the presence of Lewy bodies in the different regions of the brain, which further form the basis of the progression of the Lewy pathology.

Chapter 15 is "Amyotrophic Lateral Sclerosis: A Predominant Form of Degenerative Disease of the Motor Neuron System". This chapter delves the mechanisms for motor neuron degeneration in amyotrophic lateral sclerosis as informed by up to date knowledge on this neurodegenerative disorder. In addition, diagnosis, pharmacotherapy, and forthcoming research tips are offered.

Chapter 16 is "Spectrum of Neurodegeneration in Autism Spectrum Disorder". This chapter expresses the effect of multi-factors such as oxidative stress, neuronal loss, microglia activation and proinflammatory cytokines that further lead to progressive neurodegeneration in autism spectrum disorder patients despite of showing its regression in neurodevelopmental practices.

Chapter 17 is "Creutzfeldt-Jakob Disease: A Prion Related Neurodegenerative Disorder". This chapter attempts to answer based on recent studies on the mechanisms and pathogenesis of Creutzfeldt-Jakob disease as well other details including epidemiology, diagnosis, and treatment of the disease. The chapter also highlights current and future perspectives in various studies aimed at finding the cure for the disease.

Chapter 18 is "Childhood Neurodegenerative Disorders". This chapter focuses on almost all details of neurodegenerative disorders of the children including epidemiology, pathophysiology, and management of these disorders. Moreover, the chapter gives an insight into the recent advances, experimental trials, and possible treatment and investigational options which may come up in the near future.

Section 3 offers the neurosurgical treatments strategy for the neurodegenerative disorders consistent with current studies, recent futuristic technologies, and techniques. This section consists of only one chapter. A description of this chapter follows.

Chapter 19 is "Neurosurgical Treatments of Neurodegenerative Disorders". This chapter presents the main neurodegenerative disorders that can be treated through surgical procedures, and to describe the surgeries with a focus on the pathophysiology of the disorders.

It is expected that readers shall find this book very informative and enormously useful. Since science is constantly changing readers are strongly recommended to check the recent update. The editors are ebulliently ready to accept any comment, suggestion, advice or critique.

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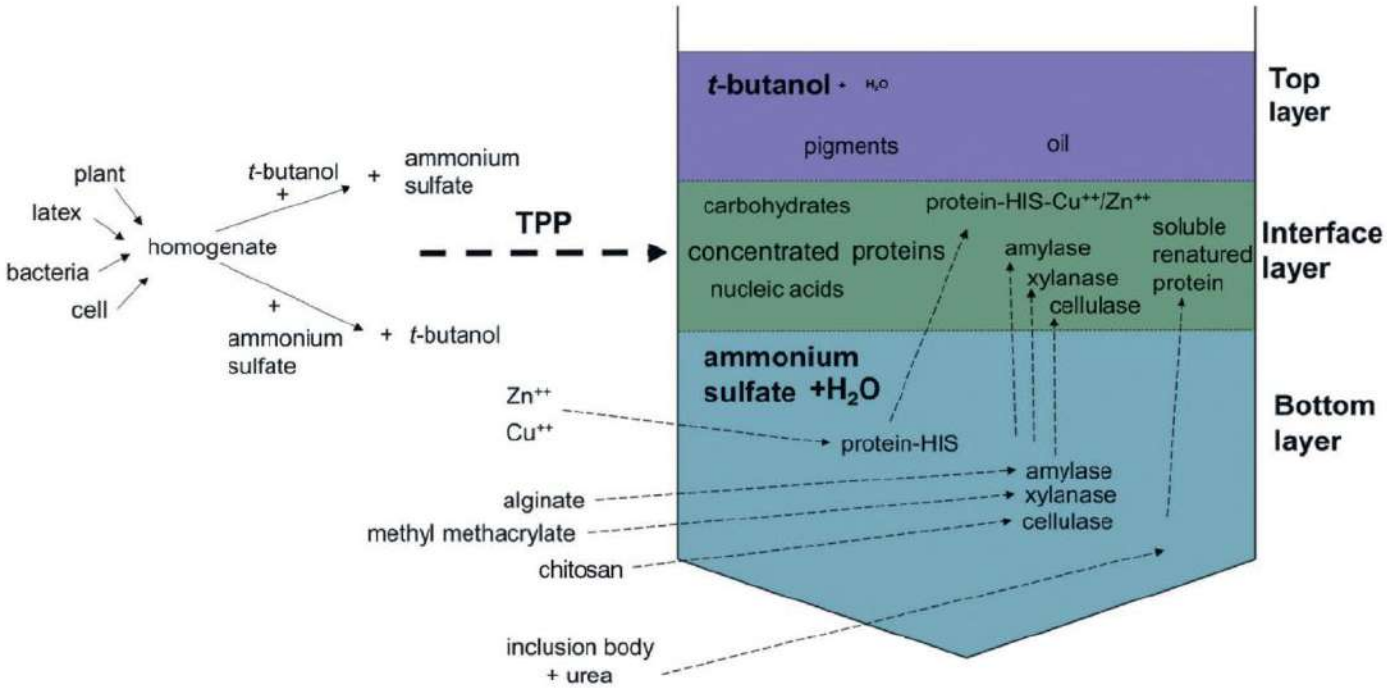
Three Phase Partitioning

Applications in Separation and Purification of Biological Molecules and Natural Products



Edited by
Munishwar Nath Gupta and Ipsita Roy

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THREE PHASE PARTITIONING

Applications in Separation and Purification of Biological Molecules and Natural Products

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Preface

In the era of high tech, three-phase partitioning (TPP) is an outlier among separation techniques in chemical and biochemical sciences.

The first two chapters of this book recall how this simple technique found its applications in isolation and purification of different kinds of molecules from diverse natural sources. We tend to overlook that our understanding of the well-known interaction of sulphate ion with proteins is still not complete. Add the synergy of t-butanol with sulphate ion to this interaction and the situation becomes quite complicated.

Chapters 2–4 discuss what we know so far about the "mechanism" of this process. Other chapters though have also alluded to the ideas discussed in these chapters.

The applications of TPP to both upstream and downstream processes in protein production continue to dominate the range of applications (Chapters 5–10). Polysaccharides (Chapter 11) and oils (Chapters 12 and 13) form two other major classes of molecules for which TPP has been described as a useful technique.

While the word "partitioning" is a part of its name, TPP is a precipitation technique as well. Combining it with the use of enzymes, ultrasonics, microwaves, etc., has given rise to many powerful variants. This has been pointed out in many chapters (1, 2, 4, 10) but Chapter 14 discusses it in a somewhat holistic fashion.

All the chapters include a fair comparison of TPP with other alternative techniques available for the respective applications. In case of proteins and oils, separate chapters (2, 12 and 11) provide overviews of these other options.

We thank all the authors who even in this unusual year (of COVID-19 pandemic) contributed to the book; it has been a very cooperative venture! We will also like to thank two members of our former group (at IIT Delhi), Dr. Aparna Sharma and Dr. Kalyani Mondal, who explored the applications of TPP in the areas of polysaccharides and oils. That is how we became fans of this technique and that fascination has endured over the years to result in this book.

We thank Dr. Eryilmaz (Acquisition Editor) who us encouraged to work on this book and was always willing to help us patiently. Apart from rest of the team (including Ms. Hill, Project Manager) at Elsevier, we will especially like to mention Mr. Bharatwaj Varatharajan (Production Manager) who painstakingly worked on the final draft; always a pleasure to work with a true professional like him!

We hope that this book will encourage others to try this magic of salt and a solvent coming together which creates this versatile technique called three phase partitioning. Maybe we will see its applications in many more areas.

Editors

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Advances in Intelligent Systems and Computing 1124

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Recently, he has completed three book projects and is currently serving as editor for a further two. Dr. Sudip is a member of various societies and professional bodies, including the APSN, ISN, IBRO, SNCI, SfN, and IEEE. He received first prize in the

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Sushruta Innovation Award 2011, sponsored by the Department of Science and Technology, Government of India, and numerous other awards, including the World Federation of Neurology (WFN) travelling fellowship, Young Investigator Award, and IBRO and ISN Travel Awards. Dr. Sudip has also served as an editorial board member for a variety of international journals, and has presented his research in the USA, Greece, France, South Africa, and Australia.

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Trust & Fault in Multi Layered Cloud Computing Architecture

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Abbreviations

ACO	Ant Colony Optimization
BLHB	Basic Load Aware Honey Bee
BBC	Big Bang-Big Crunch
CSP	Cloud Service Provider
DCSim	Data Center Simulation
DAG	Directed Acyclic Graph
DDoS	Distributed Denial-of-Service
DFS	Distributed File System
DVFS	Dynamic Voltage and Frequency Scaling
EMOTIVE	Elastic Management Of Tasks In Virtualized Environments
EMOA	Evolutionary Multi-Objective Optimization Protocol
FBBC	Fault Aware BBC
FGA	Fault Aware Genetic Algorithm
FR	Fault Rate
FLBH	Fault-Based Load Aware Honey Bee
FCFS	First Come First Serve
GA	Genetic Algorithm
IaaS	Infrastructure as a Service
ILP	Integer Linear Programming
IoT	Internet of Things
LCA	League Championship Algorithm
LRAM	Local Resource Allocation Manager
GreenMACC	Meta-Scheduling Green Architecture
MIPS	Million Instruction Per Cycle
MANETs	Mobile Ad Hoc Networks
MOS	Multi-Objective Scheduling
OLB	Opportunistic Load Balancing
PSO	Particle Swan Optimization
PaaS	Platform as a Service
QoS	Quality of Service
RAS	Resource Allocation Strategy

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SFC	Service Function Chaining
SLA	Service Level Agreement
SP	Service Providers
SJF	Shortest Job First
SaaS	Software as a Service
TDARP	Trust and Deadline Aware Resource Allocation Policy
TGA	Trust Aware Genetic Algorithm
VM	Virtual Machine
WFMS	Workflow Management System

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Chapter 1
Introduction to Multilayered Cloud Computing



1.1 Introduction

Cloud computing is a most widespread and popular form of computing, promising high reliability for customers and providers both at the same point of time from many fields of sciences or industry. Clients from the different field are served by data centers in cloud environment geographically spread over the world. Cloud serves a large number of requests coming from various sources over data center with high power consumption. However, to provide such a large computing power required a huge power, leading to high power consumption and cost. Request types in cloud system also affect the services which are public and private requests whose proportion is random in nature. A survey in 2006 over the performance of cloud environment in the USA shows that data center consumed 4.5 billion kWh units of power, which is 1.5% of total power consumed in the USA, and this power requirement is increasing 18% every year [1]. In general, cloud computing deals with various issues like poor resource utilization, load balancing, and many more. Some of these issues are discoursed as follows:

- Cloud computing tools are used by the industry, have issues with the rapidly growing request and a number of servers deployed, and also increase the power consumption.
- Task allocation of requests among data centers without having the knowledge of quality of service (QoS) provided by servers [2].
- Current task allocation algorithms only focus on balancing the request and improving unitization of the system but not the failure probability of the system.
- High-loaded data centers have high failure probability and due to high load, this may lead to slowdown of data center and poor QoS to the client and client provider [3].
- While few of the servers are overloaded, some of them are idle or underloaded.

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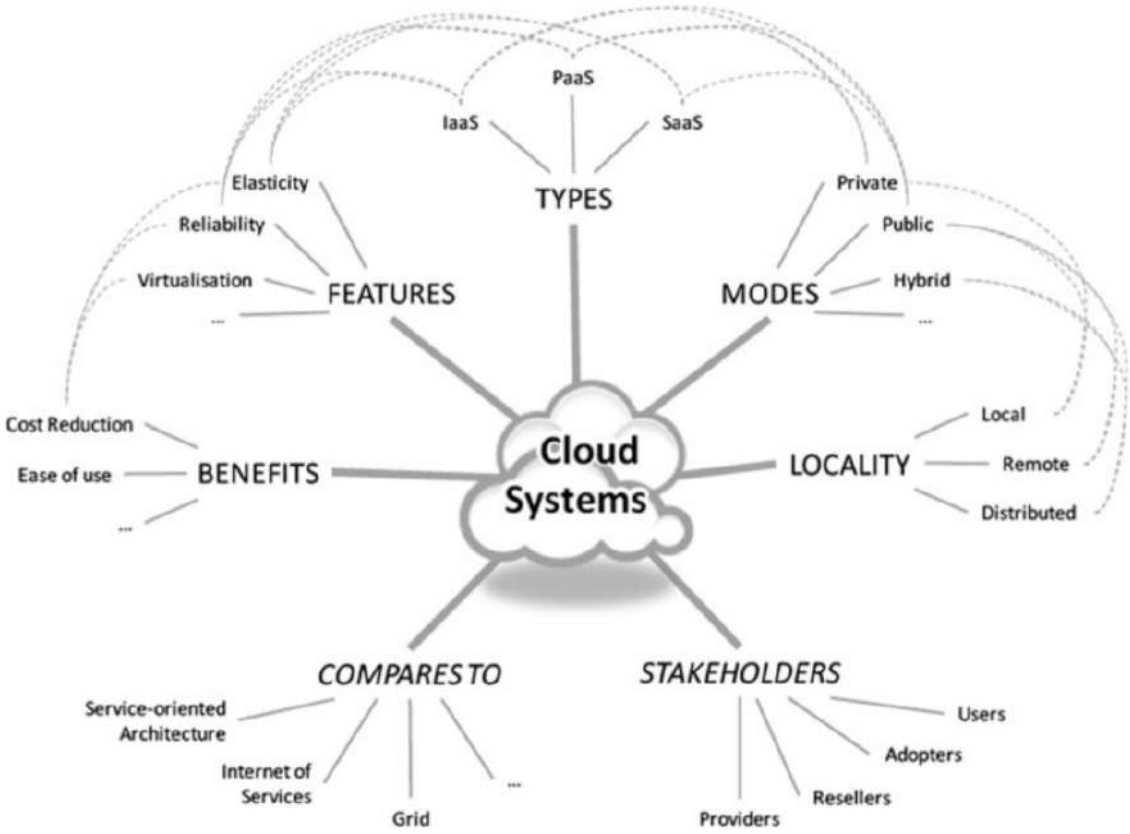

Fig. 1.1 Cloud system characteristics and properties

- Some requests need to be computed with QoS but due to high load and fault rate they may promise the QoS, which is not appropriate to the user and will be a critical issue [2].
- As per recent study [4–7], utilization of data centers is a major problem because 60% of data centers are idle and most of 20% of data centers are utilized and there is waste of resources [3].

The abovementioned issues represent the poor utilization of resources but at the same time also focus on the importance of a new approach that has sufficient strategy to minimize the waste of resources and increase reliability by allocating task over resources which in the case of cloud is virtual machine (VM) with low failure probability to provide high QoS to the users [8]. The existing algorithms only take cloud into consideration as non-faulty in nature and fail to provide specific QoS when a fault occurs. So to overcome these issues and to improve the performance of the system, we have proposed and discussed various approaches for resource load balancing and allocation. Figure 1.1 shows cloud computing features, types, and various other properties [9].

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1.2 Characteristics of Cloud [13]

Cloud is a distributed environment, where the servers are placed at various geographical locations but it seems to a user as a single entity. Cloud computing provides better performance than any other distributed system like grid computing or cluster computing and many more. There are various characteristics of cloud computing which make it superior than any other system which are as follows [9, 10]:

- *High availability*
  One of the most important features of the cloud is all-time availability of resources in the form of storage, computational capability, and high network resources. This property also states that the resources are available in overloading conditions also.
- *Pay-per-use model*
  This feature made cloud computing popular in the industry due to affordable nature of cloud by an industry with high infrastructure; a business holder with the small requirement can easily manage and have its own infrastructure and high computing system at a low cost. Cloud computing allows a user to pay for only those resources, which are used by him/her for that specific period of time, rather than purchasing a complete server or private infrastructure.
- *Elasticity*
  Cloud is said to be flexible and scalable at the same time. This feature allows the cloud to scale its resources up or down based on the user or business needs for a period of time. This allows the cloud to have high availability under overloaded condition also and provided uninterrupted services to the user without failure and high quality of service.
- *Reliability*
  Cloud computing ensures to provide highly reliable computing services and resources to the user which means that the user will be provided with uninterrupted services with the quality of services as assured to the client.

1.3 Type of Cloud and Its Services

Cloud computing provides various service-driven business models to provide a different level of computation to the users. Cloud computing provides three types of service models listed as:

- Software as a Service (SaaS)
- Platform as a Service (PaaS)
- Infrastructure as a Service (IaaS)

This chapter focuses on improving the performance of cloud infrastructure as a service in a faulty cloud environment [10]. The fault involves the behavior of every distributed system because fault may occur at any time that may be due to system failure, network failure, or disk failure.

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1.4 Issues in Cloud Computing

Cloud computing deals with various issues to maintain above-discoursed characteristics and quality of serves assured to the user by cloud providers in terms of high resource availability and computational capability [11, 12]. Some of these issues deal with resource management, resource scheduling, and managing system performance that are discussed below [13, 14]:

- Security
- Resource allocation
- Load balancing
- Migration
- Power-efficient resource allocation and load-balancing algorithms
- Cost-efficient resource allocation and load-balancing algorithms
- Fault-tolerant algorithms
- Behavior-based algorithms
- Trust management

1.4.1 Resource Allocation

Resource allocation strategy (RAS) in the cloud is all about the scheduling of tasks or requests by cloud provider in such a manner to balance the load over all the servers and provide high QoS to clients. It also includes the time required to allocate the resources and the resources available. The main aim is to improve the utilization of resources and complete all the request within the deadline and with least execution time [15].

An optimal RAS should avoid the following criteria as follows:

(a) *Resource contention* situation arises when two applications try to access the same resource at the same time.
(b) *The scarcity of resources* arises when there are limited resources.
(c) *Resource fragmentation* situation arises when the resources are isolated.
(d) *Over-provisioning* of resources arises when the application gets surplus resources than the demanded one.
(e) *Under-provisioning* of resources occurs when the application is assigned with fewer numbers of resources than the demand.

Resource allocation algorithm can be categorized into three subcategories as from the literature review conducted over existing proposed algorithms.

Categorization is as follows:

- Static
- Dynamic
- Learning based

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Here, static scheduling algorithms are referred to algorithms which are not affected by system and behavior of cloud like shortest job first (SJF), first come first serve (FCFS), and round robin [16]. On the other hand, dynamic algorithms are those whose objective function depends on the system parameters like deadline, available resources, and resource utilization of host and many more examples of these algorithms are deadline-based algorithm, cost-based algorithm, and utilization-based algorithm [7, 9, 11, 12, 15, 17]. The problem with these algorithms is that they do not take into consideration the previous performance of host and system as a whole. Moreover, the past faulty nature of the system is not taken into consideration and leads to large request failure. Dynamic algorithms deal with the issue of local minima; these algorithms are not able to find a global best solution and are stuck in local best solution. On the other hand, learning-based algorithms are better than dynamic algorithms because they learn from the past history and behavior of the system to achieve better performance. Algorithms like genetic algorithm, PSO, and Big Bang Big Crunch are some of the examples of learning-based algorithms inspired from nature.

1.4.2 Load Balancing

Load balancing aims to distribute load across multiple resources, such as server, a server cluster, and central processing. Load balancing aims to optimize resource use, maximize throughput, minimize response time, and avoid overload of any single resource [3].

Goals of load balancing are as follows [18]:

- To improve the performance substantially
- To improve system stability
- To have scalability in the system
- To improve the system condition under high load or request rate

Types of load-balancing algorithms are represented as follows [19]:

- *Sender initiated:* When load-balancing algorithm is triggered by the sender.
- *Receiver initiated:* When load-balancing algorithm is triggered by the receiver.
- *Symmetric:* It is the combination of both sender initiated and receiver initiated.

Load balancing is also used to manage the average utilization of the system as a whole to avoid creation of hot spots; that is, the request should not be clustered on a single data center; rather it should be spread over the servers. So it aims to find an underloaded server and move the requests to the selected server. This makes a requirement of a load-balancing algorithm to fulfill these requirements taking into consideration system utilization and QoS without failure.

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1.4.3 Migration

Migration in cloud infrastructure plays an important role in cloud infrastructure under system overloading condition. In cloud infrastructure when the server gets overloaded, i.e., in case of utilization beyond a threshold that is considered to be overloaded, we need to migrate a virtual machine from overloaded server to an underloaded or neutral server [20]. This helps to balance the load and prevent the server from any failure. So there is a requirement of an intelligent and efficient migration algorithm to balance the condition and improve the performance of the system.

1.4.4 Power-Efficient Resource Allocation and Load-Balancing Algorithms

The power efficiency of a cloud environment is an important issue for a green cloud environment, as 53% of the total expense of a data center is spent on cooling, i.e., power consumption [3, 21].

A survey in 2006 on data centers established that the USA consumed more than 1.4% of total power generated during the year [22]. Therefore we need to improve the power efficiency of infrastructure. The problem can be solved in various ways and various proposals have been made to solve and improve the performance. So to do this we need to design power-aware resource allocation and load-balancing algorithm to improve the total power consumption of the system and any such algorithm will result in a reduction of overall power consumption.

1.4.5 Cost-Efficient Resource Allocation and Load-Balancing Algorithms

Cloud computing uses pay-per-use model to ensure least cost and payment only for the resources used. To maintain this feature cloud controller algorithms like resource allocation migration and load balancing are responsible for maintaining this characteristic by offering the resources which can complete the client request on time and within the budget of client and can offer least cost. So we require cost-aware algorithms which are cost efficient and can provide the best system performance by improving utilization and power consumption all at the same time [17, 21]. These types of algorithms are referred to as multi-objective algorithms; there are many proposals made for improving the performance of the system but they only take into consideration either power or cost, so cannot guarantee the best performance.

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1.4.6 Fault-Tolerant Algorithms

Cloud computing environment is a type of distributed environment like grid computing and cluster computing. Existing algorithms consider cloud as non-faulty but faults are a part of distributed environment which may be due to hardware or software failure at any point of time. There are many fault-aware and fault-prediction algorithms which have been proposed for grid environment to improve the reliability of the system. So similarly, we require fault-aware algorithms to make system fault aware, reduce the failure probability of the system, and increase the reliability of the system.

1.4.7 Behavior-Based Algorithms

Most of the resource allocation and load-balancing algorithms proposed for cloud infrastructure are dynamic algorithms like min-min, max-min, and many others. These algorithms take into consideration only the current behavior/status or the server and system for selection of server. The problem with these algorithms is that they do not take into consideration the previous performance of the system for prediction of the better solution and are stuck in local minima. Behavior-based algorithm lists genetic algorithm, ant colony, particle swan optimization (PSO), monkey search, and many others. So, there is a need of algorithm taking into consideration the previous and present performance of the system for decision-making.

1.4.8 Trust Management

Trust models are used in all forms of distributed environments ranging from mobile ad hoc network (MANETS), sensor networks, and grid computing to validate the reliability of nodes over distributed network. In grid computing, various trust models are proposed to ensure trust in terms of security and reliability of the server or the node. Trust models are to resolve the problem of reliability in any heterogeneous environment, which contributed to nodes having different configuration spread over a network. There exist many models in cloud computing environment which have been proposed over the period of time.

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1.5 Multilayered Cloud Architecture

By multilevel cloud architecture, it refers to various types of cloud service layers one above the other supporting each other to provide scalable, reliable, and pay-per-use model with high quality of service. Various research articles have reported the same, where the researchers have explored each layer in detail with its various functioning components. In general cloud layered architecture is divided into three payers: infrastructure layer, service layer, and platform layer. These layers are responsible to perform various functionalities in cloud which are considered to be the base of cloud computing [23–25].

In [16], Buyya et al. have explained a layered architecture of cloud as shown in Figs. 1.2 and 1.3. Figure 1.2 explains each layer in brief with its functional units. The layered architecture is divided into five layers: (1) data center layer, (2) infrastructure layer, (3) service layer, (4) programming layer, and (5) application layer.

