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The Science behind the COVID Pandemic and Healthcare Technology Solutions



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The Science behind the COVID Pandemic and Healthcare Technology Solutions

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Foreword by The Series Editor

The Science behind the COVID Pandemic and Healthcare Technology Solutions

The COVID world pandemic started in 2019, allegedly from a wild animal at an animal market in the city of Wuhan, China, and by mid-2022, there were already 6 million deaths and more than 600 million cases worldwide (<https://coronavirus.jhu.edu/map.html>).

Scientists were puzzled as they did not know much about the virus which caused COVID and they were also puzzled by the rate of mutations of the virus. In the middle of 2022, there were still hundreds of thousands of new cases every day, despite the high rate of vaccination of the population (by mid-2022 there were 12 trillions of doses administered). With the use of the urgently developed vaccines, in some parts of the world people have been vaccinated even four times.

Many questions were raised during this pandemic, such as

- Why such an advanced Civilization, inhabiting the Earth, became suddenly threatened by a simple virus?
- How can Science help understand the genetic code and the mutations of it, and can, in turn, develop means to save the Planet?
- What new technologies need to be developed for this purpose?-What would be future consequences of a “weakened” world population?
- As humans share the Earth with other humans and with animals, both domesticated and wild, do they need to change the way of coexistence?
- The human body hosts millions of viruses and trillions of bacteria, still in a peaceful way, do we need to worry about that in the future?

Humans live on this Planet with millions of other species of animals, viruses, bacteria, plants, and fungi in a symbiotic way and each of these species exist in their own genetic and behavioral space. The main question of all is how do we preserve this symbiosis for the future generations? And the answer is through advancement in Science and Technology.

Those and more other questions are raised and addressed in this world-first systematic and comprehensive volume, revealing the Science behind the COVID and the Technologies that can be used to study and overcome the pandemic. Issues and topics covered in the volume include contact tracing, machine learning for automatic detection of respiratory symptoms, telemedicine, using wearable and smart technologies, using mobile phones, non-invasive thermal technologies, radiographs, and Artificial Intelligence in diagnosis.

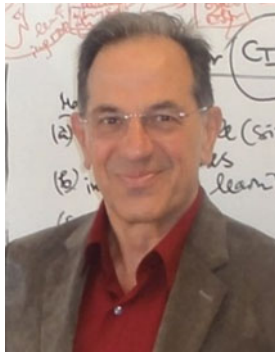
And most importantly, this volume discusses the concept of “new normal life” and how societies and individual will be affected by this “new normality”.

Prof. Nikola Kasabov

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Technology-Driven Pandemic Monitoring Applications

The Science behind the COVID Pandemic and Healthcare Technology Solutions: An Introduction



Sasan Adibi, Abbas Rajabifard, Sheikh Mohammed Shariful Islam,
and Alireza Ahmadvand

Abstract Since December 2019, with the emergence of a new family of coronaviruses named SARS-CoV-2 a global outbreak took the whole world by surprise. It soon started overwhelming the global healthcare systems, with its numerous waves and the emergence of new virus variants, making the management of the pandemic extra challenging. The fast-changing dynamics of COVID-19 pandemic gave us the opportunity to assess our healthcare infrastructure in a systematic way. There was also a growing need and desire for technology-assisted interventions to keep us safer in public spaces. To address the challenges presented by COVID-19 pandemic, this book aims to present the latest technology advances tested and utilized for the management of the current global pandemic. It further aims to propose a potential roadmap on how to move forward, develop new technology-driven paradigms and solutions, and elucidate the roadmap towards normalcy, with hopes to continue living gracefully with the help of technology while accepting the existence of this virus in our societies. In this introductory chapter, we aim to provide insights into the topics presented in various sections and chapters of this book, which is comprised of the following sections: Technology-driven pandemic monitoring applications, Non-invasive COVID-19 detection and diagnostic systems, Decision-making analytics for COVID-19, Psychological and educational interventions in COVID-19 pandemic, Location intelligence and community resilience in pandemic situations, and Future directions and roadmaps.

Keywords Introduction · Chapter review · Book overview

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In December of 2019, a new family of coronaviruses, labeled as “novel coronavirus” or SARS-CoV-2 emerged. The appearance of this new outbreak took the whole world by surprise and soon started overwhelming the healthcare systems globally by a sudden influx of patients requiring urgent medical assistance. Since then, the COVID-19 pandemic has gone through numerous waves and the emergence of new virus variants has made the management of this pandemic extra challenging.

