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

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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.

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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 compuetd 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.