1. **Data Center Layer:**
   This layer is responsible for hardware resources in data center which includes server machines, cooling mechanism, switches, and networking. This layer only provides the resources.
2. **Infrastructure Layer:**
   This layer is responsible for implementing virtualization and provides virtual machines as service to the users. This layer is responsible for creating and managing virtual network, storing over the network, and managing virtual machine and meeting their performance requirement. Some of the other functional units of this layer are as follows:

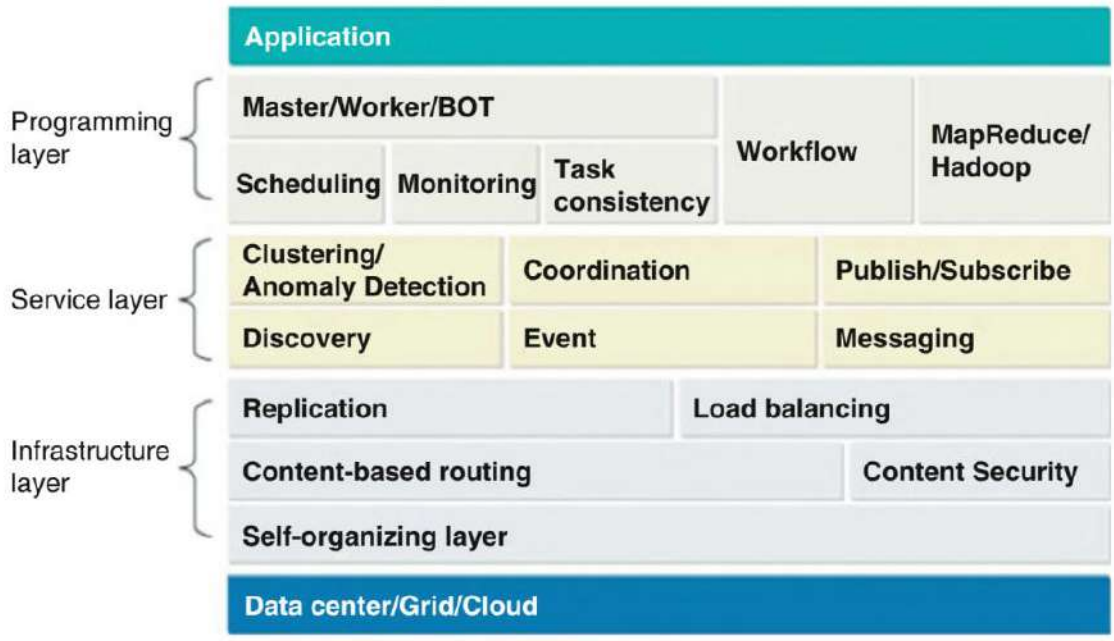

Fig. 1.2 Layered architecture with various functional units

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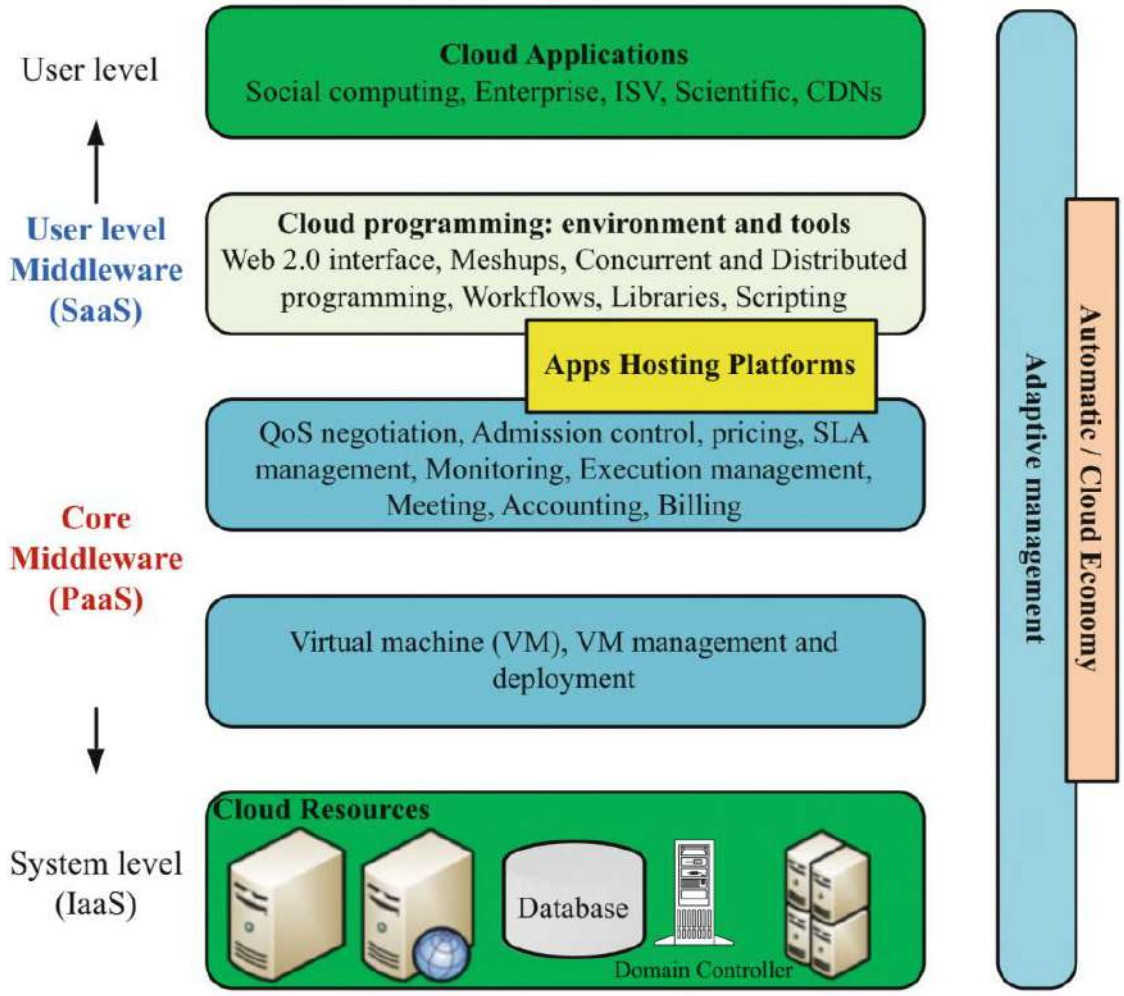

Fig. 1.3 Layered architecture with various applications of each service

(a) *Replication*
In this a replica of different type of instances of VMs is saved which can be used in any one of the VM crashes due to some reason. These replicas are also referred to as snapshots or images of VM which are updated after every small interval of time. The replica is also used during live migration of virtual machine to other host/data center.

(b) *Load balancing policy*
This unit is used to balance the task load over the virtual machine. This mechanism takes a look over the utilization of each VM and checks if the VM is overloaded, i.e., if the utilization of that VM is beyond a threshold. In such cases, some of the tasks are migrated from one VM to other VM with less load. This unit helps the environment to provide high quality of service to the user and improve the reliability of the system. Many researchers have designed innovative load-balancing algorithms to improve the performance at IaaS layer. Many such algorithms are referred in Chaps. 3 and 7.

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(c) *Resource allocation policy*
This unit is responsible for allocation of tasks from upper application layer to be executed on the VMs. This using defines the performance of IaaS in cloud because the efficiency of this layer determines whether you are using the resources of data center wisely. Generally, the algorithm takes care of many parameters and uses intelligent algorithm using performance study of the VMs in the present and past. The module is interlinked tightly with both user layer and hardware because it takes decision based on the type of request from upper layer and at the same time takes into consideration the current state of VMs. Many of such algorithms are referred in Chap. 3 where this unit also takes into consideration the performance study from the trust layer to make better decision.

(d) *Content-based routing*
This unit is responsible for better network performance to route the task and data from best network route with least network delay. This functionality allows the data to be transferred over the network with least network delay which increases the performance of the system.

(e) *VM migration policy*
This functional unit is responsible for migrating of VM from one host to another host. This is used by load-balancing algorithm for balancing the utilization. But this algorithm is responsible for selecting a host which has been underutilized and can handle the task with overloading within the deadline. Migration policy uses live migration policy for transferring the VM with our pausing the VM and informing the user.

(f) *Content security*
This is responsible to maintain isolation among the VMs. In cloud computing isolation is one of the important attributes which define the data security even if multiple data are placed on one data center. This defines the security parameter at IaaS layer where data is saved in encrypted form.

(g) *VM scaling (resource scaling)*
This functional unit defines creation of more VMs when load increases and deactivates the VMs when task load is less. This functionality is used to manage the high demand need by deploying more number of resources when required.

3. **Service Layer**
This layer is also named as Software as a Service layer which is responsible for providing service to the user in the form of web services or web-based computing service. This layer mainly manages software services, generates task for IaaS layer in the form of event, and shares data using message passing. Here also the layer has scaling functionality which helps to fulfill increasing user demands.

4. **Programming Layer**
This layer is responsible for task management and generation. This layer takes input from application layer and decides where to deploy the tasks to fulfill the

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needs and complete the task within deadline. This layer deals with workflow, independent task, and dependent tasks:

(a) Scheduling
(b) Monitoring
(c) Task consistency
(d) Workflow
(e) MapReduce

5. **Application Layer**
This layer basically consists of all forms of application deployed over the cloud.

Figure 1.3 demonstrates three basic service models, but the significance of this layered architecture is that it demonstrates various subservices which are part of each layer.

1.6 Role of Trust in Cloud and Its Various Services

As discoursed in the above sections each layer has many functionalities for decision-making like schedule, load balance, migrate, security, scalability, and many more. All such functional units are required to make a best choice/decision to use cloud resource more efficiently so as to provide quality of service to the user and improve the system performance at each layer and as a whole system with high reliability and efficiency [26].

Trust model in cloud is one of the solutions which allow all the functionality at every layer to get the current performance statistics of the system to make the best decision. Trust model is also defined as metaheuristic which not only studies the current set of performance but also takes into consideration the past performance of the resources.

Trust model can be considered as a multi-objective decision-making system which monitors the complete system and helps system as a whole to improve the performance rather than improving one functionality in a system with only one or few performance parameters. Here the global best solution is considered for the system not for individual unit. We can consider this as central monitoring unit for all the layers.

1.7 Summary

This chapter introduced cloud computing with its various service models and types. In Sect. 1.2 characteristics of cloud and various issues in cloud are discoursed which are considered to be the problem statements for researchers. This chapter gives a deep idea of all the functional units in cloud architecture with its multilayered

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2.3.2 *Trust Management and Performance Improvement*

In cloud computing various trust models have been proposed for improvements of performance like using a direct trust, indirect trust model, relative trust model, reputation-based trust model, collaborative key-based trust model, and many more. Proposed trust models exist for all type of distributed environments like grid computing, computer networks, wireless networks, and e-commerce. However, there is a similarity that resources are distinctly located and to study the performance of the resource, trust models are used. In general, reputation-based trust model and relative trust model and their variants are most popular among all types of distributed environment in cloud computing.

2.4 Existing Trust-Based Solutions in Cloud

Trust can be defined as an entity based on reliability and firm belief based on the attribute of the entity. Trust is the firm belief in the competence of an entity to act as expected such that this firm belief is not a fixed value associated with the entity but rather it is subjected to the entity's behavior and applies only within a specific context at a given time [13]. That means that the firm belief is a dynamic value which varies timely. According to Gradison trust is the activity of collecting, codifying, analyzing, and evaluating evidence relating to competence, honesty, security, and dependability with the purpose of making assessment and decision regarding trust relationship [14]. Trust can be categorized into many types like the following [14]:

- *Blind trust*: This is a default trust before any event in the system, and which would include an agent to initiate a relationship with unknown entities.
- *Conditional trust*: This is a classical state of trust during the life of the agent. This conditional trust is likely to evolve and can be subject to some sets of constraints or conditions.
- *Unconditional trust*: Such a trust is the probability to be configured directly by an administrator, and would not be sensitive to successful/unsuccessful interaction and external recommendation of any other sources of the evolution of the conditional trust.

Trust management models can be defined as models to manage and manipulate trust value. These models are basically of two types:

- Relative trust where trust value is calculated based on the relative reliability, and dependability between two entities
- Direct trust that takes into consideration the reliability of each entity independently

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Many classifications of trust management models are being proposed, that is, behavior based, domain based, network topology based, agent based, and so on [15–17]. These different domains are being considered which can provide different cloud services with their specific trust value. The resources provided by the same domain retain the same trust value. So the resources are being allocated to the user based on the trust value of the domain. The trust value degrades or increases depending on the activities over a file and time taken to complete a transaction and to transfer a file [18].

Based on reputation-based trust, a model has been proposed by Faraz Azzedin for grid computing [19]. In this model, they have considered the past experience for calculating trust values. The past experience involves the calculation based on the last transaction and last trust value. The trust value is relatively calculated based on the reputation vector of two entities. In this, two values are stored trust value and reputation. Let there be two domains D_1 and D_2; D_1 stores the trust value about D_2 based on the D_1 direct relation with D_2 as well as the reputation of D_2. Domain experience is given by $\Gamma(D_1;D_2;\ t)$, direct relation is given by $\Theta(D_1;D_2;\ t)$, and reputation of D_1 at time t is given by $\Omega(D_1;\ t)$. To manipulate the trust and reputation, they defined a decay function $\gamma(t - t_{ij})$ which is based on time; the last experience and reputation between two domain are stored as $R(D_1,D_2)$. Trust is denoted as DTT [13]:

$$\Gamma(D_i, D_j, t) = \alpha \times \Theta(D_i, D_j, t) + \beta \times \Omega(D_j, t) \tag{2.1}$$

$$\Theta(D_i, D_j, t) = \alpha \times \mathrm{DTT}(D_i, D_j) + \beta \times \gamma(t - t_{ij}) \tag{2.2}$$

$$\Omega(D_j, t) = \left(\sum_{k=1}^{n} \mathrm{RTT}(D_k, D_j) \times R(D_k, D_j) \times \gamma(t - t_{kj}) \right) / \sum_{k=1}^{n} (D_k) \tag{2.3}$$

In [20], Kumar has proposed a direct trust resource scheduling in grid computing. They have taken into consideration a few factors such as affordability, success rate, and bandwidth. On the basis of these parameters, trust matrix has been created which is further used to calculate the direct trust value of the resource and schedule the resources depending on the trust value of the resources and the type of job to be executed. Figure 2.5 explains the whole process.

The behavior-based trust model is also one of the important models for the grid which have been discussed by Papalilio in [21]. It takes into consideration the behavior of the participant, on the basis of expected response from another participant in an interaction or transaction. Other features such as the availability, accessibility, accuracy, response time, and latency all are taken into consideration to decide the behavior of the participant during the interaction. In [22], Muchahari et al. have proposed a dynamic trust model for the cloud. This work overcomes feedback-based trust models which are considered to be inaccurate and malicious in many cases. Proposed trust model has taken into consideration cloud service registry and discovery into consideration where registration refers to adding new resources to cloud and discovery refers to finding the best resource for the cloud environment. The trust model is defined upon two things: previous trust value and credibility of the

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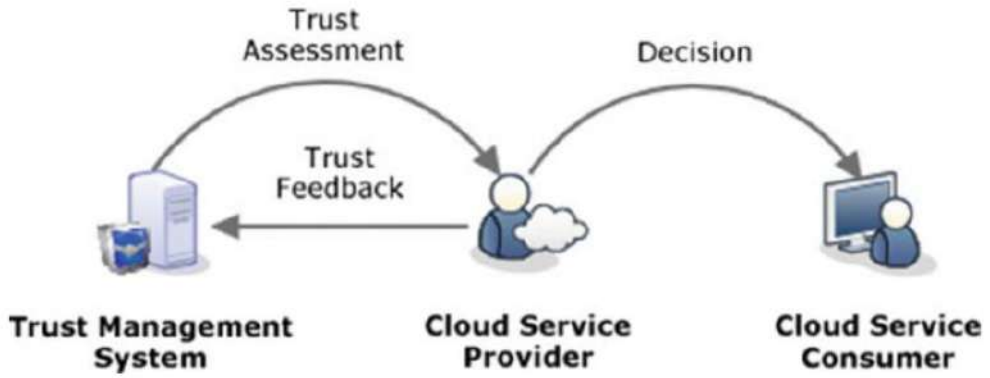

Fig. 2.11 Trust manager and cloud user

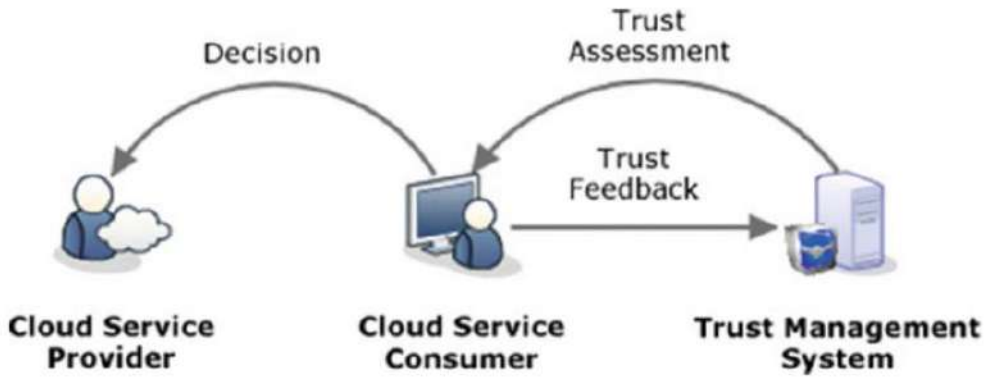

Fig. 2.12 Trust model and service provider

evaluated trust is given to the next layer for distribution to several functional modules for decision-making.

3. *Trust result distribution*: This is similar to the first layer only; rather than collecting feedback this layer is responsible for the delivery of trust value to various parties which generate queries for trust assessment. The users of this trust value are cloud service consumers, users, cloud controller, load-balancing algorithm [29], resource allocation algorithm, and providers.

2.5 Comparison with Various Reported Literature

Cloud being a distributed architecture uses trust model architecture to solve various issues in the cloud environment. Various trust management techniques and models have been proposed in the past to improve the performance of the cloud. These existing trust models aim to improve security [30, 31], QoS [32], and various other performance parameters. The existing models can be categorized into the following categories:

– *Trust policy*: Policy-based trust models refer to the most traditional rule-based trust model which already exists in grid computing, distributed computing, and

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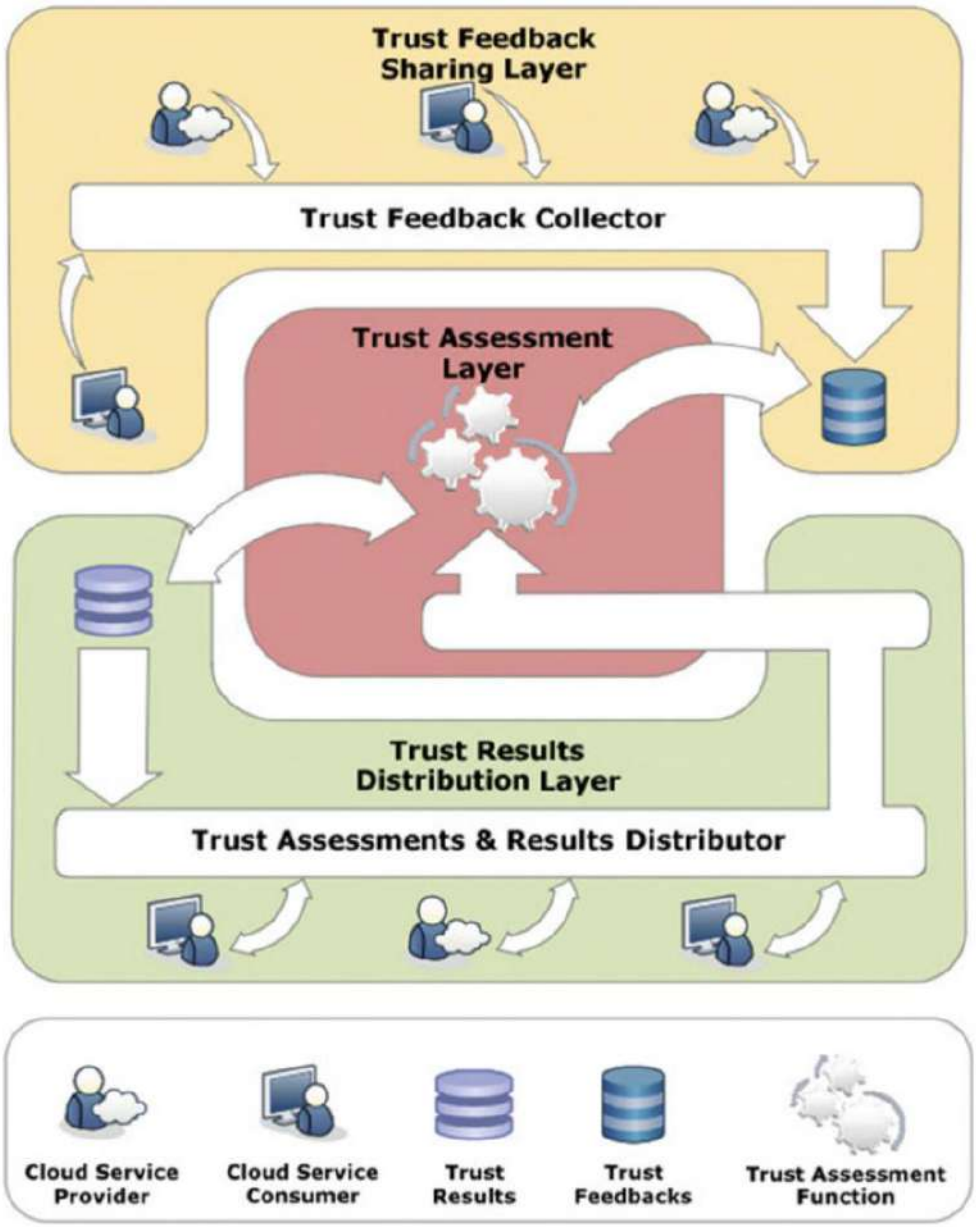

Fig. 2.13 Trust layered architecture

wireless network. These models are generally threshold- and rule-based models for SLA checking- and performance parameter checking-based models.
Some of the other existing models are:

Cloud environments [24, 33]
Grid [25, 27, 34]
Web applications [27]
Service-oriented environment [35, 36]
SLA-based trust [37]
Feedback credibility [37–43]
Figure 2.14 shows a pictorial view of the policy-based trust model.

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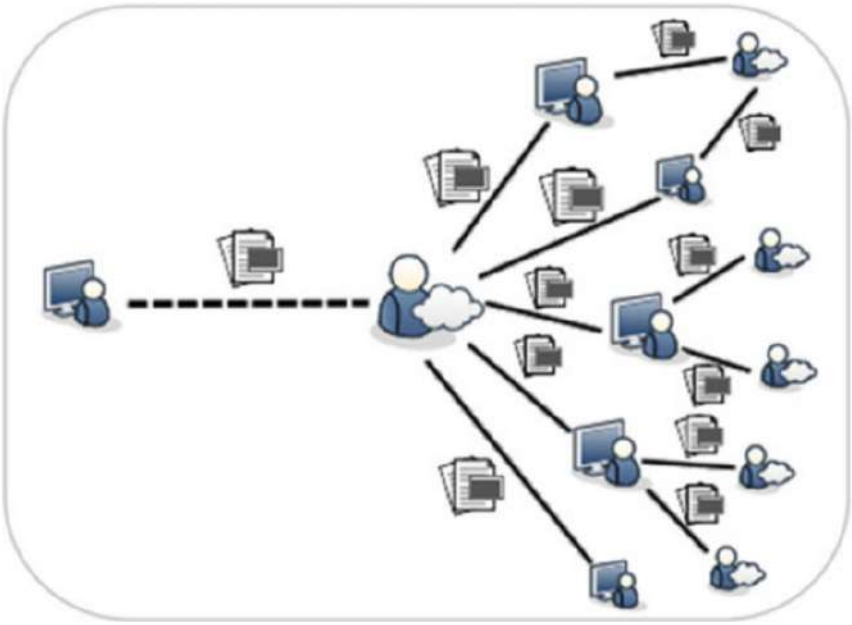

Fig. 2.14 Policy-based trust model

- *Recommendation-based trust*: This form of trust model is based on the recommendation of other service providers. Such models are more popular in the cloud environment only; the difference in the function of recommending the trust may depend on many other values and performance parameters as dictated in Sect. 2. Some of the other recommendation-based trust models are:

  Cloud [37, 44, 45]
  Grid [46]
  Service-oriented environment [47–49]
  Here, Fig. 2.15 shows a pictorial representation of recommendation-based trust model which makes a more clear overview of how the model works.