The fast-changing dynamics of COVID-19 and the resulting pandemic have given rise to the important opportunity of looking at our healthcare infrastructure in a systematic way. In some areas around the globe, cities have gone through multiple waves of COVID-19 and there has been a growing dire need and desire for technology-assisted interventions to keep us safer in public spaces. This can be achieved by assessing the well-being of the technology users as well as receiving constant updates from public health and government agencies, plus incorporating predictive mechanisms to issue a warning at times of possible outbreaks. In addition, while global communities and businesses are trying to adapt to the COVID-19 pandemic, location mapping tools and information are widely used by health departments, safety and emergency management authorities and wider professionals worldwide for gathering and analyzing data for supporting informed decisions.

To address the challenges presented by COVID-19 pandemic, this book aims to present the latest technology advances tested and utilized for the management of this global pandemic. It also aims to propose a potential roadmap on how to move forward, develop new technology-driven paradigms and solutions, and elucidate the roadmap towards normalcy, with hopes to continue living gracefully with the help of technology while accepting the existence of this virus in our societies.

This book is comprised of the following sections:

- Technology-driven pandemic monitoring applications
- Non-invasive COVID-19 detection and diagnostic systems
- Decision-making analytics for COVID-19
- Psychological and educational interventions in COVID-19 pandemic
- Location intelligence and community resilience in pandemic situations
- Future directions and roadmaps.

In this introductory chapter, we aim to provide insights into the topics presented in various sections and chapters.

1 Section I: Technology-Driven Pandemic Monitoring Applications

During the first waves of COVID-19, and before the availability of approved vaccines, monitoring the status of transmission and severity of the infection throughout different geographical areas was managed through regional and distributed contact

tracing approaches, including QR code check-ins and updating the list of hot spot infection sites or super spreader locations.

The first section of this book reports on the healthcare technologies used for contact tracing, testing, and pandemic control based on smartphone applications. This section includes 8 chapters describing contact tracing tools and techniques for proximity tracing, outbreak response, and symptoms tracking:

Chapter 2. Pandemic's Behavior of One Year in Six Most Affected Countries using Polynomial Generated SIR Model.

In this chapter, the behavior of the pandemic is studied in six most COVID affected countries of the world with the focus on the effectiveness of recovery rates, rate of infection of the virus, total active cases, deceased cases and recovered cases.

Chapter 3. Digital Contact Tracing for COVID 19: A Missed Opportunity or An Expensive Mess.

Despite the rapid adoption of digital contact tracing worldwide, there have been several causes for disparity in utilization of the technology, including privacy and accuracy concerns, which are discussed in this chapter.

Chapter 4. A Re-configurable Software-Hardware Convolutional Neural Networks (CNNs) Framework for Automatic Detection of Respiratory Symptoms.

This chapter addresses the early diagnosis of respiratory conditions using low power scalable software and hardware involving end-to-end convolutional neural networks (CNNs). This is achieved by proposing a scalable multimodal CNN software-hardware architecture.

Chapter 5. A Comprehensive Telemedicine Service in Hong Kong Provided Through a Mobile Application.

This chapter highlights the experience of developing a telemedicine program for public healthcare services in Hong Kong.

Chapter 6: Adapting to Live in the Global Pandemic Era: Case Studies.

This chapter illustrates applications and solutions that can aid the adaptation processes of living in the global pandemic era, with case studies of security concerns and how quickly a new business can be introduced to cope in the era of the pandemic we are currently living in.

Chapter 7: Towards QR Code Health Systems Amid COVID-19—Lessons Learnt from Other QR Code Digital Technologies.

This chapter features the possibility of utilizing the QR code technology for health information systems to monitor the migration patterns of people, and to validate COVID-19 test results and vaccination certificates.

Chapter 8: Optimal Testing Strategies for Infectious Diseases.

In this chapter, six main guidelines are established, dictating estimated variance of prevalence and associated risk for inflow quotas allocation between population groups, as well as optimal posterior updates via classic confidence intervals and Bayesian methods.

Chapter 9: *Contact Tracing in Healthcare Facilities Using Bluetooth.*

This chapter describes a Bluetooth-based framework consisting of a heterogeneous architecture that supports contact tracing and exposure notification in hospitals and nursing homes, while meeting the required level of accuracy and privacy.

2 Section II: Non-Invasive COVID-19 Detection and Diagnostic Systems

In the context of COVID-19 detection and diagnosis, non-invasive methods refer to a class of intervention systems used for managing COVID-19 pandemics by minimally engaging with the subjects in a physical sense, such as utilizing image, video, and other types of waveforms. This is very convenient for the subjects (the people being monitored) as well as in public health scenarios, where scalability may be supported through such non-invasive approaches.