- *Reputation-based trust*: These trust models are used because feedbacks from various cloud providers and service providers may influence in a single direction to avoid such a situation; reputation feature is added to the model so as to avoid the decision from being influenced by a group of service providers. Existing works from various fields are as follows:

  Cloud environment [40, 44, 50]
  Grid [13, 19, 39, 46, 51]
  Figure 2.16 shows a pictorial representation of reputation-based trust model.

- *Trust prediction models*: These models are new to cloud computing environment which help the trust model to predict the future trust value based on the past learning and performance which helps the trust model to make better decisions in terms of the future prospect of the cloud environment. Some of the works from this field are as follows:

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high priority. Resource allocation is applied according to the type of request as in step three. In step three if the request is private then allocate it to high-power-efficient private data center which fulfills the request requirement. It may happen that all high-efficiency private data centers are currently not available to serve request or are busy with other requests. In such cases check in public cloud data center which has high power efficiency; if such a data center is found which fulfills request then allocate private request to that data center. By doing such a resource allocation we serve private request using less power. If the request is public then allocate it to high-power-efficient public data center which fulfills the request requirement. It may happen that all public data centers are not available or busy with other requests. In such a case check in private cloud data center which has minimum power efficiency; if such a data center is found which fulfills the request requirement then allocate public request to that data center. By doing such a resource allocation we serve public request using less power and high efficiency.

Step four is a major step after allocation of resources to both public and private requests. Once requests are proceeded by step three then update their data center list according to their power efficiency and apply algorithm from step one. After allocation of VM again update data center list and start it with step one until request queue is empty.

Above-given formulations are used to calculate power efficiency of each data center on their utilization. To get power efficiency of each data center first calculate the utilization of PD_i and then use power linear model to calculate the power efficiency of that data center. After calculating the power efficiency of PE_i sort these data centers as per efficiency and then distribute requests among these data centers in that manner, so the least loaded or high-power-efficiency data centers give the best performance. After allocation of VM again update data center list and start with step until task queue is empty.

de Carvalho Junior et al. [9] proposed the use of a function that can ensure the most appropriate behavior to the principles of Green IT but not the quality of service. For this he proposed the use of GreenMACC (Meta-scheduling Green Architecture) and its module LRAM (Local Resource Allocation Manager) to automate the execution of all scheduling policies implemented in the Scheduling Policies Module so as to provide quality of service in cloud computing and determine its flexibility [10]. Task consolidation is an efficient method which is used to reduce power consumption by increasing the resource utilization but due to task consolidation resources may still draw power while being in the idle state. Young Choon Lee et al. have introduced two algorithms to maximize the utilization of resources of the cloud. The two algorithms are ECTC and MaxUtil. ECTC works on the premise of calculating the energy which is being used by a particular task when there are simultaneous tasks running parallel with it, and then it is compared with the optimal energy which is required. MaxUtil focuses more on the mean usage of a particular task when it is being processed [11].

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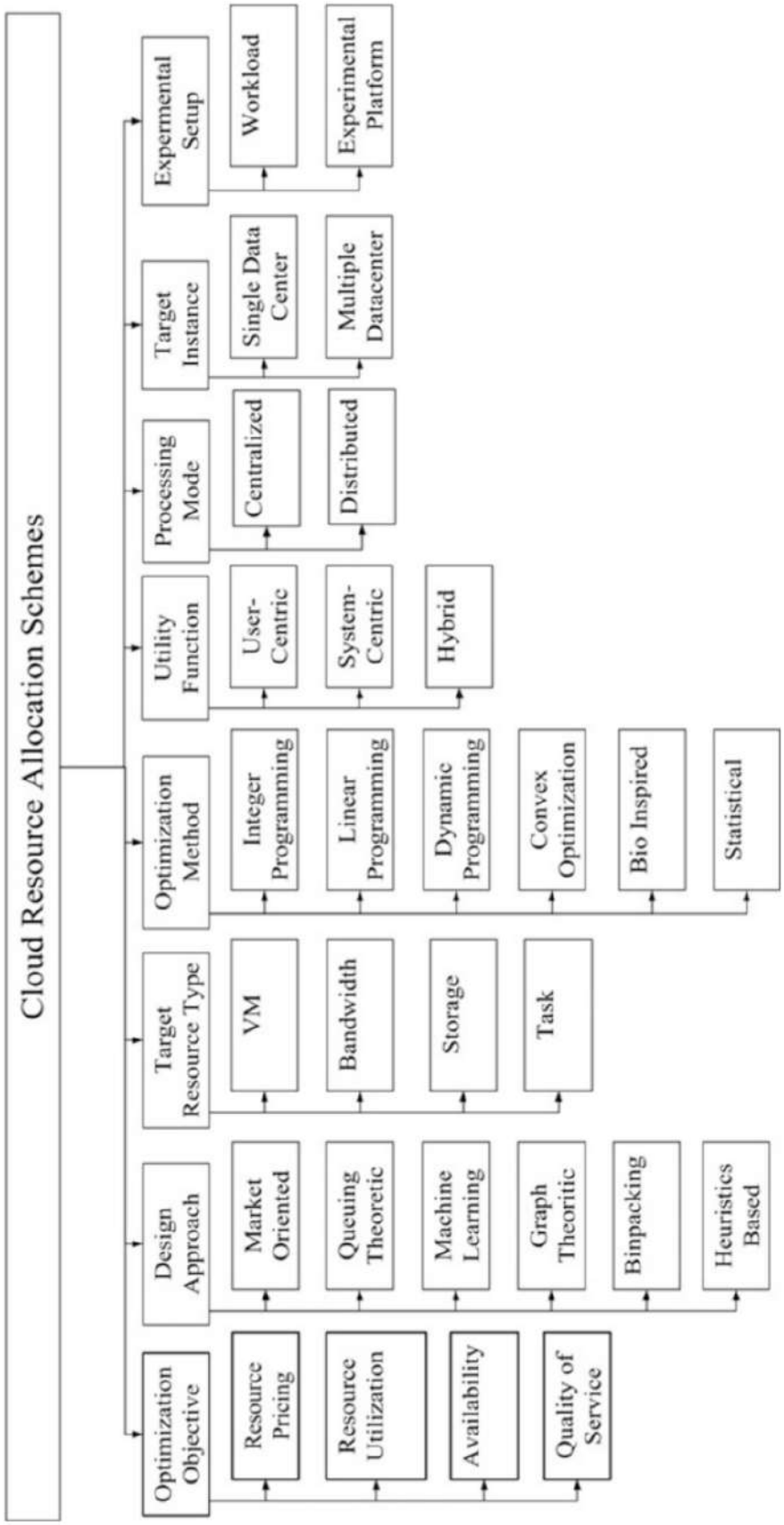

Fig. 3.3 Taxonomy for resource allocation in cloud [18]

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In [4], the authors have applied a sliding window approach to predict future values on a short-term basis using the daily closing price. For this approach, the authors had selected two different sectors, IT and Pharma. Companies were selected with the help of NIFTY-IT index and NIFTY-Pharma index. Training data consists of stock prices of Infosys over a period of time, and the test data had stock prices for Infosys, TCS and CIPLA. Three different deep learning models, namely RNN, LSTM and convolutional neural network (CNN), were used, and the performance of each model was quantified using percentage error. The authors proposed CNN methodology as the best due to sudden changes occurring in the stock market.

Kirti Pawar, Raj Srujan Jalem and Vivek Tiwari in [5] proposed implementation of RNN along with LSTM in comparison with traditional machine learning algorithms for stock market prediction. The historical data of Apple, Google and Tesla was considered from Yahoo Finance. The result shows that RNN-LSTM gives more accurate results than traditional machine learning algorithms, such as regression, SVM, random forest, FFNN and backpropagation.

In [6], Ghosh, Neufeld and Sahoo employed random forest and LSTM models as training methodologies to analyze forecasting of stocks of S&P 500 for intraday trading. They observed that LSTM outperforms random forests with higher accuracy. Social network media analytics is showcasing the promise for the prediction of financial markets [7]. Measurements of collective emotional states derived from large network scale are correlated to stock transaction data over a time period.

Forecasting on time series data for stock prices is now a trending research area. In previous years, many neural network models had been suggested to clarify the problem of economic data and to achieve precise forecasting results. The models integrated with ANN provide better results rather than using a single model. This has been concluded in [8] by analyzing the performance between BSE100 stock market index and NIFTY MIDCAP50 stock market index by different neural network models, and forecasting accuracy is analyzed and measured using performance metrics like mean absolute error (MAE), mean absolute percentage error (MAPE), percentage mean absolute deviation (PMAD), mean squared error (MSE) and root mean squared error (RMSE).

In [9], the authors have compared single-layer perceptron (SLP), multi-layer perceptron (MLP), radial basis function (RBF) and SVM and old statistical techniques including statistical methods and applications (SMA) and ARIMA to forecast the performance of market of Karachi Stock Exchange (KSE) at the end of the day using different attributes as input including oil rates, gold and silver rates, Foreign Exchange (FEX), news and social media feed and predicting the market as positive or negative. MLP performs better in comparison to other techniques.

Ping-Feng and Chih-Sheng in [10] proposed a combination approach that uses the distinctive strength of ARIMA which is one of the broadly used models in time series forecasting and SVM used in successfully solving the nonlinear regression in forecasting stock prices. The presented hybrid model greatly improves the prediction performance of a single ARIMA or single SVM model in predicting stock prices.

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invest in a particular stock instead of an index, and hence, it is advantageous to analyze a single company.

The time series data is used to predict the closing price of the stock. The LSTM [1, 5] and ARIMAX [2] algorithms used in this paper first determine the stock price based on the features like open, high, low, volume using a dataset of a calendar fiscal year.

In the next step, the sentiment analysis is embedded in both models. The news for the particular company is Web scrape using *Scrapy* and *Beautifulsoup* from the openly available news platforms for a year. The text data then collected is passed through neuro-linguistic programming (NLP) techniques mainly Valence Aware Dictionary Sentiment Reasoning (VADER) for sentiment analysis of the news data collected. The detailed description of our approach is discussed in the next section.

3.1 Dataset

The dataset used in this paper is that of Reliance Industry Limited (RIL) scrapped from the Yahoo Finance Web site [11–13]. The reason for choosing this dataset is that Reliance Industries (RIL) play a major role in the Indian financial markets. The reason being it is a part of both the Nifty50 and Sensex, the flagship indices of Bombay Stock Exchange (BSE) and National Stock Exchange (NSE), respectively. So when there is a change in the trend of it, the rest constituents of both the indices have a tendency to follow it and hence driving the financial markets along with these showing either an uptrend or a downtrend. The effect sometimes can be observed on other industries too because if suddenly RIL has undergone a downtrend meaning the investors are not interested in buying and selling its shares which they already have, its price falls leading to declining in the points of indices. Once the points of an index start to decline, all the constituents of that particular index face the outcomes whether it is positive or negative. Therefore, it can be said that sentiments play an important role and especially in the case of RIL as it is considered to be a blue-chip stock and is considered to be a benchmark for many. So what happens with RIL can sometimes happen with stocks of other companies also even if these are from a different industry.

The data size used has been kept comparatively low to get a corresponding correct and more detailed per day news headlines data for the given company. The dataset considered is for a trading year which is around 253 trading days [14, 15]. The dataset originally had six features, namely *Open, High, Low, Close, Adj Close, Volume*, the *sentiment* feature has been added later. The training to testing data ratio has been kept as 75 to 25% in this paper.

The sample of the dataset used before the sentiment analysis was incorporated is shown in Table 1.

The text data (news) for sentiment analysis has been scrapped from the financial news Web site portal using *BeautifulSoup* and *Scrappy*. The sample of the financial

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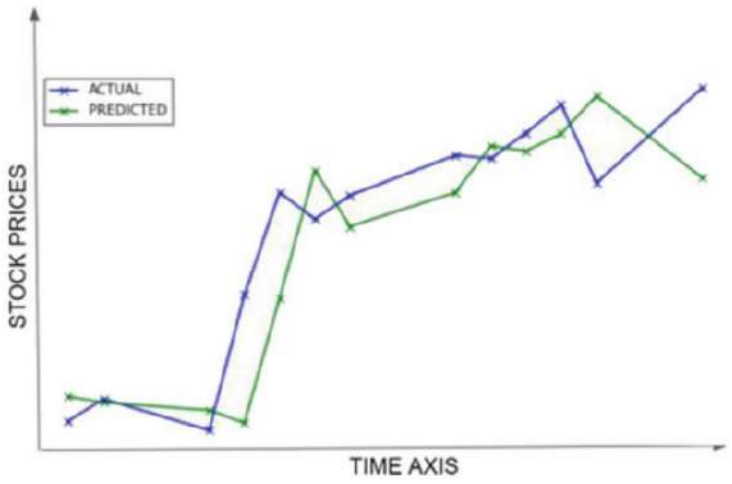

Fig. 11 Result of ARIMAX model after incorporation of sentiment analysis

Table 8 Actual and predicted price values using LSTM with sentiment analysis

Actual	Predicted
0.146275	0.157621
0.147085	0.129456
0.145920	0.149210
0.150975	0.156983

Table 9 Actual and predicted price values using LSTM

Actual	Predicted
0.17320	0.169583

Table 10 Actual and predicted price values using LSTM

Actual	Predicted
0.17320	0.171038

The following forecast has been computed by the LSTM algorithm with the corresponding actual price as mentioned in Table 9.

When the positive sentiment analysis (classified 3 according to our approach) has been accounted in the data, the LSTM algorithm computed following forecast which obtained better result as shown in Table 10.

5 Conclusion

In this paper, it is highlighted how the Indian stock market rather any stock market is highly dependent on the sentiments and news in the market. It does not matter how better an algorithm is, without considering the market news its accuracy will always be flawed. At the end of the day, the trading is done by the investors who are in

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turn human beings only and are vulnerable to this news and leaks spreading around. It has been observed that both the algorithms considered in the paper showed an improvement in upward of 30% in RMSE when sentiment analysis was considered in the dataset and thereby emphasizing the impact of the sentiment analysis in the stock market to be a major factor. Hence, it is concluded that the application of the sentiment analysis feature reduced the RMSE by 30%, and in turn, the model accuracy was increased. It has been observed that both the algorithms considered in the paper achieved an improvement in range of 15–30% when sentiment analysis was considered in the dataset and thereby emphasizing the impact of sentiment analysis in the stock market to be a major factor. In the stock market trading, a small difference even of this scale can change the game for a trader and even a company. Hence, it is concluded that application of the sentiment analysis feature increased the accuracy of the fit approximately between 15 and 30% for a given dataset. In future, this work can be extended by working on improving the efficiency more by considering the indexes from around the world and how they tend to affect the price of blue-chip stocks like RIL and also to project a live prediction.

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Hari Singh, Jaypee University of Information Technology, India
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Data processing has become an important field in today's big data-dominated world. The data has been generating at a tremendous pace from different sources. There has been a change in the nature of data from batch-data to streaming-data, and consequently, data processing methodologies have also changed. Traditional SQL is no longer capable of dealing with this big data. This chapter describes the nature of data and various tools, techniques, and technologies to handle this big data. The chapter also describes the need of shifting big data on to cloud and the challenges in big data processing in the cloud, the migration from data processing to data analytics, tools used in data analytics, and the issues and challenges in data processing and analytics. Then the chapter touches an important application area of streaming data, sentiment analysis, and tries to explore it through some test case demonstrations and results.

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Khyati Ahlawat, University School of Information, Communication and Technology, Guru Gobind Singh Indraprastha University, India
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Expansion of data in the dimensions of volume, variety, or velocity is leading to big data. Learning from this big data is challenging and beyond capacity of conventional machine learning methods and techniques. Generally, big data getting generated from real-time scenarios is imbalance in nature with uneven distribution of classes. This imparts additional complexity in learning from big data since the class that is underrepresented is more influential and its correct classification becomes critical than that of overrepresented class. This chapter addresses the imbalance problem and its solutions in context of big data along with a detailed survey of work done in this area. Subsequently, it also presents an experimental view for solving imbalance classification problem and a comparative analysis between different methodologies afterwards.

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Oshin Sharma, PES University, Bangalore, India
Anusha S., School of Engineering and Technology, Jain University, Bangalore, India

The emerging trends in fog computing have increased the interests and focus in both industry and academia. Fog computing extends cloud computing facilities like the storage, networking, and computation towards the edge of networks wherein it offloads the cloud data centres and reduces the latency of providing services to the users. This paradigm is like cloud in terms of data, storage, application, and computation services, except with a fundamental difference: it is decentralized. Furthermore, these fog systems can process huge amounts of data locally and can be installed on hardware of different types. These characteristics make fog suitable for time- and location-based applications like internet of things (IoT) devices which can process large amounts of data. In this chapter, the authors present fog data streaming, its architecture, and various applications.

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Trust and Reliability Management in Large-Scale Cloud Computing Environments 66
Punit Gupta, Manipal University Jaipur, India

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Trust is a firm belief over a person or a thing in distributed environment based on its feedback on review based on its performance by others. Similarly, in cloud, trust models play an important role in solving various open challenges in cloud environment. This chapter showcases all such issues that can be solved by trust management techniques. This work discourses various trust management models and its categorization. The work discourses existing work using trust models from the field of grid computing, cloud computing, and web services because all these domains are sub child of each other. The work provides an abstract view over all trust models and find the suitable one for cloud and its future prospects.

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Randhir Kumar, Department of Information Technology, National Institute of Technology, Raipur, India
Rakesh Tripathi, Department of Information Technology, National Institute of Technology, Raipur, India

The future applications of blockchain are expected to serve millions of users. To provide variety of services to the users, using underlying technology has to consider large-scale storage and assessment behind the scene. Most of the current applications of blockchain are working either on simulators or via small blockchain network. However, the storage issue in the real world is unpredictable. To address the issue of large-scale data storage, the authors have introduced the data storage scheme in blockchain (DSSB). The storage model executes behind the blockchain ledger to store large-scale data. In DSSB, they have used hybrid storage model using IPFS and MongoDB(NoSQL) in order to provide efficient storage for large-scale data in blockchain. In this storage model, they have maintained the content-addressed hash of the transactions on blockchain network to ensure provenance. In DSSB, they are storing the original data (large-scale data) into MongoDB and IPFS. The DSSB model not only provides efficient storage of large-scale data but also provides storage size reduction of blockchain ledger.

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Rohit Shukla, Department of Biotechnology and Bioinformatics, Jaypee University of Information Technology, India
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Tiratha Raj Singh, Department of Biotechnology and Bioinformatics and Centre for Excellence in Healthcare technologies and Informatics (CEHTI), Jaypee University of Information Technology, India

The meaningful data extraction from the biological big data or omics data is a remaining challenge in bioinformatics. The deep learning methods, which can be used for the prediction of hidden information from the biological data, are widely used in the industry and academia. The authors have discussed the similarity and differences in the widely utilized models in deep learning studies. They first discussed the basic structure of various models followed by their applications in biological perspective. They have also discussed the suggestions and limitations of deep learning. They expect that this chapter can serve as significant perspective for continuous development of its theory, algorithm, and application in the established bioinformatics domain.

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Swarup Roy Chowdhury, Sabre Corporation, India
Suman Saha, Jaypee University of Information Technology, India

We can name many industries that are still based on the same working practices and business models that they have had for a long time – maybe since they started. Despite the wealth of modern technology now available, public infrastructure, a critical component for the well-being of the society, is still an industry based on the paperwork, letters, emails, manual approvals, and a large amount of guess work. It involves a lot of manual effort and is also error prone. It is really very hard for the stakeholders and end users to get an update on the progress of the project, which impacts them directly or indirectly. The authors intend to develop a groundbreaking blockchain platform that can meet the needs of all the different stakeholders involved in creating and providing a better infrastructure. They plan to automate the entire process by using smart contracts to minimize paperwork for the government officials. This will not only eliminate the errors that can happen during manual execution but will also provide a real-time update to all the stakeholders in making the process more transparent.

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Gautam Kumar, CMR Engineering College, India
Vijender Kumar Solanki, CMR Institute of Technology (Autonomous), Hyderabad, India

The usage of information is essential for data-driven capabilities in artificial intelligence. The data-driven AI techniques lead to several security and privacy concerns. Among various digital techniques, digital rights management is required as one of collaboration scheme that ensures the security and privacy of intellectual rights. Though a number of researchers have proposed various security techniques, none of them have proposed an efficient and effective privacy procedure for digital rights. Recently, blockchain technique is considered as one of the major security methods to ensure a transparent communication among individuals. It can be used by various applications such as industries, marketing, transportation systems, etc. The aim of this chapter is to propose an ensured resource allocation algorithm that validates the scheme by comparing various security measures against previous approaches. Further, the proposed phenomenon ensures the transparency on security and privacy due to its integration.

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Geetanjali Rathee, Jaypee University of Information Technology, India
Dinesh Kumar Saini, Sohar University, Oman

In this chapter, the authors have detailed the need of blockchain technology along with its case studies in different domains. The literature survey is described that describes how blockchain technology is rising. Further, a number of domains where blockchain technology can be applied along with its case studies have been discussed. In addition, the authors have considered the various use cases with their recent issues and how these issues can be resolved using the blockchain technology by proposing some new ideas. A proposed security framework in certain applications using blockchain technology is presented. Finally, the chapter is concluded with future directions.

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Madumidha S., Sri Krishna College of Technology, India
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Venmuhilan B., Sri Krishna College of Technology, India

Internet of things(IoT) is the conception of interfacing the devices to the internet to make life more efficient. It comprises the large amount of data in its network where it fails to assure complete security in the network. Blockchain is a distributed ledger where it mainly focuses on the data security. Every block in the blockchain network is connected to its next block, which prevents threats like large data loss. In the area of agri-food supply chain, where IoT plays a very important role, there occurs data integrity issues or data tampering. This can lead to improper supply chain management, timely shortage of goods, food spoilage, etc. So the traceability of agri-food supply chain is necessary to ensure food safety and to increase the trust between all stakeholders and consumers. Many illegal activities can be prevented, and cold chain monitoring can be achieved by bringing in transparency and traceability.

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Geetanjali Rathee, Jaypee University of Information Technology, India
Hemraj Saini, Jaypee University of Information Technology, India

India is the largest democracy in the world, and in spite of that, it faces various challenges on a daily basis that hinder its growth like corruption and human rights violations. One of the ugliest phases of corruption and political mayhem is visible during the election process where no stone is kept unturned in order to gain power. However, it is the common citizen who suffers most in terms of clarity as well as security when it comes to his/her vote. Blockchain can play a very important role in ensuring that the voters registering their votes are legit and the counting of votes is not manipulated in any way. It is also needed in today's times where the world is available to people in their smart phones to also give them the opportunity to register their votes hassle free via their smart phones without having to worry about the system getting hacked. Therefore, in this chapter, the proposed layout will be based on a smart contract, using Ethereum software to create an e-voting app. In this chapter, the authors have proposed a secure e-voting framework through blockchain mechanism.

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12 Design of Frequency Selective Surface (FSS) Printed Antennas

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Jawaharlal Nehru University, New delhi

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12.1 INTRODUCTION

One of the most desired features in microwave and optical range signal processing systems is spatial filtering. Frequency selective surface (FSS) is also a type of spatial filter, which offer transmission and reflection characteristics by modifying the electromagnetic incident wave striking its surface. FSS are two-dimensional planar structures arranged in a periodic manner. Metallic arrays (apertures or patch), as shown in Figure 12.1, are etched over a dielectric substrate, exhibiting partial or full transmission or reflection of the incident wave at a particular frequency [1]. The amplitude and phase of the transmitted wave vary after striking the FSS when compared to the incident wave. This occurs when the resonance frequency of the FSS matches the plane wave frequency. Therefore, in free space, FSS can either block or pass the incident wave at a particular frequency.

Traditionally, FSS is used as filter. However, the conventional FSS do not provide adequate spatial filtering response and have a narrow bandwidth. Therefore, from last few decades, miniaturization of the FSS and improvement of frequency response for a wider bandwidth have intensively been investigated by the researchers. It is observed that single-layered FSS are inadequate due to the unstable performance when the incident angle of the EM wave varies. To eliminate this problem, multi-layer FSS have been implemented, which provides more flexibility of varying parameters for preferred performance [2–7]. For the compact structures, miniaturized arrays and fractal elements are used these days [8–10]. Embedded FSS [11], metamaterial FSS [12,13], integration of FSS with electromagnetic band gap (EBG) structures [14], reconfigurable FSS [15], and three-dimensional FSS structures [16] are some recent advancements in FSS technology.