The second section of the book focuses on non-invasive technologies for diagnosis and detection of COVID-19, and also on preventive measures. It includes four chapters covering the topics of: smart materials, non-invasive physiological markers, bedside gadgets, and patient-centric wearable devices.

Chapter 10: *Monitoring the Health and Movement of Quarantined COVID-19 Patients with Wearable Devices.*

In this chapter, a prototype wearable device and a cloud-server solution are proposed, which were tested for their usability. The findings suggest that this device can assist in the remote monitoring of the location and health condition of quarantined people.

Chapter 11: *Context-Aware and User Adaptive Smart Home Ecosystems Using Wearable and Semantic Technologies During and Post COVID-19 Pandemic.*

This chapter provides evidence-based applications and a comprehensive understanding of the use of wearables and smart home ecosystems during and after COVID-19 pandemic for health care providers, researchers, students, and technology developers.

Chapter 12. *Wearable Tracking: An Effective Smartwatch Approach in Distributed Population Tracking During Pandemics.*

This chapter highlights a generalized approach for designing and developing wearable internet of things (wIoT) with enabled health technology solutions, which can act as predictive and real-time mechanisms to issue alarms and execute notifications,

enhance context-aware location features, and promote contact tracing of the subject to promote early pandemic management procedures.

Chapter 13. *Making the Invisible Visible—A Science and Society View of Developing Non-invasive Thermal Technology.*

This chapter describes the development of a prototype for health intervention. It highlights the necessity to include interdisciplinary working practices between engineering and social sciences, and building an integrated body of knowledge, particularly in circumstances that require rapid response to global problems, such as COVID-19. It highlights socially-relevant topics such as ethics of health measures, privacy in surveillance situation and social equity in pandemic management.

3 Section III: Decision-Making Analytics for COVID-19

Decision-making analytics is a very diverse and multifaceted topic, which involves a number of key technical buzz phrases and disciplines, such as: data analytics, machine learning, artificial intelligence (AI), deep learning, and big data. These key technologies have been assisting researchers in almost any research areas to gather, classify, categorize, and make sense of the captured information. In the context of COVID-19, these key technologies have shown very promising results for important decision-making models and practices, such as contact tracing, vaccination, community assistance, and healthcare supports.

The third section of the book focuses on decision-making analytics for detection and management of COVID-19 interventions, and includes the following chapters:

Chapter 14. *EMD and Horizontal Visibility Graph-Based Disease Tagging for Covid-positive Chest Radiographs.*

This chapter describes preliminary steps in the ongoing implementation of horizontal visibility graphs (HVG) and related Hamming-Ipsen-Mikhailov (HIM) network similarity (distance) metric to provide automatic disease tag for normal and COVID-positive chest radiographs.

Chapter 15. *Mobility Analytics and COVID-19 in Greece.*

This chapter presents three main aspects of epidemic modelling in detail, with Greece and its SARS-CoV-2 outbreak during 2020–2021 as a use case. Epidemic monitoring and predictive analytics are discussed through the underlying system dynamics, as well as the limited availability of timely and reliable epidemic data.

Chapter 16. *Dynamical Modeling of Outbreak and Control of Pandemics: Assessing the Resilience of Healthcare Infrastructure under Mitigation Policies.*

This chapter introduces three dynamical methods applicable to the modeling of various aspects in healthcare infrastructures. The described model is applied to the

analysis of the COVID-19 outbreak and mitigation strategies in the city of Izeh in Iran.

Chapter 17. *COVID-19 Diagnosis with Artificial Intelligence.*

This chapter briefly introduces Artificial Intelligence, its strong potential, and its capability of making manual procedures faster and more accurate during pandemics.

Chapter 18. *COVID-19 Features Detection using Machine Learning Models and Classifiers.*

In this chapter, different machine learning techniques are implemented to detect the features of COVID-19, including chest X-Ray and computed tomography (CT) medical images to identify lung infections.

Chapter 19. *Cough Detection using Mobile Phone Accelerometer and Machine Learning Techniques.*

This chapter focuses on investigating workable methods for automatic detection and classification of cough, which allow both identification of COVID-19 patients and their long-term monitoring.

4 Section IV: Psychological and Educational Interventions of COVID-19

Two hardest hit-areas by the COVID-19 pandemic have been the psychological and mental health of individuals and the larger societies, as well as the education sector. It is no surprise that the mental well-being of people has been impacted very early on in the pandemic, due to the extended lockdowns and limitations in social gatherings. The same impact was felt in the education sector as schools and universities rolled into online learning mode with little to no prior preparation, leaving millions of students off-guard to deal with the online education challenges.

The fourth section of the book discusses technologies to mitigate the negative psychological effects of pandemics and its impact on education.