Apart from filtering, FSS serve a wide variety of applications according to one's requirements. These variations depend on the way the incident wave is modified. Some of the other major properties of FSS are multi-pole frequency response with

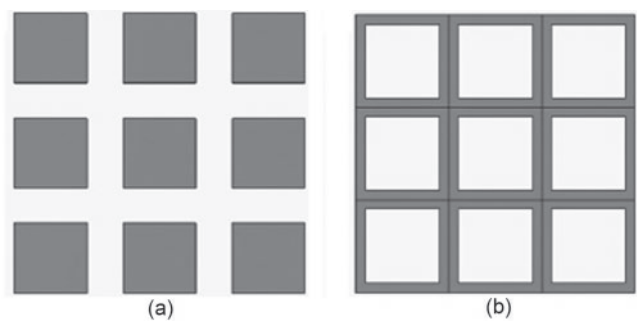

FIGURE 12.1 (a) Patch-type FSS, (b) aperture-type FSS.

huge out-of-band rejections, polarization, absorption, reduced periodicity, angular stability, low profile, low cost, ease of fabrication, and many more. However, attaining all the above features for a modified design is a difficult task for the designers [2]. To utilize the maximum EM properties of FSS, various design modification techniques are used. By varying the geometric parameters, such as dielectric substrate, element shape, and inter-element spacing, and adjusting the size of the unit cell of the FSS, the desired properties of the FSS can be achieved [17,18].

Recently, multiple features of antennas, such as low cost, compact structure, high gain with wide impedance bandwidth, lightweight, and directional beamforming, have attracted the researchers. For conventional antenna structures, it is a challenging task to achieve all the above parameters for an optimal design. FSS help in enhancing most of the aforementioned features of the antennas [19–21]. In the past, FSS were mostly used in reflector antennas [22], including resonant beam splitters, and antenna radomes [23,24]. However, these days, FSS is employed in lens antennas [25], radio frequency identification (RFID) [26], and electromagnetic shielding [27]. The most famous applications of the FSS are reconfigurable antennas, isolation in MIMO antennas, controlling radar cross section (RCS), and antenna radomes.

In this chapter, we present the basic concepts and principle of operation of the FSS. The equivalent circuit analysis is also included. Various types and techniques are discussed on the current state-of-art in the field of FSS. The applications of the FSS related to the antennas are discussed later in this chapter. Finally, the advantages and disadvantages of the FSS with future scope are summarized.

12.2 TYPES OF FSS

In this section, the classification of FSS on the basis of FSS elements, design structure, and applications is discussed, as shown in Figure 12.2.

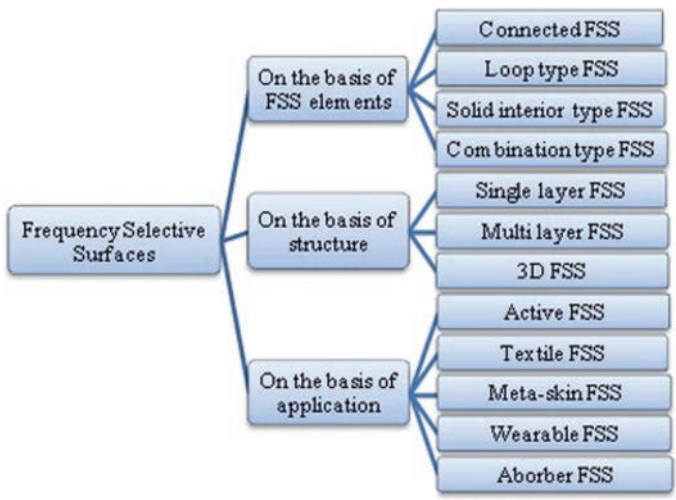

FIGURE 12.2 Classifications of the FSS.

12.2.1 On the Basis of FSS Elements

Four basic types have been classified in this category by Munk [1]. They are center-connected FSS (Group 1), which include dipoles, cross-dipoles, and Jerusalem cross; loop-type FSS (Group 2), which include square-, hexagonal-, and circular-shaped loops; solid-interior-type FSS (Group 3), which are referred to as patch-type elements; and combination-type FSS (Group 4), which are a combination of the aforementioned types. These are shown in Figure 12.3.

Thus, depending upon one's requirements, the elements are selected from these groups. From every FSS element, it is desired to have a stable frequency response at oblique angles. Group 1 consists of dipoles, cross dipoles, etc. However, this group suffers from narrow impedance bandwidth. By proper designing of the elements, the bandwidth can be enhanced with reduced inter-element spacing. Mostly, it is beneficial to select Group 2 (loop family) because it enhances the bandwidth. Resonance is achieved by loop-structured FSS when the perimeter of the loop equals the full wavelength.

Resonance also depends upon the relevant inter-element spacing and effective permittivity of the substrate [1]. By decreasing the inter-element spacing,

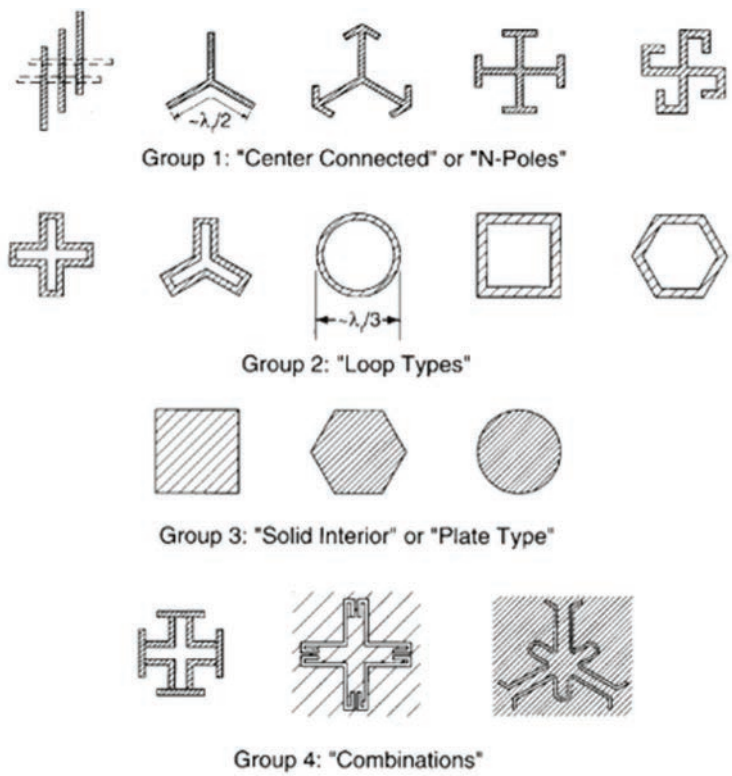

FIGURE 12.3 Basic structures of FSS [1].

bandwidth can be enhanced. However, with a certain decreased distance, inter-element capacitance builds up, dragging the resonance frequency toward lower side. By changing the shape of these structures, a wide variety in the range of bandwidth can be achieved. Therefore, for a desired resonant frequency, the perimeter of the FSS element should be minimized. Solid interior elements of Group 3 are mostly used in combination with other elements. Group 4 contains the combination of all. Generally, when the size of the patch or aperture is in the order of half the wavelength, the desired resonance is achieved. However, this large size leads to an unstable frequency response at different incident angles. To avoid this, miniaturization of the FSS elements is necessary and, for this, fractal FSS or convoluted meander FSS can be used.

12.2.2 On the Basis of Structure

On the basis of structure, FSS is classified into three categories, i.e., single-layer FSS, multilayer FSS, and three-dimensional FSS.

12.2.2.1 Single-Layer FSS

A planar periodic two-dimensional array structure is a single-layer FSS. Single-layer FSS with filtering characteristics can be used in a wide variety of applications. But due to the restricted space in a unit cell, their potential use is limited. Large element size and wide inter-element spacing result in degraded performance and realizing these surfaces is a difficult task [28]. Therefore, the role of miniaturized FSS is growing for a stable frequency response at different incident angles. These miniaturized elements are in high demand due to its ability to separate grating lobes from the desired band [29]. FSS elements, such as loops, patches, and fractal, meander, multipole and convoluted structures, help in the achievement of miniaturized FSS. Single-layer FSS are easy to design and fabricate, have low cost, and can easily be integrated with other structures, such as antennas and radars.

12.2.2.2 Multilayer FSS

Narrow operating bandwidth is one of the main issues faced by FSS, which is challenging to improve with a single-layer FSS. It is observed that even with the implementation of fractal elements and convoluted meander structures, the bandwidth performance of the FSS is narrow. Apparently, these techniques are best suitable for reducing the size and profile of FSS. The separation of individual FSS' frequency bands is possible with wider transmission/reflection bands and also faster roll-off in some of the applications. However, frequency response declines eventually on both sides of the resonant frequency in the case of single-layer FSS, making them inappropriate for such critical applications. This issue can be resolved either by making use of complex geometry for resonation or by constructing multiple layers of FSS [30]. Complex geometries typically are not easy to design and produce multiple bands instead and, moreover, widen the overall bandwidth without improving the bandwidth of the individual resonant band. Consequently, for enhancing the bandwidth of individual resonance, multilayer FSS become a better option. Due to the discontinuity in between the FSS layers, multilayer FSS achieve a wideband response at a

certain frequency. Better frequency response and faster roll-off can be achieved by higher-order passband FSS when compared to single-layer FSS. However, it requires the thickness of the substrate to be approximately of the order $\lambda/4$, which is not appreciable these days. Moreover, non-resonant array elements largely increase the FSS size; consequently, a trade-off is certain. Therefore, the more are the FSS layers, the better is the roll-off and the broader is the bandwidth, but this results in a bulky and complex system.

12.2.2.3 3-Dimensional FSS

Applications, such as terahertz sensing, communication system, and radar cross section reduction, demand a broader bandwidth with a fast roll-off. Conventional FSS structures are easy to design and fabricate; however, these single-layer or multilayer FSS are unable to provide the aforementioned characteristics efficiently and therefore are not potentially suitable for various applications [31]. To overcome these limitations, a new and unique class of FSS has been introduced. These are the three-dimensional FSS [32]. For the realization of the 3D FSS, the same methods that are used by 2D FSS are applied. The only difference is that for the deduction of 3D structure, additional cavities or structures are etched over a 2D FSS. Vias, metallic lines, metal plate bits, etc., can be used in the inter-structure additions. These 3D FSS structures provide better roll-off, broad bandwidth, flexibility to the design, and angular stability due to surplus choices in their designing. For unit cell miniaturization and better angular stability, 3D FSS was implemented and then fabricated [33], as shown in Figure 12.4a. Four layers of substrate were stacked together, over which four-legged loop elements were printed, and via holes were created on this multilayer PCB board. It was noticed that from 0° to 60°, this FSS structure had a stable response at 6.4 GHz and shown a good agreement in between the simulated result and measured result.

In the literature, various methods have been proposed to describe the behavior of the FSS. A 3D band-pass filter had been implemented with high frequency selectivity [34], as shown in Figure 12.4b. Each individual unit cell contained multiple resonators, which permits multiple number of transmission poles and zeros. Open-circuited and short-circuited resonators help in the production of transmission poles in the passband, whereas transmission zeros were produced by the resonant frequencies of the

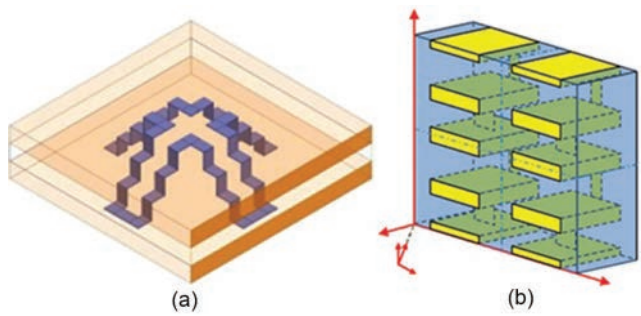

FIGURE 12.4 Unit cell structure of 3D FSS [33,34].

other short-circuited resonator. Here, a three-layered FSS structure was made, which gives an angular stability from 0° to 50°.

12.2.3 On the Basis of Application

12.2.3.1 Active FSS

Conventional FSS elements are passive in nature and, once fabricated, become inflexible. In order to achieve the design flexibility for better performance, a new class of FSS is introduced, which is known as active frequency selective surfaces (AFSS) [35]. Active elements such as PIN diodes, Schottky diodes, and varactor diodes are used for the electromagnetic beam switching and work in two states, i.e., ON or OFF. These are mostly used in reconfigurable antennas for frequency or pattern reconfiguration, and a detailed discussion on this is performed later in this chapter.

12.2.3.2 Textile FSS

Textile FSS are the new emerging class of FSS. Having a unique feature of integrating with clothes for off-body and on-body communications [36], these structures are printed over a paper or cloth by lithographic processes, screen printing, stamping, and inkjet printing. Smoothness, flexibility, higher strength-to-weight ratio, and lightweight are some benefits offered by textile structures.

12.2.3.3 Meta-Skin FSS

Recent trends in flexible and stretchable electronic devices have made it feasible to create liquid metal FSS. With the introduction of this technology, the shape, size, and characteristics of a material changes with the injection of liquid metal into an elastomeric substrate, making it an active element, which has been used in the reconfigurable antenna applications lately. Other applications of these meta-skin FSS are artificial skin sensors, probes, electrical interconnects, etc. Inside an elastomer, an array of liquid metal split ring resonators are enclosed [37]. With the injection of the liquid, wide tuning range and high FSS performance were obtained.

12.2.3.4 Wearable FSS

Owing to the features such as wide impedance bandwidth and flexibility, wearable FSS are manufactured for the applications such as heart rate monitoring and communication. As per the requirement, these devices can be placed at any part of the body. In [38], a heart rate monitor based on FSS was designed with attached photodiodes and a LED. This device was made to wear on the finger.

12.2.3.5 Absorber FSS

Devices such as missiles, airplane, radars, and airplanes have a high tendency to get detected. To eliminate the possibility of being caught, highly efficient broadband absorbers are required. Generally, FSS provide good reflection characteristics in its stopband. However, with the addition of some absorbing elements, these strong

backward waves can be reduced and get absorbed in the stopband. These types of FSS are absorber FSS and are especially designed to be undetected by radars [39].

12.3 PRINCIPAL OF OPERATION

12.3.1 FSS Operational Theory

The operational theory of FSS unit cells is explained as follows [1]: When the EM waves are incident on the FSS, the current inside the FSS unit cells gets excited. The amount of coupling decides the amplitude and phase of the current generated. These produced currents serve as EM source and hence produce added scattered fields. These fields are then combined with the incident fields, thereby making the resultant fields. By proper designing of the FSS elements, the required field and current characteristics can be attained, as shown in Figure 12.5 [40]. Therefore, for example, elements such as patch type exhibit stopband characteristics and slot type exhibit passband characteristics.

12.3.2 Periodic Structure (FSS)

Periodic FSS structures are designed on the basis of Floquet theorem. It says that when a plane wave of infinite length hits the surface of an infinite planar periodic structure, then the same amount of current distribution and field is attained in every individual element present in that periodic structure. However, due to the inter-element spacing and phase of the incident EM wave, phase shift occurs.

A planar periodic infinite FSS configuration is shown in Figure 12.6. Here, identical inter-element spacing is considered in x-axis and z-axis ($D_x = D_z$). Assuming that the incoming incident wave is moving in a particular direction of â, the equation is given by [41] eq. (12.1):

$$\hat{a} = \hat{x}\,a_x + \hat{y}\,a_y + \hat{z}\,a_z \tag{12.1}$$

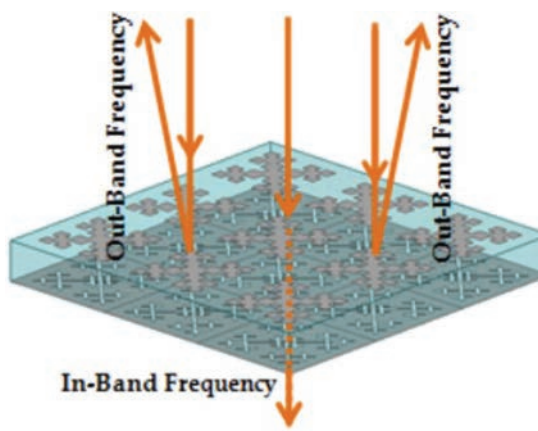

FIGURE 12.5 Operation of the FSS [40],

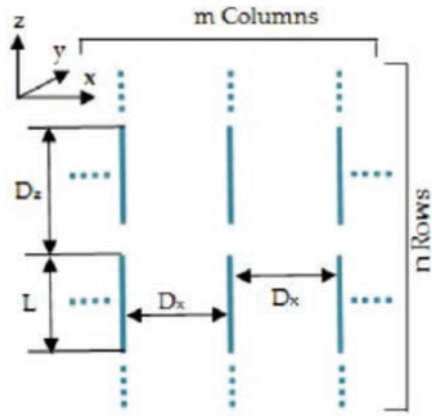

FIGURE 12.6 Periodic structure with identical inter-element spacing [41],

The current distribution inside all FSS unit cells remains identical; however, the phase varies with the phase of the currents [29], as shown in eq. (12.2).

$$I_{mn} = I_{oo} e^{-j\beta m D_x a_x} e^{-j\beta n D_z a_z} \tag{12.2}$$

By Ohm's law, the voltage of a reference unit cell is given in eq. (12.3).

$$V_{oo} = \left[Z_L + \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} Z_{0,mn} e^{-j\beta m D_x a_x} e^{-j\beta n D_z a_z} \right] I_{oo} \tag{12.3}$$

The impedance of the scanning array is given by eq. (12.4).

$$Z_L = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} Z_{0,mn} e^{-j\beta m D_x a_x} e^{-j\beta n D_z a_z} \tag{12.4}$$

12.4 EQUIVALENT CIRCUIT MODEL

To understand the physical background of the designed FSS geometry, equivalent circuits are created. There are various conventional structures for which the equivalent circuit model is studied.

12.4.1 Grating Strip

The basic FSS structures are the metallic strip structures. The analysis of the metallic strip FSS is shown in Figure 12.7. If the E-field is aligned in the direction of the metallic strip, inductive strip grating filter is deduced, and if the E-field is perpendicular to the strips, then capacitive strip grating filter is deduced. For modeling the arrays at oblique angles, there is a requirement to model in transverse electric (TE) and transverse magnetic (TM) incidence.

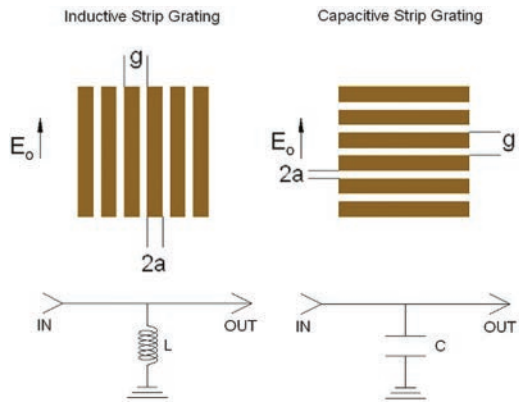

FIGURE 12.7 Strip grating filter with equivalent circuit [42].

When the E-field is polarized parallel to the incident plane, TM incidence occurs, i.e., $\theta = 0°$, and when the E-field is perpendicular to the incident plane, TE incidence occurs, i.e., $\Phi = 0°$. The resonance frequency is given by eq. (12.5):

$$w_r^2 LC = 1 \tag{12.5}$$

The normalized shunt inductance of the inductive strip filter [43] is given by:

$$\frac{w_r C}{Y_o} = 4\frac{d}{p}\sec\theta\left[\frac{p}{\lambda}\ln\left(\csc\left(\frac{\pi g}{2p}\right)\right) + G(p,w,\lambda,\theta)\right](\varepsilon_{\text{eff}}) \tag{12.6}$$

The normalized shunt susceptance of the capacitive strip filter [43] is given by:

$$\frac{w_r L}{Z_o} = \frac{d}{p}\cos\theta\left[\frac{p}{\lambda}\ln\left(\operatorname{cosec}\left(\frac{\pi w}{2p}\right)\right) + G(p,w,\lambda,\theta)\right] \tag{12.7}$$

To avoid grating lobes,

$$p(1+\sin\theta) < \lambda \tag{12.8}$$

The correction factor is given by eq. (12.9):

$$G(p,w,\lambda,\theta) = \frac{\left(1-\beta^2\right)\left[\left(1-\frac{\beta^2}{4}\right)(A_+ + A_-) + 4\beta^2 A_+ A_-\right]}{\left(1-\frac{\beta^2}{4}\right) + \beta^2\left(1+\frac{\beta^2}{2}-\frac{\beta^4}{8}\right)(A_+ + A_-) + 2\beta^6 A_+ A_-} \tag{12.9}$$

where

$$A_{\pm} = \frac{1}{\left[1 \pm \frac{2p\sin\theta}{\lambda} - \left(\frac{p\cos\theta}{\lambda}\right)^2\right]^{1/2}} - 1 \tag{12.10}$$

$$\beta = \frac{\sin \pi w}{2p} \tag{12.11}$$

Here, d, g, p, and w are the length of the unit cell, gap in between two FSS unit cells, periodicity of the FSS, and angular resonant frequency of the unit cell, respectively. θ is the angle of incidence of the EM wave with which it strikes the surface of FSS, and λ is the resonant wavelength.

12.4.2 Square Loop

The frequency characteristics of square loop FSS have a lower-frequency transmission band with a single reflection band which can be presented in the form of capacitance and inductance using an equivalent circuit. In the FSS model, the array is represented by a single series LC circuit shunted across a transmission line of impedance Z_o as shown in Figure 12.8b, where Z_o is the characteristic impedance of free space. The normalized shunt inductive reactance expression of the square-loop FSS is given by [44] eq. (12.12):

$$X_{\text{TE}} = F(p, 2w, \lambda) \tag{12.12}$$

$$X_{\text{TE}} = \frac{w_r L}{Z_o} = p\frac{\cos\theta}{\lambda}\left[\ln\left(\cos ec\left(\frac{2\pi w}{2p}\right)\right) + G(p, w, \lambda, \theta)\right] \tag{12.13}$$

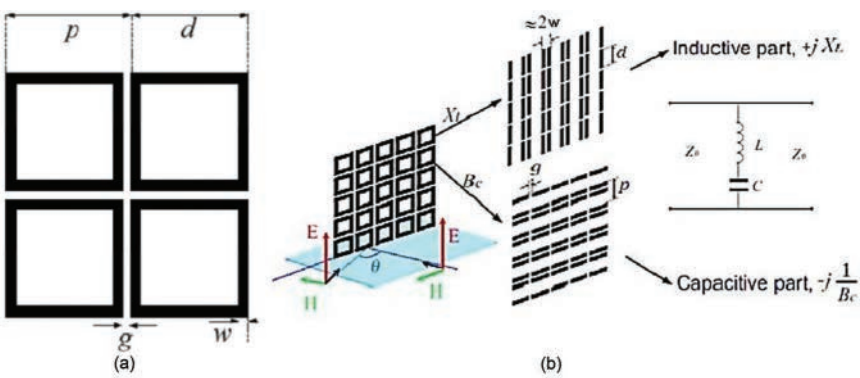

FIGURE 12.8 Square-loop FSS and its equivalent circuit [42].

The normalized shunt susceptance expression of the capacitive strip grating is given by

$$B_{\mathrm{TE}} = \frac{w_r c}{Y_o} = 4p\frac{\sec\theta}{\lambda}\left[\ln\left(\cos\mathrm{ec}\left(\frac{\pi g}{2p}\right)\right) + G(p,w,\lambda,\theta)\right] \tag{12.14}$$

Therefore, the inductive reactance is given by

$$\frac{X_f}{Z_o} = \frac{1}{\sqrt{\varepsilon_e}}\frac{d}{p}F(p,2w,\lambda) \tag{12.15}$$

The capacitive reactance is given by

$$B_f Z_o = \frac{4d}{p}\sqrt{\varepsilon_e}F(p,g,\lambda) \tag{12.16}$$

The net permittivity is given by

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\cdot\frac{1}{\sqrt{1+\frac{12t}{w}}} \tag{12.17}$$

where t and ε_r are the thickness and relative permittivity of the substrate.

12.4.3 Jerusalem Cross

The structure of a J-cross is shown in Figure 12.9.

The inductive reactance XL of width w is given by eq. (12.18):

$$\frac{w_r L}{Z_o} = F(p,w,\lambda,\varphi) = p\frac{\cos\varphi}{\lambda}\left[\ln\left(\cos\mathrm{ec}\left(\frac{\pi w}{2p}\right)\right) + G(p,w,\lambda,\theta)\right] \tag{12.18}$$

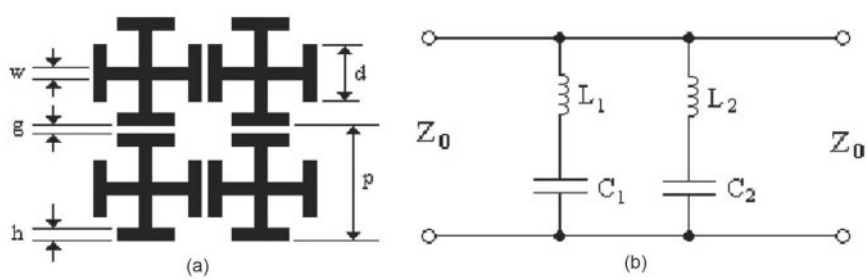

FIGURE 12.9 Jerusalem cross and its equivalent circuit [42].

The susceptance $B = B_d + B_g$, where B_g is the capacitance between the horizontal arms, with a spacing g, and is reduced by a factor of d/p

$$B_g = \frac{4d}{p} F(p, g, \lambda) \tag{12.19}$$

The susceptance B_g is between the vertical capacitors spaced by $(p - d)$, and it is given as

$$B_d = \frac{4(2h + g)}{p} F(p, p - d, \lambda) \tag{12.20}$$

The inductive reactance XL is given as:

$$\frac{X_{L2}}{Z_o} = \frac{d}{p}.F(p, 2w, \lambda, \theta) \tag{12.21}$$

12.5 APPLICATIONS OF FSS

There is a wide range of applications that FSS can provide in the field of antennas. They are as follows.

12.5.1 Enhancement of the Gain and Bandwidth of the Antenna Systems

In the fields such as communication, high-resolution medical imaging, military, and ground-penetrating radars (GPR) [45], antennas with high gain and narrow beam are required. Conventional antennas provide narrow bandwidth and low gain. Therefore, intensive research has been done by the researchers on the improvement of the antenna design. FSS, when integrated with antennas, not only provide filtering characteristics but also help in the enhancement of gain and impedance bandwidth [46–49]. Due to the reflections in between the FSS layer and the antenna, the gain gets enhanced. Moreover, FSS show very less variation in the impedance bandwidth of the antenna and provide its own impedance bandwidth; therefore, the impedance bandwidth gets enhanced.

One way to position a FSS is below the antenna as a back-reflector. The FSS is used as a back-reflector in order to extend the usable frequency range. The FSS provides additional impedance bandwidth, resulting in multi-band characteristics [50]. The back-reflector helps in the enhancement of the gain of the antenna as well, without disturbing the impedance bandwidth of the antennas. These reflectors have very less effect on the impedance bandwidth of the antennas.

In Figure 12.10, the antenna is placed at a distance L from the FSS layers. The FSS layer provide reflection at a particular frequency. ϕT is the reflection phase from the reference plane T; ϕS is the back and forth reflections in between the antenna and FSS; and ϕR is the overall reflected phase from the FSS layer.

$$\phi_T = \phi_R + \phi_S \tag{12.22}$$

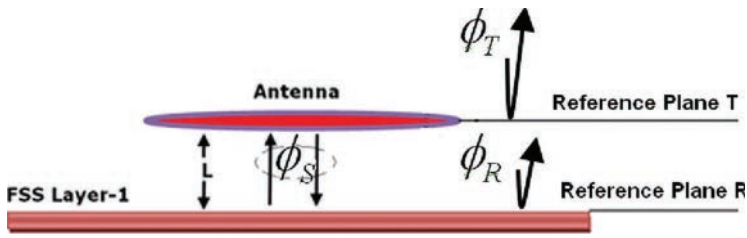

FIGURE 12.10 FSS as a back-reflector.

When an incidence wave travels toward the FSS layer, it is reflected back and gets added to the wave radiating directly from the antenna. If both the waves are in phase, they create a constructive inference, resulting in enhanced gain, and hence provide the maximum gain. However, these are suitable for small frequency bands. To enhance the front-to-back ratio with enhanced gain, the FSS was sandwiched in between the connected dipole antenna array and the ground plane in [51]. A dual-polarized radiator was mounted over a FSS back-reflector surface for UWB, and it exhibited an enhanced average gain of 9.5 dBi [52].

To obtain flattened gain over a given impedance bandwidth, the multilayer FSS are useful. A two-layer FSS was used below the antenna [53], as shown in Figure 12.11. Of the two layers of FSS used, FSS layer 1 reflects at lower frequency band and FSS layer 2 reflects at higher frequency band for a wide impedance bandwidth with stable average gain over the whole UWB frequency range. This antenna system provides an impedance bandwidth of 122% over the entire UWB frequency range with an average gain of 7.8 dBi, as shown in Figure 12.13a. Similarly, to obtain more gain, a four-layer FSS was used below the antenna in [54], as shown in Figure 12.12. It was observed that due to more reflection in between the FSS layers and the antenna, the gain gets more enhanced. The gain gets enhanced from 4 to 9.3 dBi due to the FSS layer underneath. A stable gain variation is obtained in between 3 and 15 GHz in the limits of ±0.5 dBi. The bandwidth of the UWB antenna was 145% with FSS and 149% without FSS, which is well under the limits, as shown in Figure 12.13b.

Conformal FSS is a trending topic for the researchers these days, as it can be molded into any shape and size [55,56]. To enhance the radiation diversity of hybrid monopole dielectric resonator antennas, a conformal FSS was used in [57], as shown in Figure 12.14a. FSS as a parabolic reflector was placed at half-wavelength distance. It was observed that the impedance bandwidth gets enhanced by approximately 27% in 4–6 GHz band, with a gain enhancement of 5–6 dBi over this band. A stable gain was obtained around 9.5 dBi with a variation of ±1.5 dB. Moreover, an omnidirectional radiation was maintained in this FSS at 7–9 GHz.

The classical way to position the FSS is as a superstrate. To enhance the gain, several techniques have been proposed. An X-slot was etched in a radiating dielectric resonator with FSS as a superstrate layer to resonate at MMW range [58], as shown in Figure 12.14b, and in [59], a FSS superstrate was embedded over an electromagnetic band gap (EBG) antenna. The impedance bandwidth gets enhanced by 145% with the

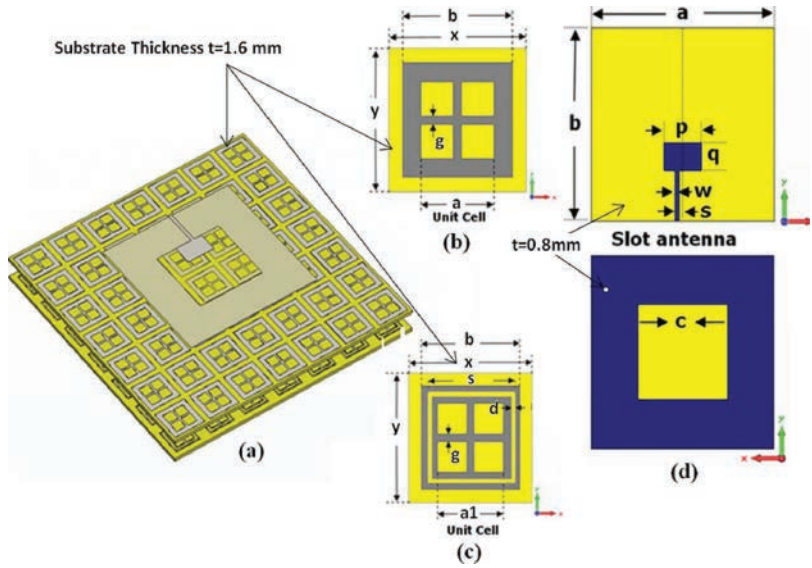

FIGURE 12.11 (a) Slot antenna with a FSS reflector: (b) FSS layer 1. (c) FSS layer 2. (d) UWB slot antenna [53].

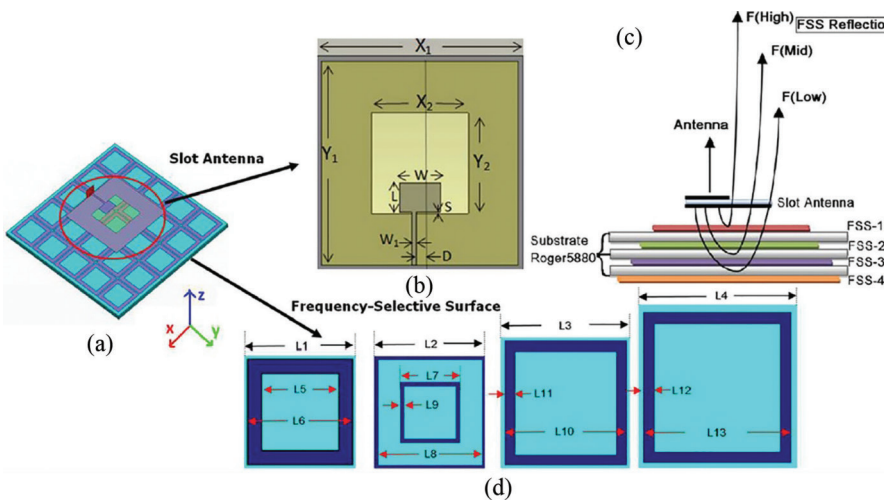

FIGURE 12.12 (a) UWB slot antenna with FSS: (b) slot antenna; (c) reflection mechanism; (d) different layers of FSS [54].

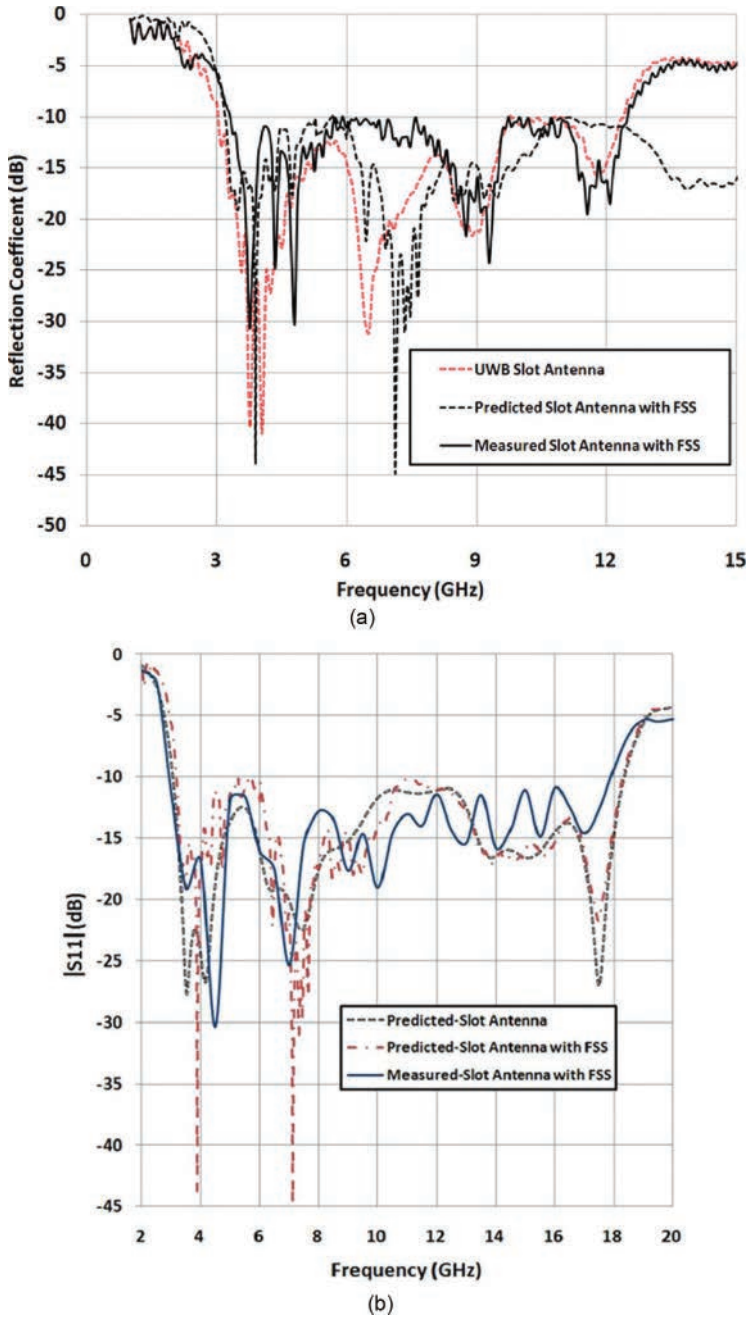

FIGURE 12.13 Impedance bandwidth with and without the use of FSS, [53] and [54].

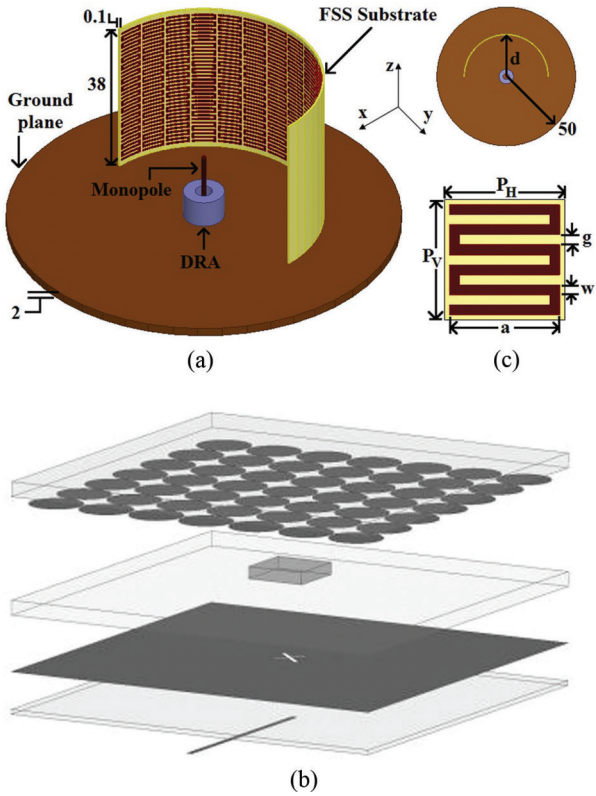

FIGURE 12.14 (a) Conformal FSS integrated with monopole DRA; (b) FSS layer as a superstrate over a DRA [57,58].

peak gain of 22.5. Apart from enhancing the gain, FSS help in the elimination of the unwanted radiation emitted from the feed line [60]. Therefore, it is evident that FSS help in the enhancement of the gain and bandwidth of the antenna.

12.5.2 Isolation in MIMO Antennas

For a high data rate with fixed power and bandwidth, multiple-input multiple-output (MIMO) technology has been chosen in the fourth-generation communication systems over its conventional counterpart, i.e., single-input single-output system. MIMO system solves the problem of multi-path fading, which tends to degrade the performance of wireless communication links. By sending multiple data streams, the data rate and the reliability of the system increase rapidly. Multiple antenna elements are integrated together in a MIMO system to provide a higher data throughput at the same operating band. The designing of an MIMO antenna is a challenging task, as the antenna elements are placed in very close proximity to each other. Due to this, the port coupling and field coupling increase. This affects the efficiency and channel capacity of the antenna system. Therefore, there is a requirement of high

port isolation and low correlation level [61–64]. It is desirable to have TARC <0 dB, ECC <0.5, and CCL <0.5 bits/s/Hz for the acceptable performance of a MIMO system [65].

To obtain a wideband structure in U- and V-bands, the metal was printed on both sides of the RO4003 substrate [66]. On top of the substrate, a Jerusalem cross was imprinted, whereas at the bottom, a FAN shape was imprinted. Every element of the substrate gives its own resonance. It was observed that the J-cross resonates at 48 GHz and FAN resonates at 60 GHz, when simulated separately. Due to its better performance, this structure was used for mutual coupling reduction in a 60-GHz MIMO dielectric resonator antenna [67], as shown in Figure 12.15. Two slots of different size were etched over the ground plane, and a FSS wall was built in between the MIMO antenna elements. The slots minimize the surface current, and the wall provides the isolation in between two MIMO antenna elements by decreasing the free space radiation. This MIMO antenna provides a stable response from 57 to 63 GHz, and the gain was enhanced by 1.5 dB in comparison with the reference antenna.

It was observed that with the implementation of the slots and FSS wall, an isolation of about −30 dB was achieved. An ECC of less than 5e−6 was obtained, which implies good MIMO antenna performance. Similarly, a graphene-based FSS was used for mutual coupling reduction in dense plasmonic nano-antenna arrays for multi-band [68]. In this MIMO system, an ECC of less than 0.01 was obtained at 1.1–1.7 THz frequency with a high isolation of −25 dB. In [69], a FSS structure with Y-shaped slots was embedded over the four-element MIMO antenna to achieve a good isolation of 20 dB. A silicon substrate was used for the UWB MIMO antenna [70]. Six FSS elements were placed in between the antennas for obtaining a good isolation of about −16 dB. In [71], a dual-passband FSS was designed at 2–3.4 GHz and 5.5–6.8 GHz frequency bands. The FSS had two layers and was designed to improve the scattering performance and radiation of the antenna. This structure helps in the enhancement of the bandwidth by 31.4% and 50% at lower frequency band and higher frequency band, respectively. The gain also gets enhanced by 2.53 and 1.86 dB at 5.8 and 6.4 GHz, respectively.

The correlation coefficient deals with the individual radiation pattern of the MIMO antenna elements and measures the degree of correlation that all the radiation patterns will add along the propagation channel in a given environment. When the

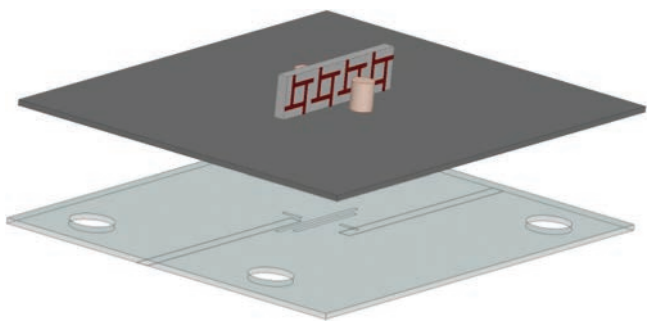

FIGURE 12.15 FSS is placed in between the two elements of DRA MIMO antenna [67].

antenna elements are placed in close proximity to each other, the radiation patterns overlap; to avoid this, a practical reflective surface (PRS), which is a FSS, was used in a two-element Fabry–Perot cavity MIMO antenna [72], as shown Figure 12.16. To reduce the height of the cavity to $\lambda/4$, the reflection phase of the wave should be 0 (or 2Π). To achieve this, the PRS was made of a composite structure. On one side of the substrate, an inductive layer was embedded, and on the other side, a capacitive layer was embedded [73]. At the top layer, unit cells are identical and provide propagation in boresight direction as the wave combines with the same phase; however, at the bottom, there is a gradual variation in the dimension of the FSS unit cells. Therefore, when the wave combines with a different phase, the wave tilts in the same axis. Therefore, when the wave propagates through this MIMO antenna, due to the unevenly distributed FSS unit cell structure, the wave tilts and the correlation between the two field patterns reduces, leading to a rapid decrease in the correlation coefficient. It was observed that a change in the inductive surface gave a more tilt to the wave. It was observed that more than 95% of the correlation value was improved at 5.25 GHz.

Further, a four-element DRA MIMO antenna also used this technique for the decorrelation of the fields [74], as shown in Figure 12.17a and b. Two DR elements were placed above the substrate, and the other two elements were placed below the

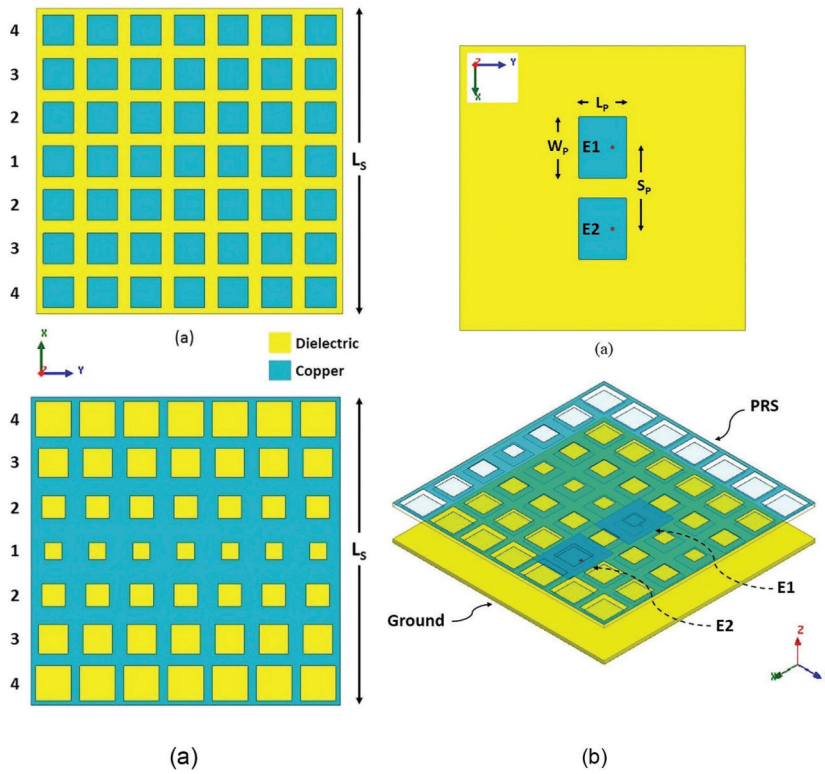

FIGURE 12.16 (a) FSS structure; (b) FSS with two-element MIMO antenna [72].

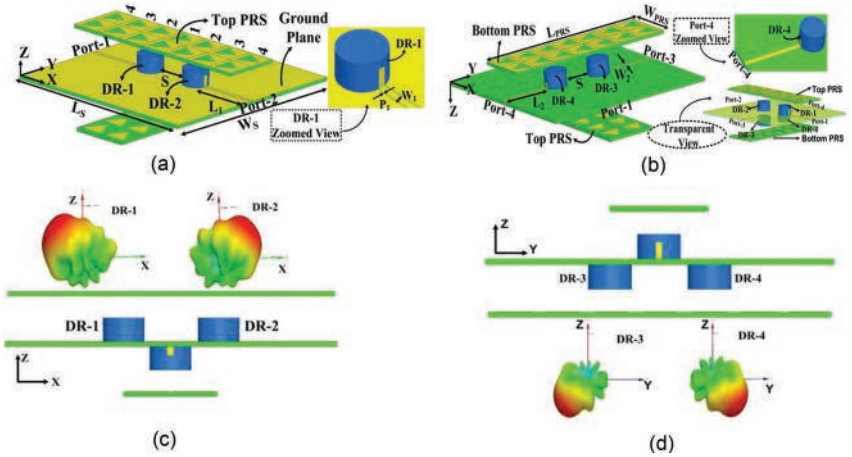

FIGURE 12.17 DRA MIMO antenna with two-layer FSS: (a) top view, (b) bottom view, (c), (d) radiation patterns at 5.25 GHz [74].

substrate, orthogonally. Two triangular-shaped FSS phase gradient layers were positioned as the superstrate to all the four DRA elements. It was observed that without using a PRS layer, the four-element MIMO antenna provided an ECC value of 0.31, gain of 4.9 dB, and efficiency of 89%. However, with the use of the PRS layer, a very low value of ECC of up to 0.1 was obtained, with a gain and efficiency of 7.2 dB and 81%, respectively. It was observed that it provided better isolation in between the antenna ports, which was equal to 20 dB.