Chapter 20: *Mental Healthcare in the 'New Normal': Digital Technologies for Pandemics.*

This chapter offers an overview of digital technologies to support mental health during the current and future pandemics. It analyses the mental health effects observed during the Covid-19 pandemic, highlighting social groups that are vulnerable to those effects and showing how digital technologies can help, now and in the future.

Chapter 21. *Innovations in Surgery—How Advances in the Delivery of Surgical Care and Training can Help Hospitals Recover from COVID-19.*

This chapter discusses how adopting technological innovations might help reduce the backlog of unmet surgical care. It examines how the shortfall in surgical training could be mitigated through technology-enhanced learning (TEL), based on extended reality (XR) tools.

Chapter 22: *A Biomarker-Based Model to Assist the Identification of Stress in Health Workers Involved in Coping with COVID-19.*

This chapter describes a theoretical study concerning the health of professionals who work on the front lines. It proposes a model based on some biomarkers for identifying and classifying stress levels. It discusses the possibility of integrating the model in a recommender system aiming at proactively proposing mitigation actions in the surveillance of occupational stress of those professionals.

Chapter 23: *Diagnosis and Management of Oral Maxillofacial Surgery and Dental Education During the Pandemic.*

This chapter deals with two topics: maxillofacial surgeons being prone to infections through respiratory droplet transmissions and close contact with their patients, and ways to deal with this problem, and e-learning dental training tool that can help to educate clinical staff, for example, to reduce such an exposure risk. It reviews different e-learning software and 3D environments for dentistry education and reviews different measures for patient management during pandemics.

5 Section V: Location Intelligence and Community Resilience in Pandemic Situations

Currently businesses are being tasked to push towards recovery post pandemic and take positive steps towards developing the agility required to stay on top of COVID-19 reemergence.

To that effect, location intelligence and spatial analytics are absolutely essential to strategically enable the leading enterprises to mitigate associated challenges and unlock invisible opportunities.

Therefore, the fifth section of the book covers the spatial and location intelligence, as well as community resilience, which are discussed in the following chapters:

Chapter 24. *Digitizing Pandemic Response Operations in a Resource-Poor Setting.*

This chapter demonstrates the possibility of digitizing the pandemic response management for effective control of the pandemic, in a resource-poor and logistically challenging environment. It examines the information and data flow concerning the business processes of the pandemic response, the technologies adopted and used in these processes and how these were used in the operations and decision making in the Maldives.

Chapter 25: *Resilience to COVID-19 Pandemic.*

This chapter defines a health resilience score to compare the performance of the countries in handling the COVID-19 outbreak. In addition, the causes and effects of stress on mental health and immune system during a pandemic are addressed. Techniques and strategies that reduce stress and increase resilience are also explained.

Chapter 26: *Use of Remote Sensing and GIS Techniques for Adaptation and Mitigation of COVID-19 Pandemic.*

In this chapter we discuss the use of advanced tools, such as Geographic Information Systems (GIS) and Remote Sensing (RS) to devise adaptation and mitigation strategies to control such pandemics. Case studies from various states of India are discussed to explain the controlling strategies which can be developed from these tools and techniques.

Chapter 27: *Mapping Blockchain Technology Prospects and Solutions in the Healthcare Industry for Pandemic Crises.*

This chapter covers fundamental aspects of blockchain technology and its applications within the healthcare industry, particularly targeting smart monitoring systems based on wearables that can provide updates about the individual's health-related conditions (e.g., blood pressure, temperature, location, etc.) to physicians and monitoring agencies.

6 Section VI: Future Directions and Roadmaps

The COVID-19 pandemic was the biggest global challenge we have faced in recent years and graceful emergence from this dire strait, requires a multifaceted international harmony, collaboration, and participation.

The sixth and last section of the book covers lesson learned from the current approaches to manage the pandemic and the roadmap to tackling the next generation pandemic management systems, which are discussed in the following final five chapters:

Chapter 28: *The Role of Healthcare in the Post-Pandemic Era—"COVID Normal".*

This chapter discusses the impact of the pandemic on healthcare industry and how to adapt to the post-pandemic era by modifying the current healthcare management to enable a smooth transition and enhance the healthcare system to combat future pandemics.

Chapter 29: *Scenario Assessment for COVID-19 Outbreak in Iran: A Hybrid Simulation-Optimization Model for Healthcare Capacity Allocation.*

This chapter investigates the effect of spatial units and factors affecting the prevalence of the COVID-19 and reaching an optimal capacity allocation in the health care centers by intervening in government decisions in Iran on disease control. This research is the first to analyze and develop a healthcare capacity allocation strategy

by considering the mutual effects of disease outbreaks and government actions as decision aiding tools via a hybrid simulation–optimization framework.

Chapter 30: *Ensuring a Superior Level of Preparedness and Readiness by adopting a Knowledge-based Network-Centric approach Leveraging Information Systems for Emergency and Disaster Management.*

This chapter offers a new approach to emergency and disaster management such as the COVID-19 pandemic grounded in information/knowledge needs based on the combination of the doctrine of network-centric operations. The presented framework provides appropriate guidance and support for decision-making in real-time, facilitates the flow of factual information and knowledge among all stakeholders, and assists in eliminating disinformation as a factor in decision-making.

Chapter 31: *mHealth Systems and Applications in Post-Pandemic Healthcare.*

This chapter discusses the available contact tracing apps and their technical specifications. Several mobile health (mHealth) apps are discussed, including an overview of the opportunities and challenges of mHealth systems dealing with pandemics.

Chapter 32: *Synergistic Effects of Environmental Factors on the Spread of Corona Virus.*

This chapter investigates workable methods for automatic detection and classification of cough for long-term activity monitoring and identification of patients. An early diagnostic tool in the form of a mobile phone application is used to identify the severity of the disease and to indicate the need and urgency for hospitalization.

Chapter 33: *CFD Analysis of COVID-19 Dispersion via Speaking, Breathing, Coughing, and Sneezing.*

This chapter investigates the mechanism by which, majority of respiratory diseases spread, which is typically based on droplet production and associated physical processes, including fluid instability, breakup, and droplet conversion. The feasibility of this study is achieved using Computational Fluid Dynamics (CFD) tool through accurate simulations. The outcomes of this study can be extended to study future pandemics driven by other respiratory illnesses.

Chapter 34: *COVID-19 Pandemic: Lessons Learnt and Roadmap for the Future.*

This is the final chapter of the book, which discusses the key technological steps towards future post-pandemic directions.

Pandemic's Behavior of One Year in Six Most Affected Countries Using Polynomial Generated SIR Model



Monika Verma and Phalguni Gupta

Abstract In this chapter, the behaviour of the pandemic has been studied for the six most COVID affected countries of the world. The time period considered for the study is one year between April 1, 2020 and March 31, 2021. At the times of uncertainty, the mathematical models play a decisive role in shaping and designing the policies of the government. The characteristics of the pandemic are primarily measured with respect to the number of positive cases, deceased cases, recovered cases, active cases and test cases per day. On this set of data, polynomials of different degrees are plotted to obtain the best fit model of the data. The fitted models are analysed using three statistical parameters namely Root Mean Square Error (RMSE), χ^2 , and R^2 Error. It has used Polynomial Generated SIR Model to determine various epidemic parameters like the basic reproduction number, recovery rate, rate of infection of the pathogen and the likes. The comparative tests are done and they reveal the accuracy of the developed model. The behaviour of the pandemic is observed to be different for different countries according to the recovery rates of the infectives, rate of infection of virus, total active cases, deceased cases and recovered cases.

Keywords Coronavirus · Mathematical modelling · SIR model · Beta · Alpha and delta parameters · Root mean square error · χ^2 · R^2 error

1 Introduction

New challenges always lie a step ahead of human thinking. Right from the Plague of Justinian to 2019-nCoV, human race has been encountered with numerous emerging pathogens of various orders. Zoonotic diseases are a health hazard if not controlled. The continuing threat of the spread of 2019 n-CoV would change the history of mankind to new normal (social distancing, mask wearing, changing patterns of education, altering the nature of jobs etc.). The epidemic of COVID-19 has the origin in Wuhan, China in December of 2019 in a “wet market” where live animals

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were being sold such as bats, dogs etc. Within few months the contagious virus has set its foot almost everywhere in the world. As per the World Health Organisation (WHO), almost the entire population of the world has been affected by the said virus. On February 12, 2020, WHO has officially named the disease caused by the novel coronavirus as COVID-19.

The 2019-nCoV (novel Corona Virus) is one of the seven members of coronavirus family that causes respiratory disorders ranging from mild infection to even death in humans. The four members of the coronavirus family, viz. 229E, OC43, NL63 and HKU1, cause common cold symptoms while the two other strains—severe acute respiratory syndrome coronavirus (SARS-CoV) and Middle East respiratory syndrome coronavirus (MERS-CoV) are zoonotic in origin and are fatal. Bats and camels are the potential hosts of MERS-CoV whereas racoon dogs, ferret badgers carry SARS-CoV. The coronaviruses are extensively spread over the entire planet and their genomes frequently combine to form new variants resulting in the periodical arrival of the infections [1].