12.5.3 Spatial Filtering

In some applications, a specific band of frequency is required where the highly directional beam is focused by the antennas. For example, for designing an ultra-wideband (UWB) antenna, some frequency ranges such as WiMAX (3.3–3.6 GHz), WLAN (5–6 GHz), and X-band satellite communication band (7.2–8.4 GHz), which are extensively used in various applications, create interference problems [75–77]. There is a need to stop these frequencies from interfering. Since these particular bands are difficult to suppress by conventional antennas, for such applications, there is a requirement of spatial filters. FSS is called spatial filter, since it modifies the wave incident on its surface by transmitting or reflecting the wave partially or fully through the surface. Spatial filtering is categorized as low-pass, high-pass, band-pass, and band-stop filtering. In low-pass FSS filters, lower frequency ranges get passed while eradicating the higher frequency band. However, for designing high-pass FSS filters, Babinet's principle is applied, since the high-pass FSS filter operation is complementary to the low-pass FSS filter operation. Similar is the case with band-pass and band-stop filtering. Band-pass filter permits a specific frequency band to pass, while band-stop filter rejects one. Size, shape, and material of the substrate and array elements are very important parameters in the designing of the FSS filters. For a required operating band, metallic patches or apertures are embedded on the

FSS substrates. Metallic patch elements act as a band-stop filter [75], whereas aperture elements act as a band-pass filter [78].

In the literature, a wide range of band-pass and band-stop structures have been presented. Single, dual, and multiple frequency bands are obtained using different shapes and sizes of the FSS. The main motive of all the researchers is to make a miniaturized structure for stable frequency response and better angular stability. To stop WLAN frequency band to pass through the FSS, a modified swastika-shaped unit cell was designed [75], as shown in Figure 12.18a and b. The structure was etched over a FR4 substrate with 35° rotation of the arms. This FSS structure provided an impedance bandwidth of 400 MHz with a stable TE and TM frequency response. For dual-band-stop characteristics [76], a modified structure was made. In this, a metallic square patch was etched at the center of the FSS structure and L-shaped arms were attached to it with a separation of 45°.

The L-shaped arms permit dual-band-stop characteristics; i.e., vertical arms have a control on lower resonating frequency (8.47 GHz), while horizontal arms have a grip over upper resonating frequency (10.45 GHz), as shown in Figure 12.18c and d.

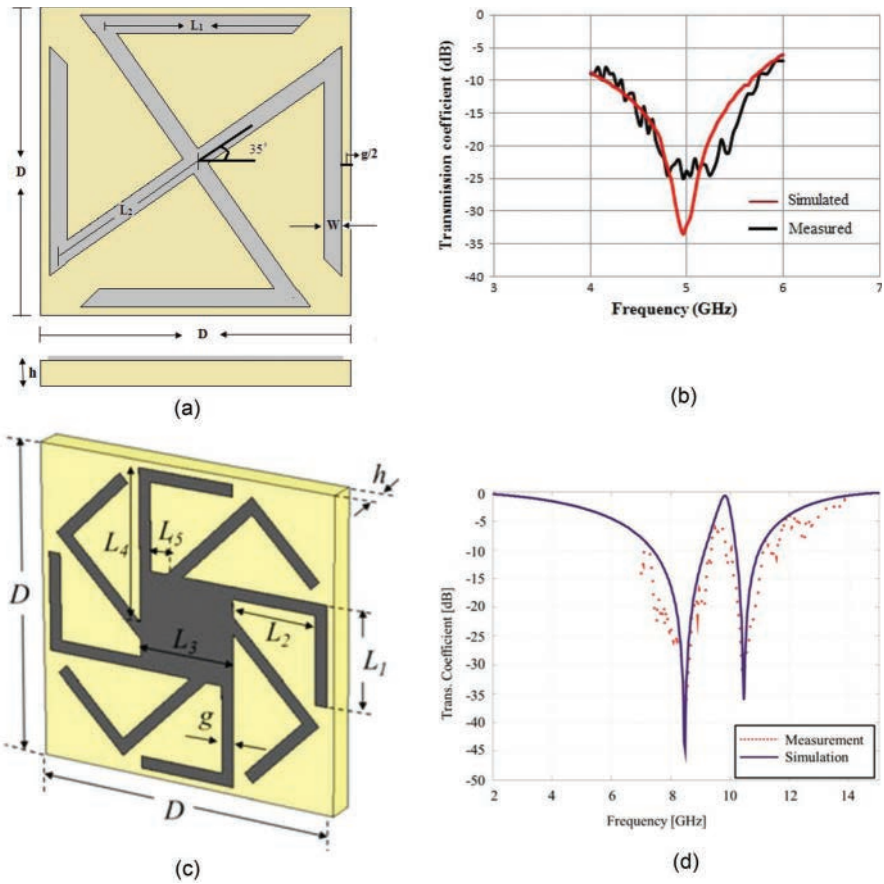

FIGURE 12.18 (a, c) Unit cell of FSS structure and (b, d) its transmission characteristics, respectively [75,76].

Similarly, for multiple bands, structure modifications are required. To obtain triple-band-stop characteristics, two square loops were embedded on both sides of a FR4 substrate; moreover, at the backside of the substrate, two folded metallic arms were etched with the square loop to obtain the triple-notch band at WiMAX, WLAN, and X-band [77], as shown in Figure 12.19a and b. A comparison of different types of FSS is made in Table 12.1. It is observed from this table that with the miniaturization of the size of FSS, the angular stability increases, which results in better frequency response.

Therefore, these structures can be implemented with the antennas for filtering purposes.

12.5.4 FSS for Reconfiguration of the Antennas

The wireless communication system has become a very fast and dynamic growing sector in the past few years. There is a requirement to make new antennas that can adapt themselves to the increasing demands of the new systems easily. Therefore, reconfigurable antennas (RA) are the smart choice as they can provide better performance to support the emerging applications [81–85]. Reconfiguration leads to the change in the current distribution inside the radiating elements, i.e., change in the electromagnetic field distribution, which results in the change in the radiation properties of the antenna and impedance as well. Nowadays, these reconfigurable antennas are used in wide varieties of applications such as satellite networks, tactical radio relay systems, cordless systems, public security systems, and military applications. However, traditional RA, such as phased arrays, need a large number of feedback networks and phase shifters, which makes the whole system costly, bulky,

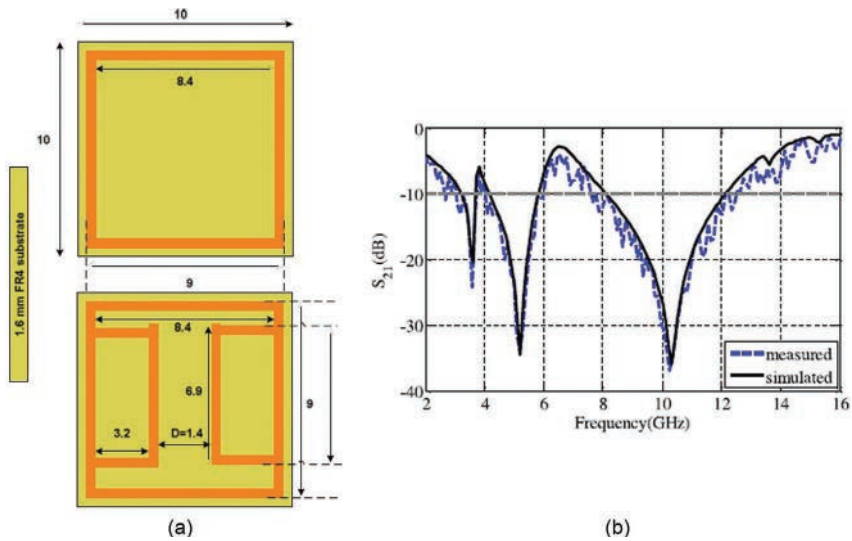

FIGURE 12.19 (a) Unit cell of FSS structure and (b) its transmission characteristics, respectively [77].

TABLE 12.1
Comparison of Various FSS Techniques

Reference	Unit Cell Dimension (mm)	Resonant Frequency (GHz)	No. of Operating Bands	Frequency Bands	Angular Stability	Rejection Bandwidth
[75]	7×7×1.6	5	1	WLAN	0°–60°	400 MHz
[76]	8.8×8.8×0.762	8.47, 10.45	2	Wideband X-band	0°–60°	–
[77]	10×10×1.6	3.5, 5.2, 10.2	3	WLAN, WiMAX, X-band	0°–30°	0.5 GHz (3.1–3.7), 1.9 GHz (4.1–6), 4.1 GHz (8–12.1)
[79]	56×56×40	1.86, 3.10	2	L- and S-bands	0°–45°	660 MHz
[80]	10×10×1.6	3.5, 4.5, 8.4	2	Wideband operation	0°–30°	1 GHz (3, 4) 11.4 GHz (4.6–16)

complex, and more power-consuming [86]. Therefore, recently, a new technique of beam-switching antennas has been introduced, which incorporates reconfigurable FSS [87]. Reconfigurable FSS are achieved by tuning and switching the response of the FSS by integrating active controlling devices. Reconfiguration can be performed on the basis of frequency response [88], radiation pattern [89], and polarization [90].

Active elements such as PIN diodes, Schottky diodes, and varactor diodes are used for the electromagnetic beam switching. These allow the rapid switching in between the ON and OFF states of the FSS depending upon the external DC bias source. When the PIN diode is in ON state, the FSS becomes a source of transmission for the incident waves generated from the dipole antenna, whereas when PIN diode is in OFF state, a high reflection of the incident waves occurs, as FSS unit cells have a high reflection coefficient [91–93]. In [94], a dipole antenna was located at the center of a cylindrical AFSS. The AFSS comprised of ten circular metallic loops per column. A metallic strip was imprinted along the ring loops. PIN diodes were positioned on this metallic line. When the diode was in OFF state, a passband was generated at 2.8 GHz, while two stopbands were also generated due to the working of both the metallic strips and ring loops. However, when the bias was applied, the stopband remained due to the ring loops. The parasitic elements of diode caused the first stopband to disappear and generated a passband at 1.8 GHz. This is shown in Figure 12.20. The maximum gain of 9.2 dB was obtained at 1.8 GHz. In [95], an omnidirectional antenna was surrounded by a cylindrical AFSS. Each AFSS unit cell comprises of discontinuous split-ring resonator (SRR) cross-shape structure with four active elements. The maximum gain of 8.1 dB was obtained at 2.1 GHz. Similarly, for dual-band frequency reconfiguration, a cylindrical AFSS was proposed in [96]. PIN diodes were used for switching the AFSS between ON and

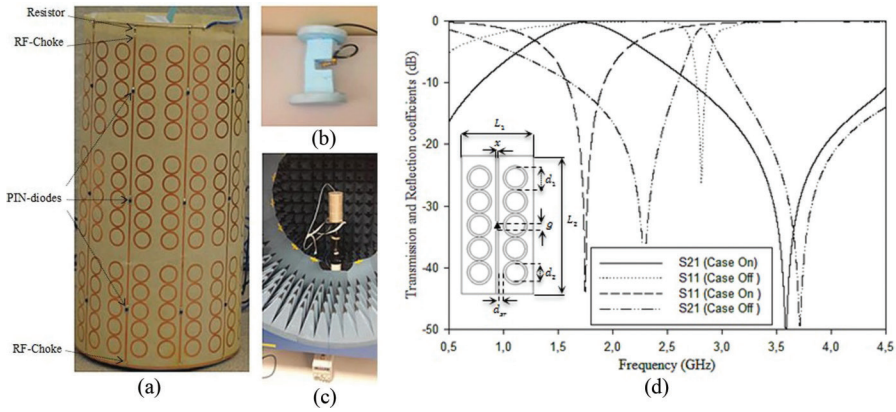

FIGURE 12.20 (a–c) AFSS embedded over antenna; (d) frequency response of AFSS [94].

OFF states. By controlling the DC bias voltage applied to different PIN diodes, the beam sweeps in the whole azimuthal plane. This antenna operated at 2.5 and 5.3 GHz when all the diodes were OFF, whereas when the diodes were ON, a transmission level below −15 dB between 2 and 6 GHz was achieved.

PIN diodes, metallic switches, etc., are readily available; however, they are costly, have a complicated bias network, and increase the system complexity. Therefore, in [97], a hexagonal-shaped cantilever-enabled FSS was mounted over a cylindrical DRA for dual-plane beam sweep. The antenna was designed to operate at a resonating frequency of 30 GHz, as shown in Figure 12.21a–c. It was observed that beam sweeping occurred in both the azimuthal and elevation planes. In six 60° steps, the whole azimuthal plane was covered. The gain of the antenna was measured as 8.1 dB.

Due to the design flexibility, the use of microfluidic technology for reconfiguration is in trend. A liquid metal is poured into the microchannels that are carved inside an elastomeric substrate. The amount of liquid injected signifies the new resonant bandwidth. In [98], a fluid-reconfigurable FSS was presented with multifunctionality, as illustrated in Figure 12.21d. On both sides of the elastomeric substrate, orthogonally polarized meandered patterns were placed. The substrate used was made of polydimethylsiloxane (PDMS), which was laser-etched to mold into a microfluidic channel of any arbitrary shape. To achieve reconfiguration, eutectic gallium–indium (EGaIn) was poured inside the meander lines, mechanically. This liquid-reconfigurable FSS provided four different pattern reconfiguration states (dual-polarized all-pass, dual-polarized band-pass, single-polarized band-pass, and single-polarized low-pass) and a stable frequency response up till 60°.

12.5.5 Electromagnetic Shielding

To avoid the interference created by any other device which can degrade the performance of the antennas, electromagnetic shielding is necessary. FSS due to its good transmission and reflection properties are a suitable candidate for this application [99]. In [100], a FSS consisting of cross-dipoles and rings imprinted on the opposite

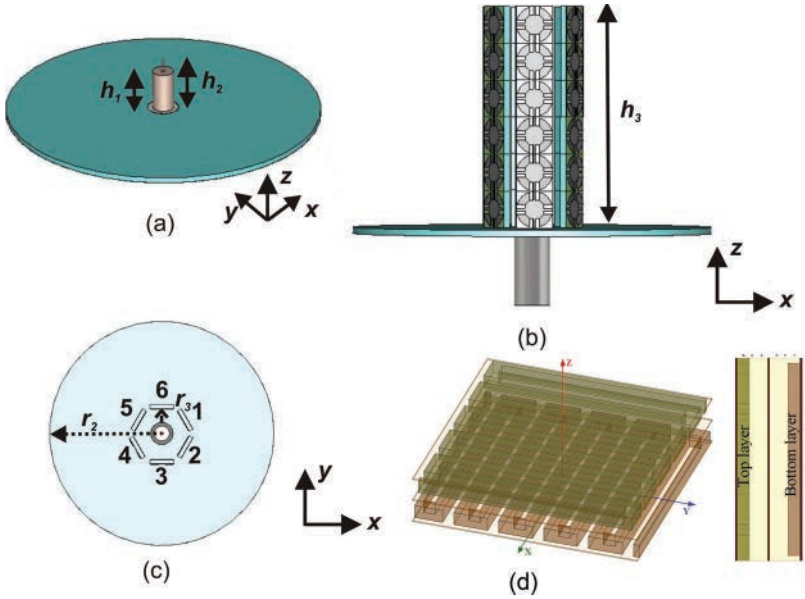

FIGURE 12.21 Structure of a beam-sweeping antenna using (a-c) cantilever-enabled FSS and (d) fluidic FSS [97,98].

sides of the substrate was presented and it exhibited a stopband of 7.5 GHz ranging from 6.5 to 14 GHz, as shown in Figure 12.22a. This FSS structure provided effective shielding in X-band and Ka-band with minimum attenuation of 20–35 dB. Electromagnetic shielding can also be achieved using reconfigurable frequency-selective surfaces (RFSS) [101], as shown in Figure 12.22b. In this, two pairs of squares were connected together to create an individual unit cell. Frequency tuning was obtained by varying the distance between the unit cells, mechanically. The frequency shifted toward the left with the increase in the distance between the FSS, and vice versa. This structure provided electromagnetic shielding for WiMAX (3.5 GHz), WLAN (5 GHz), and ISM/WiMAX bands (5.8 GHz). The reconfiguration range of 3.5–8.2 GHz was obtained by varying the space between the unit cells.

12.5.6 FSS Radomes for Antenna Protection

Antennas or radar systems are vulnerable to the physical environment; consequently, the performance gets affected when exposed to the outer world. Therefore, radomes came into existence. A radome is a protective layer that is positioned around an antenna or radar to protect it from physical wear and tear with least impact on the performance [102]. FSS due to its unique property of manipulating the EM waves is a good option to make hybrid radomes. FSS radomes can work in absorption band [103], reflection band [104], and passband [105] for various military and commercial requirements. With the development of stealth technology and detection, a low radar

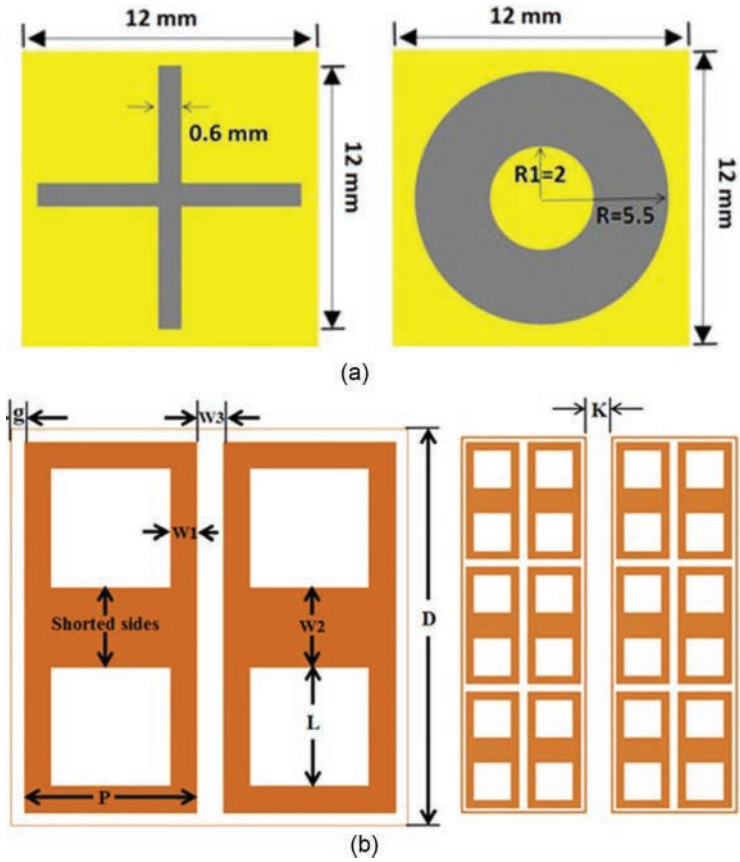

FIGURE 12.22 Unit cell dimension for electromagnetic shielding FSS [100,101].

cross section is of utmost importance. If the FSS radomes are transparent to EM waves, the transmission of the signal is smooth. However, if they are opaque, the entire incoming signal gets reflected. Due to the dome shape of the radomes, the energy is reflected and backscatters in bistatic direction; therefore, the back-reflected signals become weak in strength in different directions. Hence, the RCS is reduced [1]. Radomes are suitable for other applications as well, such as weather broadcast, telemetry, satellite, radio astronomy, and surveillance. The comparison of monostatic RCS of FSS radomes and dielectric radomes in [106] makes it clear that FSS radomes control the RCS of the antenna better than dielectric radomes. It is shown in Figure 12.23.

In [107], a dual-layer four-legged loop FSS radome was integrated over a slotted waveguide antenna to reduce the RCS. This antenna system provided a wideband of 7.8–11.2 GHz operating at 9.5 GHz. It was observed that the return loss of the FSS was greater than 9 dB over the entire passband range; however, this FSS radome had some effect on the electrical performance of the antenna in terms of reduced polarization with increased side lobe levels and more transmission losses.

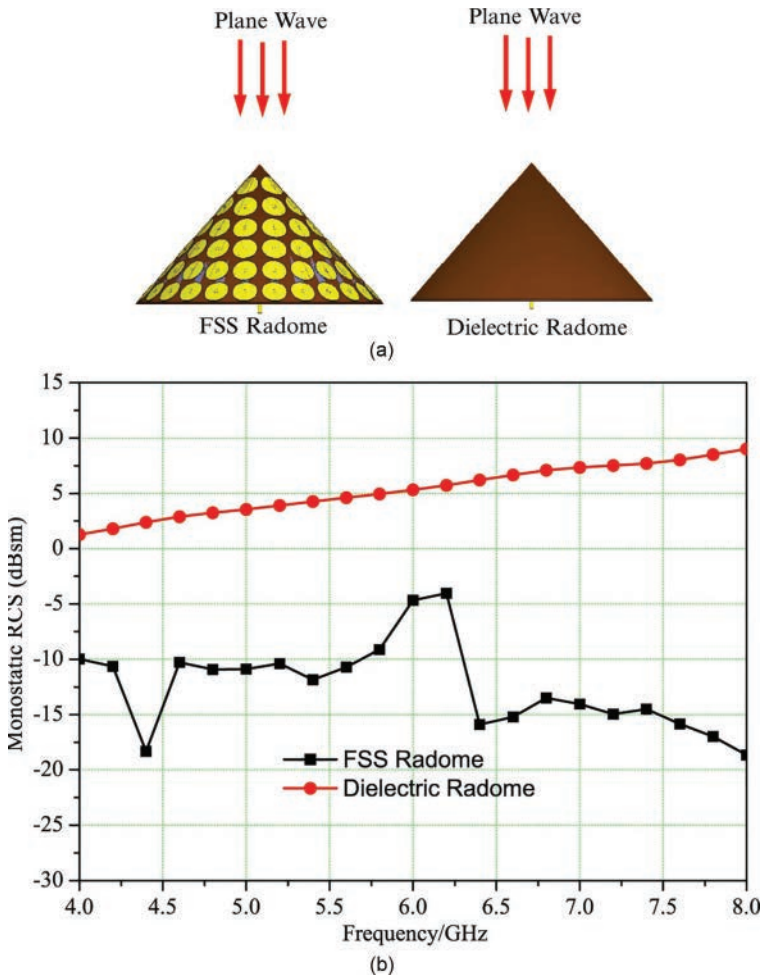

FIGURE 12.23 Comparison of monostatic RCS of FSS radome and simple dielectric radome [106].

The monostatic RCS with and without a FSS radome is shown in Figure 12.24. It was observed that the RCS was reduced effectively with the integration of the FSS at 9.5 GHz. The RCS value at 0° is high. It is assumed that at 0° the antenna behaves as a perfect electromagnetic hard surface.

A conical thick-screen FSS was integrated over a monopole antenna to obtain a narrow passband response and control reflected band RCS [108]. In [109], a folded substrate band-pass 3D FSS was implemented. Compared to its conventional 3D FSS counterpart, the thickness of this FSS unit cell was reduced by 79% (five-layer folded substrate). It was observed that this semicylindrical conformal FSS radome integrated with horn antenna provided a transmission bandwidth of 26.9% operating at 3.57 GHz and a stable performance was observed at oblique angles.

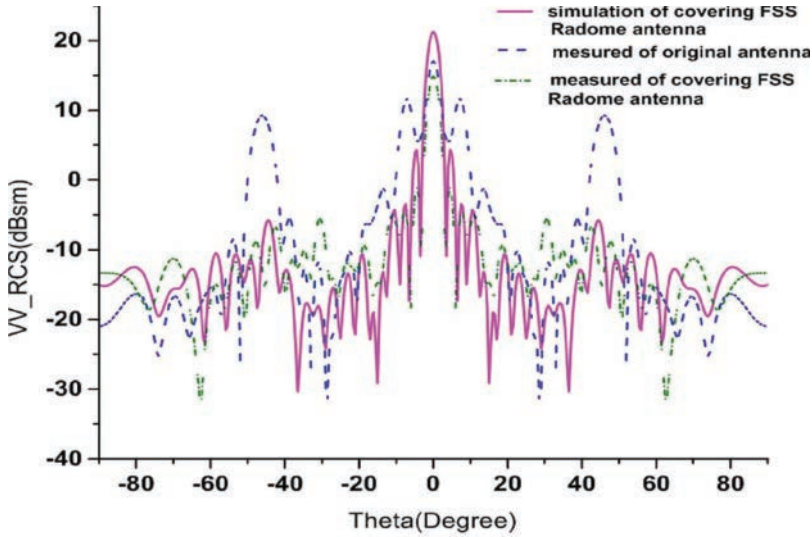

FIGURE 12.24 Monostatic RCS of the covering symmetric dual-layer FSS radome antenna at 9.5 GHz [107].

A reconfigurable AFSS reflector was presented for RCS reduction in [110], as shown in Figure 12.25a. Around 3.8 GHz, the FSS reflector was able to switch between ON state (band-pass) and OFF state (band-stop) using PIN diodes, as illustrated in Figure 12.25b. It resulted in a switchable RCS reduction in a dipole antenna with and without the bias to the FSS.