Either through direct transmission from infected persons or through the contact from inanimate objects or through an airborne transmission, the SARS-COV-2 coronavirus can enter the susceptible persons and make them infectives. The symptoms, diagnosis, management, treatment (SDMT) is looked after once a person contracts to the disease [2]. As the infections caused by the virus is exploding at a fast pace, the different phases of SDMT post a challenge to the all the concerned subjects whether it be the infective persons or the susceptible persons or the hospitals or the government. The preventive methodology of vaccinating the entire population or isolation of infected persons or curbing the disease at the containment zone offers a large challenge till now.

The re-emerging lethal zoonotic diseases of these orders are conforming to the future where the pandemics would become more common and the preparedness of the governments and the concerned authorities would play a major role in handling the intervention approaches. One of the key roles in this preparedness depends on the mathematical models.

2 Mathematical Models

To predict the future of 2019-nCoV worldwide for each and every country, quite a good number of mathematical models have been proposed in the literature. They can prove to be helpful for governments to stop or minimize the spread of the pandemic and also to see the effects done by the epidemic. The government can then take proper measures for controlling the impact of the virus in general on the public and can reduce the dreadful consequences of the same. Mostly these epidemiological models are a boon in the crisis which the world is currently facing at present.

The main issue of concern is what needs to be estimated through these models. The predictions can be made on a wide variety of subjects. The projections which these models can predict would help the health care department to look into the

various issues like the number of ICU beds, the number of ventilators, the number of health care persons needed in the hospitals, the medical instruments needed for curing the patients, the medicines required, when would the next peak of coronavirus expected, when would the offices, schools and the colleges be opened and when they will be in working condition. The short-term projections are better in comparison to long term predictions as the parameters change unexpectedly in each upsurge of the wave of COVID-19. If we want to predict/analyse the parameters for different countries, the mathematical models cannot predict accurately as:

1. The strictness of social distancing norms which are considered for one country cannot be applied for another country
2. There may be the parameters which are true in the first wave of some country but are not applicable for the second wave of same country
3. Data is not properly reported and the data is underreported
4. Models do not consider a possibility of the second wave [3].

With all these considerations, two types of models are used for predictions and they are simple mathematical models and complex mathematical models. The simple mathematical model does not take into consideration some of the parameters like the ways in which the virus is continuously upgrading itself to spread itself in an effective way, the way in which human population behaves when there is no lockdown, the undetected test cases, whether government policies are followed or not and so on. They simply work on the data that is statistically provided such as the number of positive cases, the number of active cases, number of death cases and test cases.

At the same time, the complex mathematical models are dependent on a more detailed account of the pandemic and they can create the impression of reality as they are considering many parameters such as which age group is getting affected, comorbidity factors such as diabetes, cancer, the risk factors as smoking, pollution levels at a particular place, the population distribution and the likes.

The possibility of correct outcomes in a complex model is also rare because the input are dependent on various factors that are difficult to manage in a particular time as well as the parameters required by the complex model is quite difficult to count and tally. With changing times, the collected input may not be accurate and valid in the near future and that is why instead of calculating single numbers and also to encompass the variations, the range must be given as the results predicted cannot have accurate input.

The assumptions made in the mathematical epidemiological model should be very evident and those parameters that are known but not as such are encompassed in the model should be described with their qualitative implications. The model should be such that it should be able to incorporate the accuracies when the data is uploaded as it keeps on becoming better and better with time. Lastly the models should be such that they should give appropriate warnings to avoid the misinterpretations arising from the forecasts that the model depicts.

As the epidemic does not follow exactly the same trends everywhere, the models should take some local considerations also. The mathematical models are becoming important for predictions as the number of deaths is increasing at an alarming rate

globally. Earlier the models predicted the areas in which the pandemic is likely to spread, for how much duration the virus circulated in a particular community, the number of death cases, all these predictions are found to be helpful before the onset of the spread.

In the current scenario, the mathematical models play a vital role in forecasting the seriousness of the disease, at which scale the pandemic is spreading, how to use the limited resources, the way the government policies are getting changed with time, as the duration of lockdown, banning the public gatherings, going to the temples, restricted people's movement keeps on changing. If one follows the predictions of the mathematical modelling then it is expected that the number of death cases can be reduced, overall scenario can be made better.

Epidemiological mathematical models are best when they are using an adaptive science approach to include the sociological as well as anthropological work. A triangulation approach of the three needs to be developed. In this approach, the input is attuned to the contexts of many factors like ethnography, social conditioning and the local expertise. The output of the models should map to the new context inputs. As the effects would be seen socially and materially the parameters of predictions also include the way in which n-CoV spreads in a given area, which age group is being affected, whether the people are following the social distancing norms properly or not, whether the number of persons who needs the hospital is on the upsurge trend or is there a diminution in the trend of hospitalization.

The longer the time of the pandemic, the better the raw data obtained through which better predictions can be made. First of all, there should be a numerical stability and reliability in these predictions which is quite difficult to achieve due to numerous factors including the speed at which the virus is mutating, the general health of the public, which age group is being looked at and the likes, this output should be traced when they become a part of public life or they form an important part in forming the policies of the locality/government. While following the adaptive science approach, we have to look what is the impact of the use of models in context with the intervention of the government with respect to the general health of the public, the forecasting of the diseases. As the stakeholders are there in every scenario, the models should comply with developing concerns through changing times of the pandemic. Local matters are also a part of concern when there is causality so the modelling using adaptive approach should also pay attention to these things of apprehensions [4].

Telles et al. [5] have recommended that social distancing of 1–2 m and usage of masks with the disinfectants are useful measures for preventing and controlling the pandemic behaviour. In [6], Khalid et al. have focused on the implication of using zinc as the immune function. In [7], the authors have shown the possibility of using wavelets to measure the effect of COVID-19.

In this chapter a model has been used to calculate and analyse the different parameters for six, countries so that the different aspects of the pandemic can be seen clearly and based on it some standpoints can be taken.

2.1 *Susceptible-Infected-Recovered (SIR) Model*

SIR (Susceptible-Infected-Recovered) model and its variations are used by many authors around the world to predict the forecast of the said disease. The model in combination with genetical algorithm has been proposed by Rodrigues et al. [8]. Considering the age-related information, Singh and Adhikari [9] have studied a hybrid SIR model. Hybrid model of SIR with three phases is used by Chaves et al [10] to determine the reproduction number. To forecast the Pandemic in India, Dhanwant and Ramanathan [11] have worked on a SIR approach by using the SciPy software. SIR model with statistical machine learning has been used by Das [12] to predict the pandemic in China and India.

An approach of Bayesian methodology together with SIR is used for prediction of cases in Brazil by de Oliveira et al. [13]. Postnikov [14] SIR model combined with logistic Equation using the MATLAB software has been used to guess the COVID-19 spread in different countries. Using SIR model, Deo et al. [15] have predicted the subtleties of COVID-19 epidemic in India, Hazem et al. [16] have done the same in six countries of the world, while Jakhar et al. [17] have analysed and calculated the pandemic cases for 24 different states of India. Mujallad and Khoj [18] have studied COVID-19 cases in Makkah and Saudi Arabia.

Lopez and Rodo [19] have used SEIR (Susceptible-Exposed-Infectious-Removed) model by enlisting multiple scenarios in Spain and Italy. SEIR with artificial intelligence approach is employed by Yang et al. [20] to forecast outbreaks in China with the time-slice data. Stochastic SEIR model is used by Engbert et al. [21] to forecast the spread of COVID-19 in Germany. A general SEIR model for COVID-19 cases has been employed by Godio et al. [22] to compare cases in Italy, Spain and South Korea. SEIR with regression is analysed to predict the COVID-19 cases in India by Pandey et al [23]. SEIR has emphasized the operative contact rate of pandemic cases in India and has related the results with six other countries. With SEIR, Bonnasse-Gahot et al. [24] have monitored the bed obtainability in France. Using three features of regression, smoothing and age structure, through SEIR model, Dixit et al. [25] have predicted the pandemic. SEIR model of the pandemic for twelve countries is employed by Kohanovski et al [26]. A time dependent SIER modelling has been developed by Teles [27] for the country of Portugal. SEIR with auto regression is studied for epidemic cases in India by Wagh et al [28].

Ray et al. [29] have used extended SIR model for studying the lockdown in India to predict the role of interventions. Cruz and Cruz [30] have modelled SEIR-A (Susceptible-Exposed-Infected-Recovered-Asymptomatic concentration) for the analysis of the COVID-19 outbreak in one of the states of Brazil. Using the SS-SIR (State-Spate-Susceptible-Infected-Recovered) model, Kobayashi et al. [31] have analysed the intervention effect of the Pandemic in Japan. By means of SEIARD (Susceptible-Exposed-Infected-Asymptomatic-Recovered-Dead) model, de Leon et al. [32] have predicted the pandemic results of Mexico. SIR(D) dynamical model is used by Rajesh et al. [33] for the analysis of data in India. SEIAR model for COVID-19 cases in India has been predicted by Khatua et al [34].