It is evident from the above discussion that hybrid FSS radomes suits better in RCS reduction in an antenna performance, without affecting the performance of the antenna.

12.6 CONCLUSION

This chapter gave an idea of what frequency selective surface is and how important it is in modern electromagnetism. Basic concepts and principle of operation were explained briefly. With rising trends in various fields such as communication, a vast amount of research on FSS and its characteristics and applications has been conducted. Different types of FSS have been studied, such as single-layer FSS, 3D FSS, multilayer FSS, wearable FSS, and active FSS. Various equivalent circuits have been explained with the LC responses. This includes simple 2D structure to complex 3D and active FSS structures. Wide bandwidth, high gain/directivity, good radiation characteristics, and better efficiency are some of the salient features of an antenna. However, a conventional antenna system is insufficient to provide all the aforementioned characteristics. So, later in this chapter, all the applications of FSS based on antennas were explained. It was studied that FSS not only work as a filter, but also helps in the enhancement of gain, bandwidth, reconfigurability, isolation between MIMO antennas, and RCS reduction.

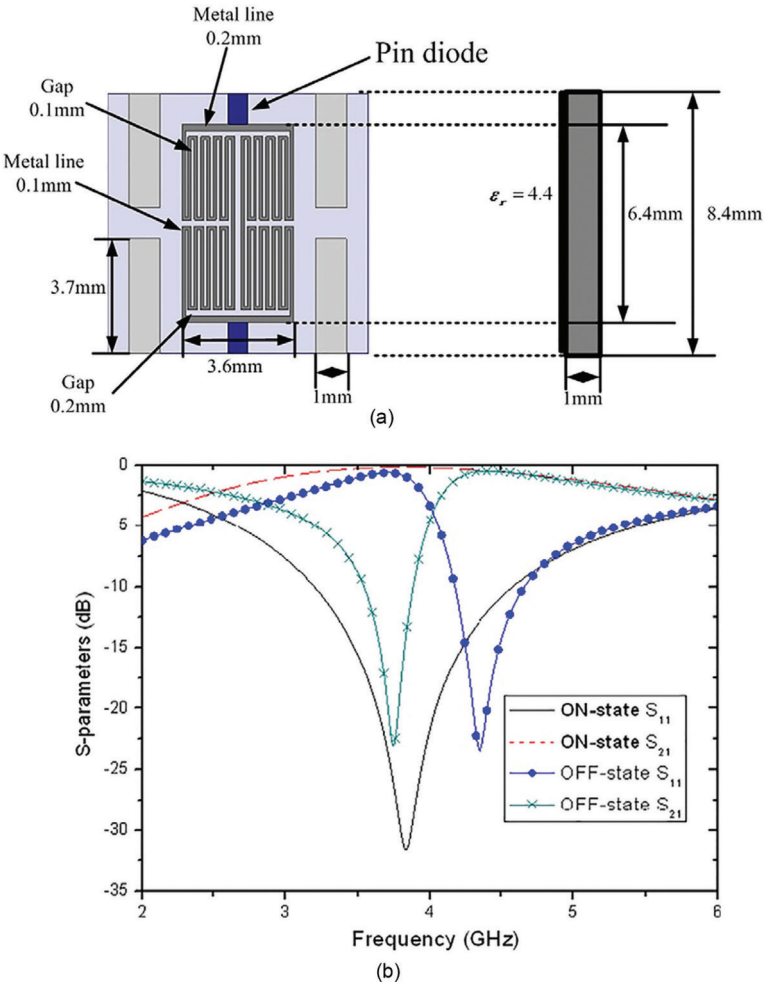

FIGURE 12.25 Configuration of reconfigurable AFSS [110].

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Edited by Pardeep Kumar, Yugal Kumar, and Mohamed A. Tawhid



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Preface

Medical informatics, also known as healthcare analytics, is a useful tool that can assess and monitor health-related behavior and conditions of individuals outside the clinic. The benefits of medical informatics are significant, including improving life expectancy, disease diagnosis, and quality of life. In many individual situations, a patient requires continuous monitoring to identify the onset of possible life-threatening conditions or to diagnose potentially dangerous diseases. Traditional healthcare systems fall short in this regard.

Meanwhile, rapid growth and advances have occurred in the digitization of information, retrieval systems, and wearable devices and sensors. Our times demand the design and development of new effective prediction systems using machine learning approaches, big data, and the Internet of Things (IoT) to meet health and life quality expectations. Furthermore, there is a need for monitoring systems that can monitor the health issues of elderly and remotely located people. In recent times, big data and IoT have played a vital role in health-related applications, mainly in disease identification and diagnosis. These techniques can provide possible solutions for healthcare analytics, in which both structured and unstructured data are collected through IoT-based devices and sensors. Machine learning and big data techniques can be applied to collected data for predictive diagnostic systems. However, designing and developing an effective diagnostic system is still challenging due to various issues like security, usability, scalability, privacy, development standards, and technologies. Therefore machine learning, big data, and IoT for medical informatics are becoming emerging research areas for the healthcare community.

Outline of the book and chapter synopses

This book presents state-of-the-art intelligent techniques and approaches, design, development, and innovative uses of machine learning, big data, and IoT for demanding applications of medical informatics. This book also focuses on different data collection methods from IoT-based systems and sensors, as well as preprocessing and privacy preservation of medical data. We have provided potential thoughts and methodologies to help senior undergraduate and graduate students, researchers, programmers, and healthcare industry professionals create new knowledge for the future to develop intelligent machine learning, big data, and IoT-based novel approaches for medical informatics applications. Further, the key roles and great importance of machine learning, big data, and IoT techniques as mathematical tools are elaborated in the book. A brief and orderly introduction to the chapters is provided in the following paragraphs. The book contains 23 chapters.

Chapter 1 presents a survey of machine learning and predictive analytics methods for medical informatics. This chapter focuses on deep neural networks with typical use cases in computational medicine, including self-supervised learning scenarios: these include convolutional neural networks for image analysis, recurrent neural networks for time series, and generative adversarial models for correction of class imbalance in differential diagnosis and anomaly detection. The authors then continue by assessing salient connections between the current state of machine learning research and data-centric healthcare analytics, focusing specifically on diagnostic imaging and multisensor integration as crucial research topics within predictive analytics. Finally, they conclude by relating open problems

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of machine learning for prediction-based medical informatics surveyed in this article to the impact of big data and its associated challenges, trends, and limitations of current work, including privacy and security of sensitive patient data.

Chapter 2 presents a proposed model for geolocation aware healthcare facility with IoT, Fog, and Cloud-based diagnosis in emergency cases. An end-to-end infrastructure has been modeled for the healthcare system using geolocation-enabled IoT, fog, and cloud computing technology to identify the nearest hospital or medical facility available to the patient. It has also achieved 25%–27% less delay and 27%–29% less power consumption than the cloud-only environment.

Chapter 3 aims to capture the status of medical computer vision threats and the recent defensive techniques proposed by researchers. This chapter intends to shed light on the vulnerability of machine learning models in medical image analysis, e.g., disease diagnosis, and to become a guide for any researcher working in medical image analysis toward the development of more secure machine learning-based computer-aided diagnosis systems.

Chapter 4 demonstrates a model for skull stripping and tumor detection from brain images using 3D U-Net. The demonstrated model has been tested over 373 MRIs of the LCG Segmentation Dataset, showing good standard performance over metrics of dice coefficient, and the accuracy results are competitive with the existing methods.

Chapter 5 addresses the issue of corrupted laparoscopy video by haze, noise, oversaturated illumination, etc., in minimally invasive surgery. To effectively address the issue, the authors have proposed a novel algorithm to ensure the enhancement of video with faster performance. The proposed C^2D^2A (Cross Color Dominant Deep Autoencoder) uses the strength of (a) a bilateral filter, which addresses the one-shot filtering of images both in the spatial neighborhood domain and psycho-visual range; and (b) a deep autoencoder, which can learn salient patterns. The domain-based color sparseness has further improved the performance, modulating the classical deep autoencoder to a color dominant deep autoencoder. The work has shown promise toward providing a generic framework of quality enhancement of video streams and addressing performance. This, in turn, improves the image/video analytics like segmentation, detection, and tracking the objects or regions of interest.

Chapter 6 presents an alternative way of estimating respiratory rate from ECG and PPG by using machine learning to improve estimation accuracy. The proposed methods are based on respiratory signals extracted from raw signals and use a support vector machine (SVM) and neural network (NN) to estimate respiratory rate. The proposed methods achieve comparable accuracy to current methods when the number of classes is low. Once the number of classes increases, the accuracy drops significantly.

Chapter 7 serves as an introductory guideline to address the challenges and opportunities while designing machine learning-enabled Healthcare Internet of Things (H-IoT) networks. It provides a discussion on traditional H-IoT, challenges, and opportunities in the Network 2030 paradigm. It also discusses potential machine learning techniques compatible with H-IoT and points out open issues and future research directions.

Chapter 8 presents a skin lesion segmentation approach based on the Elitist-Jaya optimization algorithm. The proposed method contains two stages: image preprocessing and edge detection. The experimental sample consists of a set of 320 images from the skin lesion dataset. The outcomes proved that the proposed approach improved the segmentation accuracy of the affected skin lesion area and outperformed the compared methods.

Chapter 9 provides its readers with an all-encompassing review that will enable a clear understanding of the current trends in glove-based gesture classification and provide new ideas for further research. The

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authors have analyzed deep learning approaches in terms of their current performance, advantages over classical machine learning algorithms, and limitations in specific classification scenarios. Furthermore, they present other deep learning approaches that may outperform current algorithms in glove-based gesture classification.

Chapter 10 presents an ensemble approach for evaluating the cognitive performance of the human population at high altitude. The authors identify the key multidomain cognitive screening test (MDCST) and clinical features among the lowlander ($\leq$350 m) and highlander ($\geq$1500 but $<$4300 m) populations, staying at an altitude $\geq$4300 m for a prolonged duration. A goodness-of-fit test was applied to the two population cohorts for identifying significant independent measures. Rule-based mining was followed to discover associative rules between the clinical, behavioral, and cognitive screening parameters. Conclusively, a unique set of association rules have been identified with at least 30% support and more than 60% confidence in behavioral and clinical features associated with the cognitive parameters.

Chapter 11 presents the role of machine learning in expert systems for disease diagnostics in human healthcare. The authors discuss essential existing expert systems for human disease diagnosis in detail. They also provide a brief evaluation of various techniques used for the development of expert systems.

Chapter 12 presents an entropy-based hybrid feature selection approach for medical datasets. A stable linear-time entropy-based ensembled feature selection approach is introduced, mainly focusing on medical datasets of several sizes. The suggested approach is validated using three state-of-the-art classifiers, namely C4.5, naïve Bayes, and JRIP, over 14 benchmark medical datasets (drawn from the UCI machine learning repository). The empirical results achieved from the datasets demonstrate that the proposed ensemble model outperforms the selected learners.

Chapter 13 shows how to utilize machine learning algorithms to create models that can predict healthcare systems' critical issues. The chapter's discussion relates to the COVID-19 pandemic and highlights the solutions offered by machine learning in such scenarios. The chapter also highlights the significance of feature engineering and its impact on machine learning models' accuracy. The chapter ends with two case studies. The first case study shows how to build a prediction model that can predict the number of diabetic patients who will visit certain hospitals in a specific geographic location in future years. The second case study analyzes health records during the COVID-19 pandemic.

Chapter 14 presents an interpretable semisupervised classifier for predicting cancer stages. Authors illustrate the self-labeling gray-box applications on the omics and clinical datasets from the cancer genome atlas. They show that the self-labeling gray-box is accurate in predicting cancer stages of rare cancers by leveraging the unlabeled instances from more common cancer types. They discuss insights, the features influencing prediction, and a global representation of the knowledge through decision trees or rule lists, which can aid clinicians and researchers.

Chapter 15 presents an overview of applications of blockchain technology in smart healthcare. The authors overviewed the fundamental blockchain concepts and applications to be used for different aspects of the smart healthcare industry and proposed a live patient monitoring system by deploying blockchain technology in the model. Keeping an eye on recent technologies in connected healthcare, they finally presented various research factors and potential challenges where blockchain technologies can play an outstanding role in realizing the concept of smart optimization in the healthcare industry.

Chapter 16 focuses on clustering and classification techniques for the prediction of leukemia. The proposed work consists of Phase I, which will be dealing with the collection of datasets and visualization of datasets, whereas Phase II will be dealing with the machine learning and data mining

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techniques for the prediction of leukemia disease. The authors claim that the proposed techniques would give higher performance than the existing techniques.

Chapter 17 presents a performance evaluation of fractal features toward seizure detection from electroencephalogram signals. The authors have evaluated the ability of three well-known fractal dimension feature extraction methods (the Katz fractal dimension, Higuchi fractal dimension, and Petrosian fractal dimension) to classify epileptic and nonepileptic electroencephalogram signals. The features are fed to an SVM classifier for the classification of epileptic and nonepileptic electroencephalogram signals. The SVM classifier results show that the fractal features are good measures to characterize the complex information of epileptic signals.

Chapter 18 presents an integer period discrete Fourier transform-based algorithm to identify tandem repeats in the DNA sequences. The authors have discussed the importance of tandem repeats in diverse applications. They proposed an integer period discrete Fourier transform (IPDFT)-based algorithm to detect the tandem repeats in DNA sequences. A comparison of the proposed algorithm's performance has also been made with existing methods.

Chapter 19 discusses the scope, applicability, and usage of blockchain technology to preserve patients' sensitive medical data. A framework is also proposed that allows patients and hospitals to store medical records. The framework allows patients to share the information by providing access to their data and by invoking smart contracts for automatic payments for their medical claims.

Chapter 20 presents a novel approach to securing e-health applications in the cloud environment. The authors provide an algorithm to secure data in e-health applications in the cloud environment. A new architecture for e-health applications in the cloud environment is proposed, which will provide application-level security and server-level security using certificates.

Chapter 21 presents different ensemble learning algorithms and explains how these algorithms can be used to classify health disorders. The authors have discussed an ensemble classifier approach for thyroid disease diagnosis using the AdaBoostM algorithm.

Chapter 22 presents a review of the latest artificial intelligence research in this immense medical science field, including various architectures and approaches, with special attention given to brain tumor analysis. The authors discuss various deep learning architectures used to diagnose brain tumors and compare results with existing architectures. They have examined case studies from basic clustering techniques such as K-means clustering to fuzzy and neurotrophic C-means clustering techniques and kernel graph cuts (KGC) to advanced artificial intelligence techniques such as deep convolution neural networks (DCNs), atrous convolution neural networks (ACNs), and unit architectures to find the area of interest in the coherent/incoherent regions.

Finally, Chapter 23 focuses on machine learning in precision medicine. An overview of how machine learning is used in precision medicine and its potential use in the detection, diagnosis, prognosis, risk assessment, therapy response, and discovery of new biomarkers and drug candidates is presented in this chapter.

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Large-Scale Data Streaming, Processing, and Blockchain Security

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Hari Singh, Jaypee University of Information Technology, India
Abhinav Kirti Gupta, Jaypee University of Information Technology, India

Data processing has become an important field in today's big data-dominated world. The data has been generating at a tremendous pace from different sources. There has been a change in the nature of data from batch-data to streaming-data, and consequently, data processing methodologies have also changed. Traditional SQL is no longer capable of dealing with this big data. This chapter describes the nature of data and various tools, techniques, and technologies to handle this big data. The chapter also describes the need of shifting big data on to cloud and the challenges in big data processing in the cloud, the migration from data processing to data analytics, tools used in data analytics, and the issues and challenges in data processing and analytics. Then the chapter touches an important application area of streaming data, sentiment analysis, and tries to explore it through some test case demonstrations and results.

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An Insight on the Class Imbalance Problem and Its Solutions in Big Data 39
Khyati Ahlawat, University School of Information, Communication and Technology, Guru Gobind Singh Indraprastha University, India
Anuradha Chug, University School of Information, Communication and Technology, Guru Gobind Singh Indraprastha University, India
Amit Prakash Singh, University School of Information, Communication and Technology, Guru Gobind Singh Indraprastha University, India

Expansion of data in the dimensions of volume, variety, or velocity is leading to big data. Learning from this big data is challenging and beyond capacity of conventional machine learning methods and techniques. Generally, big data getting generated from real-time scenarios is imbalance in nature with uneven distribution of classes. This imparts additional complexity in learning from big data since the class that is underrepresented is more influential and its correct classification becomes critical than that of overrepresented class. This chapter addresses the imbalance problem and its solutions in context of big data along with a detailed survey of work done in this area. Subsequently, it also presents an experimental view for solving imbalance classification problem and a comparative analysis between different methodologies afterwards.

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Oshin Sharma, PES University, Bangalore, India
Anusha S., School of Engineering and Technology, Jain University, Bangalore, India

The emerging trends in fog computing have increased the interests and focus in both industry and academia. Fog computing extends cloud computing facilities like the storage, networking, and computation towards the edge of networks wherein it offloads the cloud data centres and reduces the latency of providing services to the users. This paradigm is like cloud in terms of data, storage, application, and computation services, except with a fundamental difference: it is decentralized. Furthermore, these fog systems can process huge amounts of data locally and can be installed on hardware of different types. These characteristics make fog suitable for time- and location-based applications like internet of things (IoT) devices which can process large amounts of data. In this chapter, the authors present fog data streaming, its architecture, and various applications.

Chapter 4
Trust and Reliability Management in Large-Scale Cloud Computing Environments 66
Punit Gupta, Manipal University Jaipur, India

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Trust is a firm belief over a person or a thing in distributed environment based on its feedback on review based on its performance by others. Similarly, in cloud, trust models play an important role in solving various open challenges in cloud environment. This chapter showcases all such issues that can be solved by trust management techniques. This work discourses various trust management models and its categorization. The work discourses existing work using trust models from the field of grid computing, cloud computing, and web services because all these domains are sub child of each other. The work provides an abstract view over all trust models and find the suitable one for cloud and its future prospects.

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Large-Scale Data Storage Scheme in Blockchain Ledger Using IPFS and NoSQL 91
Randhir Kumar, Department of Information Technology, National Institute of Technology, Raipur, India
Rakesh Tripathi, Department of Information Technology, National Institute of Technology, Raipur, India

The future applications of blockchain are expected to serve millions of users. To provide variety of services to the users, using underlying technology has to consider large-scale storage and assessment behind the scene. Most of the current applications of blockchain are working either on simulators or via small blockchain network. However, the storage issue in the real world is unpredictable. To address the issue of large-scale data storage, the authors have introduced the data storage scheme in blockchain (DSSB). The storage model executes behind the blockchain ledger to store large-scale data. In DSSB, they have used hybrid storage model using IPFS and MongoDB(NoSQL) in order to provide efficient storage for large-scale data in blockchain. In this storage model, they have maintained the content-addressed hash of the transactions on blockchain network to ensure provenance. In DSSB, they are storing the original data (large-scale data) into MongoDB and IPFS. The DSSB model not only provides efficient storage of large-scale data but also provides storage size reduction of blockchain ledger.

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Application of Deep Learning in Biological Big Data Analysis 117
Rohit Shukla, Department of Biotechnology and Bioinformatics, Jaypee University of Information Technology, India
Arvind Kumar Yadav, Department of Biotechnology and Bioinformatics, Jaypee University of Information Technology, India
Tiratha Raj Singh, Department of Biotechnology and Bioinformatics and Centre for Excellence in Healthcare technologies and Informatics (CEHTI), Jaypee University of Information Technology, India

The meaningful data extraction from the biological big data or omics data is a remaining challenge in bioinformatics. The deep learning methods, which can be used for the prediction of hidden information from the biological data, are widely used in the industry and academia. The authors have discussed the similarity and differences in the widely utilized models in deep learning studies. They first discussed the basic structure of various models followed by their applications in biological perspective. They have also discussed the suggestions and limitations of deep learning. They expect that this chapter can serve as significant perspective for continuous development of its theory, algorithm, and application in the established bioinformatics domain.

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Building Better India: Powered by Blockchain.....149
Swarup Roy Chowdhury, Sabre Corporation, India
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We can name many industries that are still based on the same working practices and business models that they have had for a long time – maybe since they started. Despite the wealth of modern technology now available, public infrastructure, a critical component for the well-being of the society, is still an industry based on the paperwork, letters, emails, manual approvals, and a large amount of guess work. It involves a lot of manual effort and is also error prone. It is really very hard for the stakeholders and end users to get an update on the progress of the project, which impacts them directly or indirectly. The authors intend to develop a groundbreaking blockchain platform that can meet the needs of all the different stakeholders involved in creating and providing a better infrastructure. They plan to automate the entire process by using smart contracts to minimize paperwork for the government officials. This will not only eliminate the errors that can happen during manual execution but will also provide a real-time update to all the stakeholders in making the process more transparent.

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The usage of information is essential for data-driven capabilities in artificial intelligence. The data-driven AI techniques lead to several security and privacy concerns. Among various digital techniques, digital rights management is required as one of collaboration scheme that ensures the security and privacy of intellectual rights. Though a number of researchers have proposed various security techniques, none of them have proposed an efficient and effective privacy procedure for digital rights. Recently, blockchain technique is considered as one of the major security methods to ensure a transparent communication among individuals. It can be used by various applications such as industries, marketing, transportation systems, etc. The aim of this chapter is to propose an ensured resource allocation algorithm that validates the scheme by comparing various security measures against previous approaches. Further, the proposed phenomenon ensures the transparency on security and privacy due to its integration.

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Understanding Blockchain: Case Studies in Different Domains 181
Hemraj Saini, Jaypee University of Information and Technology, India
Geetanjali Rathee, Jaypee University of Information Technology, India
Dinesh Kumar Saini, Sohar University, Oman

In this chapter, the authors have detailed the need of blockchain technology along with its case studies in different domains. The literature survey is described that describes how blockchain technology is rising. Further, a number of domains where blockchain technology can be applied along with its case studies have been discussed. In addition, the authors have considered the various use cases with their recent issues and how these issues can be resolved using the blockchain technology by proposing some new ideas. A proposed security framework in certain applications using blockchain technology is presented. Finally, the chapter is concluded with future directions.

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Integrating Blockchain and IoT in Supply Chain Management: A Framework for Transparency and Traceability 203
Madumidha S., Sri Krishna College of Technology, India
SivaRanjani P., Kongu Engineering College, India
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Internet of things(IoT) is the conception of interfacing the devices to the internet to make life more efficient. It comprises the large amount of data in its network where it fails to assure complete security in the network. Blockchain is a distributed ledger where it mainly focuses on the data security. Every block in the blockchain network is connected to its next block, which prevents threats like large data loss. In the area of agri-food supply chain, where IoT plays a very important role, there occurs data integrity issues or data tampering. This can lead to improper supply chain management, timely shortage of goods, food spoilage, etc. So the traceability of agri-food supply chain is necessary to ensure food safety and to increase the trust between all stakeholders and consumers. Many illegal activities can be prevented, and cold chain monitoring can be achieved by bringing in transparency and traceability.

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Electronic Voting Application Powered by Blockchain Technology.....230
Geetanjali Rathee, Jaypee University of Information Technology, India
Hemraj Saini, Jaypee University of Information Technology, India

India is the largest democracy in the world, and in spite of that, it faces various challenges on a daily basis that hinder its growth like corruption and human rights violations. One of the ugliest phases of corruption and political mayhem is visible during the election process where no stone is kept unturned in order to gain power. However, it is the common citizen who suffers most in terms of clarity as well as security when it comes to his/her vote. Blockchain can play a very important role in ensuring that the voters registering their votes are legit and the counting of votes is not manipulated in any way. It is also needed in today's times where the world is available to people in their smart phones to also give them the opportunity to register their votes hassle free via their smart phones without having to worry about the system getting hacked. Therefore, in this chapter, the proposed layout will be based on a smart contract, using Ethereum software to create an e-voting app. In this chapter, the authors have proposed a secure e-voting framework through blockchain mechanism.

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COMPENDIUM OF DATA SECURITY IN CLOUD STORAGE BY APPLYING HYBRIDIZATION OF ENCRYPTION ALGORITHM

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ABSTRACT

This paper is about preserving the Cloud data whose idea is to cure everyday problems with computing. Cloud computing is fundamentally pooling the resources virtually and the resources like storage are provided to the end-users through the web. Information preservation, security, uniform quality, and interoperability are some issues related to cloud computing. However, the most essential issue is Security and how it is ensured by a cloud supplier. Security of data can be offered by means of cryptography. This paper presents an improved composite data protection mechanism to protect data on the cloud from illegitimate access.