In the SIR model, the population is split into three categories: Susceptible, Infectives and Removed. All those persons who have contracted the n-CoV are termed as infectives, the public who has not yet been exposed to coronavirus are termed as susceptible, and all those who have been either recovered or dead are termed as removed. The removed people cannot cause any infection to the susceptible and therefore are not a hazard to the pandemic.

In this model, the basic reproduction number is an important number which is denoted by the alphabet R_0 . Right from the way in which the infection grows in the body to the way the infection spreads in the society, the basic reproduction number captures all these features and then allows the health care persons to work accordingly. In any outbreak this reproduction number holds an important value. If the value of R_0 is less than one then the assumption is that the disease would wane out of its own, but if the number is greater than one then it signifies that the spread of the disease is exponential and necessary measures are needed to curb the spread. Larger the value of R_0 , the worst is the situation for the public.

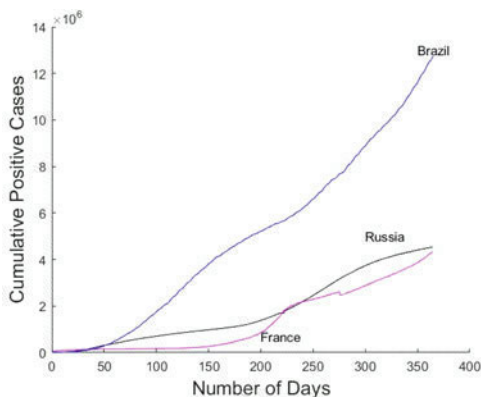
The estimates of the basic reproduction number at the beginning of the outbreak are found to be lying between 1.5 and 4.0. That means the entire human population could have been exploded with the disease if measures are not taken properly with time.

Figure 1 shows the cumulative number of positive cases for the six countries. As actions are taken, practically the exponential growth of the pandemic cannot continue its pace as there would be lesser interaction between the infectives and the susceptible. If no action is taken to control the spread of CoV then only 2% of the population would remain uninfected. The population size, the rate of infection and the death rate are the three components of the basic reproduction number. So, to control the spread of the pandemic, either rate of infection has to be reduced or the population has to be less or the number of recoveries have to be more. The difference between the basic reproduction number and the effective reproduction number is that the effective reproduction number is the average number of infections that are caused by the primary infected people. In either case, the number has to be less than one in order to wane out the outbreak.

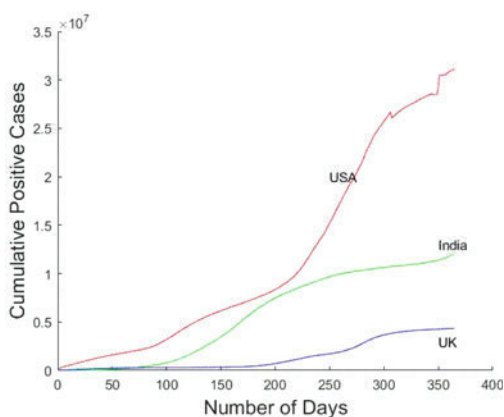
The total fatality rate is not dependent on the basic reproduction number as it does not tell the degree of dangerousness of the disease for an individual. Measles, for example, has a basic reproduction number which has an average value of 15 but is not deadly but the epidemic of EBOLA which has a reproduction number of 1.5 has caused more (approximately 60% of the total infected persons) number of deaths due to the disease.

In the case of COVID-19, the demographics of the population affected is worst in the case of older people. If the infection rate is high and fatality is low then the pandemic may end up killing more people but if the case fatality rate is high during pandemic, then it might create fear but it is less infectious as it might not get sufficient chance of spreading to the other people. The need to control the outbreak is best achieved when the number of susceptible are directly removed without having infection, i.e., by vaccination drive. It's often unfeasible to have vaccine in a suitable timeframe if it is spreading in full swing. So, isolation of infective patients and the

Fig. 1 Diagram of exponential rise of the pandemic of six countries



(a) Cumulative Positive Cases against Number of Days in three countries: Brazil, Russia and France



(b) Cumulative Positive Cases against Number of Days in three countries: USA, India and UK

quarantine of healthy people is used effectively to curb the spread. This chapter considers a simple model of SIR with polynomial generation for comparing the statistics of various countries. Comparison of various parameters of SIR model has been done. The model calculates the basic polynomial fitting of each country followed by SIR model to calculate the graphs.

The mathematical model SIR has been proposed by Kermack and McKendrick, in 1927 [35]. It has explained the dynamics of the communicable disease spreading amongst the susceptible persons in a very simple way which is diagrammatically shown in Fig. 2.

The SIR model describes three classes of the population as depicted in Fig. 2. They are the susceptible, the infectives and the removed. During any disease, people fall in any of these categories. The total population M is the summation of all the