Keywords Cloud Computing, Data Protection, Encryption, Decryption, Cryptography, RSA

1 INTRODUCTION

There is no such thing as "THE CLOUD", it's just somebody else's computer. Cloud computing is also called on-demand computing and it is a kind of web-based processing, where participating resources and data are rendered to workstations and different gadgets according to demand [1, 2]. Cloud computing is essentially intended to give the

most extreme limit from the least resources [3, 4]. The end client has the base equipment necessity yet utilizes the most extreme capacity of processing [5]. It is a technique that makes use of the Internet and Remote access servers to manage application programs and data [6, 7]. Cloud computing can provide services at a substantially reduced cost by commoditizing the IT assets and on-demand usage patterns [8]. Virtualized hardware, provisioning services rapidly, scalability, elasticity, accounting graininess, and cost assigning models make Clouds able to efficiently adapt resource issuing to the changing demands of the users on the Internet [9–11]. Recently service of cloud computing which is storage as a service (StaaS) has become popular for providing services to both private users and public users [12–14]. STaaS is a service model in Cloud in which a special organization leases the storage space to people or organizations [15–17]. The data residing on the Cloud becomes vulnerable to exploitation by the service provider or by other unauthorized persons thus this data is sensitive and needs a security [18–20]. This fragility led us to find some solution that can make users able to protect the data on the cloud [21–23]. There are various research challenges in cloud computing such as portability, exchanging data, accessing the storage, protection, expenditure, energy efficacy, etc. [24–26]. Fig. 1 presents the importance of data security and other critical issues, where data security and privacy is one of the biggest barriers to the spread of this on-demand Computing. To upgrade the protection mechanism of cloud computing it becomes essential to facilitate the users with authorization and access in a controlled manner for the security of data.

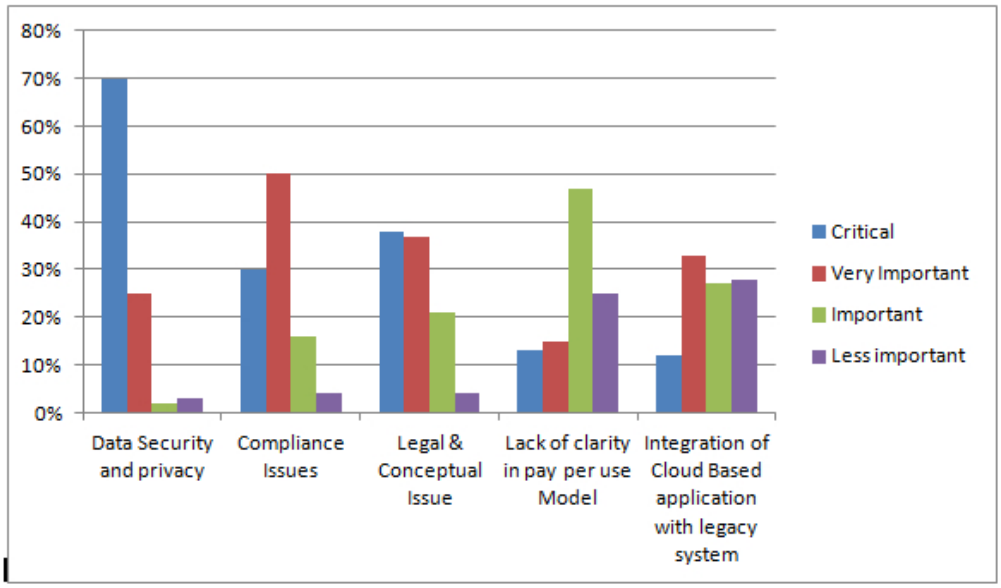

Figure 1: Data Security and Critical Issues.

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2 RELATED WORK

Suruchee V.Nandgaonkar et al. [27] gave "A Comprehensive Study on Cloud Computing "which describes that cloud computing is conforming to a growing in-demand outfit in which computing assets are delivered on-demand. It defines the architecture that is all the services of the cloud. They have defined cloud computing and have described that cloud computing is becoming the next buzz in the IT industry. The structure of Cloud, Servicing Models of Cloud (IaaS, PaaS, SaaS) are explained by them. Different cloud service models are compared in their work. Different motivating factors and challenges related to cloud computing are explained by them. Zhibin Chen et al. [28] proposed a report in which they have defined cloud computing and have described all the service models. They have discussed various issues associated with cloud computing such as securing the cloud data, Privacy of user's data, Legal issues, Compliance, Freedom, etc. They have concluded the paper by describing that the Cloud environment leads us to approximately never-ending capabilities in computing, good expandability, and on-request service. Anuradha Thilakarathne et al. [29] describes "current security risks and attacks on cloud such as Virtual Machine escapes and Virtual Machine hypervisor, Cloud Zombie, DoS attacks, etc. "They have addressed the security issues associated in cloud data storage and have explored many of them such as security, privacy, reliability, legal issues, open standards, compliance, freedom, and long term viability." They have defined different security issues, the different existing security threats and attacks. They have explained Cloud Security has unavoidably turned into a significant business recognizer.

There are certain things in the cloud we need to focus on which have been explained above. In conclusion to this, security should be provided to the cloud data. There are certain encryption techniques that can be utilized to encrypt that data to protect it from malicious attacks. Techniques of encryption are further presented in modified forms."Zaid kartit et al. [30] it is proposed to apply encryption technique enhancing data security in cloud storage which is easy, secure, and provides an architecture which preserves privacy while sharing data between clouds. Encryption/Decryption algorithms are the basis of this architecture which focuses on protecting the cloud data from unauthorized access. There are two parts to these algorithms. The first is the file upload part in which, plain text is encrypted by applying the AES algorithm. The next part, which is about downloading a file, states two phases of the algorithm. The first phase comprises the decryption of the AES key by applying RSA (Rivest-Shamir-Adleman) algorithm. The second phase comprises the decryption of ciphered text by applying the AES key obtained from the server. Here, the AES key is decrypted using RSA, there are some demerits to RSA which are that are both public and private keys are directly related to 'x' which is the product of two prime no's which is easy to factorize in cases where the public key is well known to all. Uma Somani et al. [31] have described the encryption of data before sending it to the network along with electronic signature, describing RSA to be the most significant algorithm with asymmetry, associating it with electronic signature and asymmetric cryptography for increasing the protection of cloud. This is a two-tier security procedure. Viswanath et al. [32] proposes a method to enhance the protection of cloud data by making use of a combined form of (Rivest Shamir Adleman & Advanced Encryption Standard) techniques for securely uploading as well as downloading the files. Ganesan et al. [33] proposed the security which comprises a procedure with four tasks based on cryptographic techniques of Diffie Hellman and Elliptic curve algorithm to verify the legitimacy of a user within the environment of the cloud. The first task is Initiating a connection, Creating the account is the second task, Checking the legitimacy of the user is the third task and the fourth and last comprises exchanging the information. The main advantage of this technique is that its time complexity is sub-exponential due to which it is difficult to break. Prashant et al. [34] proposes Digital Signature and associating it with Advanced Encryption Standard encryption and Diffie Hellman algorithm to perform file upload as well as download over the Cloud.

3 PRELIMINARIES

3.1 Cloud Computing

It is a mechanism to enable a benefic, on-demand organized approach to a shareable domain of operating resources (for example workstations, server systems, backlogging, application programs, and management systems) that can be provided rapidly as well as released with minimal management efforts [35]. Cloud computing is generally considered as the delivery of demands [36]. It is a kind of computing in which computing resources from application programs to processing centers are asked across the Web for use and pay accordingly. [37]

(A) Features

(a) Service according to demand: The user does not require to interact with each service provider to provision facilities like time-slots of server and storage on the network.

(b) Access to Broad Cloud Network: Abilities become obtainable across the inter-network and got over basic components that encourage utilizing at different server-dependent or server-independent clients stages (for example smartphones, smart notepads, Laptops, and computer systems) [38, 39].

(c) Grouping resources: The resources figured by a supplier are grouped to provision various users utilizing multiple-inhabitant display, along with resources intangible and virtual form, powerfully relegated as well as reassigned with respect to customer's needs. Memory repositories, operating processes, and transmission capacity on the web are included in cloud resources.

(d) Quick Flexibility: Facilities provided by the cloud are flexible enough to be provided and released, correspondingly rapidly outside and inside comparative according to the need of user [40, 41].

(B) Service Model for On-Demand Computing

(a) Software As A Service (SAAS): This mechanism explains that the user doesn't really have to worry about any particular software installation; it means the client can use desired software without installing it on its own system. The applications which run off the cloud are included in this layer. They are paid off on the basis of use from anywhere and anytime. These applications are available on-demand on the web [42].

(b) Storage as a service (STAAS): This service provides online remote storage independent of the client system and its platform. It felicitates cloud applications to a scale beyond their limited servers [43].

(c) Infrastructure As A Service (IAAS): Virtualized resources for computing over the internet are provided by this model. This service model delivers computer infrastructure on an outsourced site to help organizational operations. In this model, a third-party hosts its infrastructure components like hardware, software, servers, storage, etc. in place of its users. IaaS suppliers likewise have client, application programs along with maintaining systems, keeping backups, and making plans for tolerance are managed by the same [44].

(d) Platform As A Service (PaaS): This is a mechanism using which software and hardware tools needed by the user for any software development across the internet are provided by the service provider. It is a service where an integrated environment for development is provided. Example: service for java or service for c language is configured accordingly like the required software's and editor is installed and is made available to user [45].

(C) Cloud Deployment Models

(a) Private Cloud: It is a cloud environment that is hosted at both internal and external ends as well as controlled internally or by a mediator. It is available for single use and accessible exclusively by a single organization having multiple consumers that share common concerns, policies, and considerations. It may be a costlier way however it can provide a greater degree of protection, safety, and/or conforming to policies. Google's "Gov Cloud "is one of the examples of a Cloud formed by a community [46].

(b) Cloud for Public: It is a mechanism using which capabilities are obtainable by everyone; these services may be free. There is generally not much difference in the architecture of public cloud or private cloud, but security considerations can be different for them. Example: Amazon AWS, Google.

(c) Community cloud: It is an environment where the configurations can be utilized by a particular community of consumers of particular organizations having a common concern and having specific security requirements. It can be managed through multiple organizations included in that group, a mediator, or both [47].

(d) Hybrid cloud: It is the model which is the combination of two or more deployment models that are unique entities but are unified together and provide the advantages of both the models [48].

3.2 Security

The name 'Cryptography'was obtained from 'Kryptos'which is a Greek word, it stands for hidden or secret. Sometimes confidentiality of the data is a very important aspect of data transmission. Cryptography is the hiding information [49]. It is the science that is used to keep the information safe and secret. Basically, cryptography is a technique which used to transfer data safely between two parties without getting interfered with by external entities. Cryptography is based on an algorithm and key which converts information into un- understandable format [50]. The original information is called plain text. And after the conversion of information, the converted information is ciphertext [51].

When a message (data) is sent over a network or from one party to another party that message is encrypted from plain text to ciphertext and that conversion means encrypting the message. When a receiver receives ciphered data, the receiver applies decryption on the ciphered data and gets the plain text and that conversion of cipher text into plain text is called decryption [52]. The process of Encrypting and Decrypting the data is shown in Fig. 2.

Security permits the classification, respectability, and accessibility of data. The improvement of advancements and their institutionalization makes accessible an arrangement of calculations and conventions for reacting to these issues [53]. There are two categories of Cryptography, Symmetric-key encryption, is a kind of algorithm that employs the same key to apply cryptography in both the operations, encrypting and decrypting the data whereas asymmetric encryption algorithm (encryption based on public key) employs distinct keys, one key which is public, used for encrypting the data and another key which is kept private, used for decrypting the data. These two keys are linked mathematically to each other [54]. Someone is able to encrypt a message using a public key, which provides confidentiality, and then the only person possessing the private key is able to decrypt it [55]. To have cloud computing with enhanced security, it is essential to cater to objectives like verifying authenticity, authority, and accessing data in a controlled manner while working with data residing on cloud [56]. The four essential aims concerned with a security system are:

1. Authorization: This indicates that the message should be accessed by only the sender and the intended receivers. If any unauthorized person gets access to that data then confidentiality gets compromised.

2. Authentication: Using this mechanism, proof of identity is established. The origin of an electronic message or document is correctly identified and verified using this authentication process.

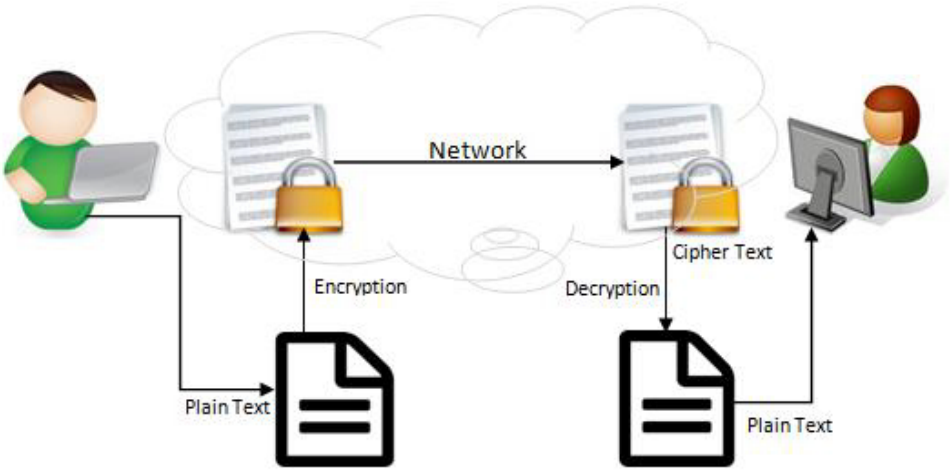

Figure 2: Encryption and Decryption Process

3. Integrity: If the contents of a message are altered after sending the data, but before reaching the intended receiver, it is known as the integrity of the message not retained. A message with lost integrity results in modification.

4. Availability: It is the extent up to which the data on the cloud is available to the user unceasingly from anywhere. [57]

4 PROPOSED WORK

Data encryption using Cryptography is specifically the best way for protecting the information in the cloud environment. Here we propose an algorithm for the encryption of data. The process of encryption will go through several steps of encryption. Our proposed algorithm mainly comprises two steps, the first being the substitution of letters that will follow a particular procedure and the second being the hybrid form of the RSA algorithm. "RSA is an asymmetric encryption algorithm and it was given by Ronald Rivest, Adi Shamir, and Leonard Adleman in 1977. In this algorithm, the Public key is used for encryption and the Private key is used for decryption.". "Here, the security is based upon supposition such that it becomes tough to guess multiples of big integer values and get "private key "which is utilized to decrypt the data. However few shortcomings are associated with the Rivest-Shamir-Adleman technique such as the decrypting process is performed using q and M, so factorizing and deriving the "private key "is easy like "public key "because everyone knows it. Here M is obtained by multiplying two prime numbers and the private key is represented by q.". RSA is a Block Figure in which each message is represented as a whole number. Once the encryption of the message is done by applying the Public key, then decryption will be done using the comparing Private Key as it were. RSA is fundamentally an unbalanced form of encoding/decoding calculation. It is unbalanced in the sense, that here the public key is broadcasted to everyone such that everyone can encode data and the secret key which unscrambles the data, is kept secret and unshared by everyone. The Algorithms 1 to 3 depict the procedures for RSA key generation, encryption, and decryption respectively. The encrypted file is uploaded to the cloud. Further, the file is downloaded by the authorized user, who decrypts the file and then reads it. Fig. 3 explains the whole process of file uploads and file downloads.

(A) File Upload
The encryption is done in two phases. The first phase is about encrypting the plain text using the position of the prime no and taking the modulo of that number. Further, in the second phase, encrypted text from the first phase is taken as an input for the second phase, and a hybrid RSA algorithm is applied to generate the final encrypted text. The basic idea behind this hybrid form is to introduce a third prime no, instead of using two prime no's, we are using three prime no's to generate "public key"and "private key". The steps for key generation using a hybrid form of RSA (HRSA) are depicted in Algorithm 4. The enciphering process is explained in Algorithm 5 that uses the public key(e) generated in Algorithm 4 for encryption.

Algorithm 1 Generate_RSA_Key()

INPUT: Select two random distinct prime numbers a and b.
OUTPUT: Find Public Key (p), Private Key (q) and Modulus (x).
Begin
Procedure(x, y,p, d, M)
$M \leftarrow x * y$
$Calculate\ Euler\ \Phi()of M$
$\Phi(M) \leftarrow (x-1) * (y-1)$
Generate a public key p , such that
$GCD(p, \Phi, (M)) = 1, 1 < p < \Phi(M)$
Compute the private key q,
such that, $d \leftarrow p^{-1} mod(\Phi(M))$
End Procedure
End

Algorithm 2 Encryption_RSA()

INPUT: Select Plain text (X), Public key (p) and Modulus (M).
OUTPUT: Find Cipher text (E).
Begin
Procedure (X, p, M, E)
$E \leftarrow X^p$ mod M
End Procedure
End

Algorithm 3 Decryption_RSA()

INPUT: Select Cipher text (E), Private Key (q) and Modulus (M).
OUTPUT: Find Plain text (X).
Begin
Procedure (X, p, M, E)
$X \leftarrow E^q$ mod M
End Procedure
End

Algorithm 4 Key_Generation_HRSA ()

INPUT: Select three random prime Numbers x, y, and z.
OUTPUT: Find Public Key (p), Private Key (d) and Modulus (M).
Begin
Procedure(x, y, p, d, M)
$M \leftarrow x * y * z$
$Calculate\ Euler\ \Phi()of M$
$\Phi(M) \leftarrow (x-1) * (y-1) * (z-1)$
Generate a public key p , such that
$GCD(p, \Phi, (M)) = 1, 1 < p < \Phi(M)$
Compute the private key q,
such that, $d \leftarrow p^{-1} mod(\Phi(M))$
End Procedure
End

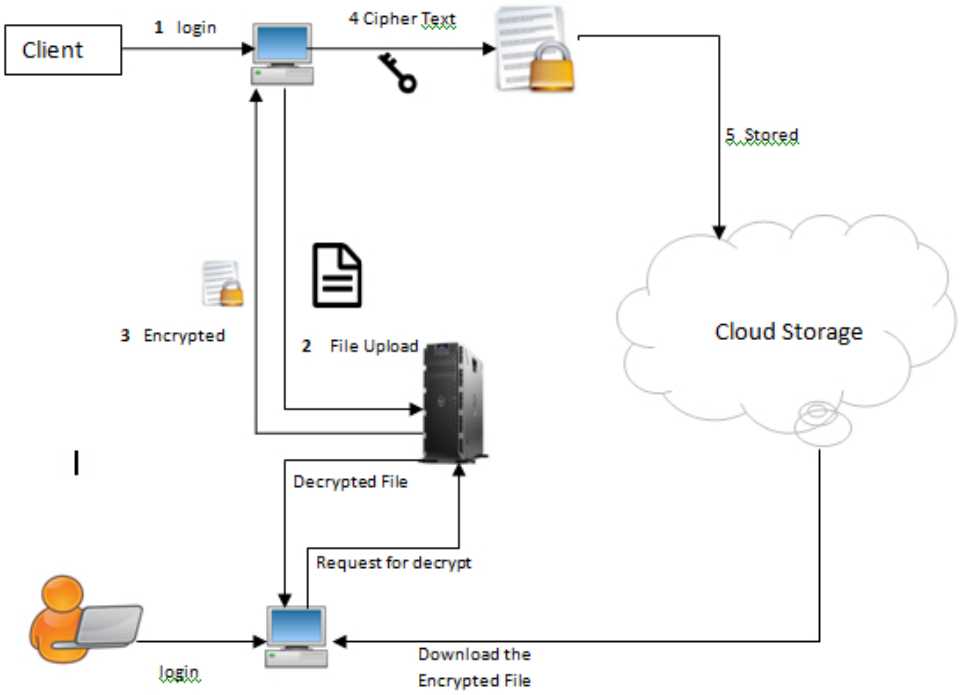

Figure 3: Procedure of File Upload and Download

Algorithm 5 Encryption_HRSA_Encryption ()

INPUT: Select Plain Text (T), Prime no(Z)
OUTPUT: Generation of Cipher Text (Z_0).
Begin
Encryption Process
Step I: INPUT(T, Z) [substitution process]
Calculate position of T
Further Z= prime no of position $T + 1$
$z_1 = Z \bmod 51$
$z_2 = Z/51$ (ignore the floating part)
Further $z_1 = z_1 + 57$
$z_3 = z_1/51$
Cipher text $Z_0 = z_1 \bmod 51$
Step II: **Encryption_HRSA()**
INPUT: Select text (Z_0), Public key (e) and Modulus (M).
OUTPUT: Calculate Cipher text (E).
Procedure (Z_0, e, M and E)
$E \leftarrow Z_0^e \bmod M$
End Procedure
End

(B) File Download
The uploaded encrypted files can be downloaded by the authorized user, then he can decrypt them and can see the file on his system. The decryption process is explained in Algorithm 6. The decryption is also done in two steps: In the first step, the ciphered data generated through the use of a public key (e) is decrypted using a private key (d), and Z_0 is generated. In phase two, Z is generated which will finally replace the position of the alphabet (original plain text).

Algorithm 6 Decryption_HRSA()

INPUT: Select Cipher Text(E), Private key (d) and Modulus(M)
OUTPUT: Plain Text (P)
Step I: Find Plain Text (Z_0)
Begin
Procedure (Z_0, e, M and E)
$Z_0 \leftarrow E^d \bmod M$
End Procedure
Step II: Z_0 (Decrypted text from 1st step of Decryption)
Final Decryption
Step 1: $z_4 = ((51 * z_3) + Z_0) - 57$
Step 2: $Z = ((51 * z_2) + z_4)$
Step 3: Z is a prime no. calculate the position of prime no
from the list of Prime no starting from 2. Let the position is i.
Step 4: Replace the Z with the alphabet at position $i - 1$.
The alphabet is the final Decrypted message(T).
End

The tool hereby is providing an interface, to transfer data over the server system, from where a logical volume is shared with the client over ISCSI protocol. The features are enhanced by applying a cryptographic hash over the data before the data is transferred over to the server system. Therefore the security and integrity of data will be maintained and any kind of snooping risk over the server is also eliminated. Encryption will be provided by a C/java executable program before it gets uploaded over the drive. For all this purpose the various tools and technologies are applied at different levels of the project.

At Frontend: HTML, CSS, bootstrap, and JavaScript will be used. A user interface will be provided by HTML/CSS web pages having Cross-platform responsiveness by bootstrap and verification from javascript. At Backend: Python CGI integration with HTML, C: The Python CGI program will be integrated to execute Linux kernel command through a web interface. It will pass user input along with the Linux command to the bash shell terminal. Redhat Enterprise Linux 7.3 will be used as Operating System. PHP, My SQL Databases. Data for all the registered users will be saved in a database file using PHP, and MySQL. All the backend of RHEL OS various configurations for a repository of yum, epel, etc. are made and software like ntfscrogs, sshpass, and others are installed to provide stem less virtualization environment. General Protocols are used such as HTTP, ISCSI, and SSH. The HTTP protocol is here providing the web interface to the user for which the HTTP daemon is started on the server-side. The SSH protocol is used to log in from client to server system to make the permanent drive entry and from server to client-side to mount the drive permanently. ISCSI protocol is providing the connection for block storage.

5 CONCLUSION AND FUTURE SCOPE

Regardless of the advantages of cloud storage, there are as yet numerous real issues concerning security that should be understood. In this paper, we have explained literature related to the cloud, its models, its security issues, different encryption techniques, and its modifications to encrypt data before storing it in the cloud in such a way that the data is accessible to the legitimate person only and there would not be loss of data confidentiality. If somehow any intruder tries to access the data and somehow is able to access the data from the cloud, then he will get it in non-readable format. The algorithm proposed makes the Cryptanalysis complex as it changes the position of the plain text alphabet using the prime no and finally it applies the Hybrid RSA Algorithm with the usage of three prime no which makes it more difficult to factorize the variable 'x 'as x is directly related in key generation. In the future, perspectives, digits, and ASCII values can also be included for encryption. Encryption can also be done on portable document files.

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