Medical Virology: From Pathogenesis to Disease Control
Series Editor: Shailendra K. Saxena

Sachi Nandan Mohanty
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Applications of Artificial Intelligence in COVID-19

Springer

Medical Virology: From Pathogenesis to Disease Control

Series Editor

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This book series reviews the recent advancement in the field of medical virology including molecular epidemiology, diagnostics and therapeutic strategies for various viral infections. The individual books in this series provide a comprehensive overview of infectious diseases that are caused by emerging and re-emerging viruses including their mode of infections, immunopathology, diagnosis, treatment, epidemiology, and etiology. It also discusses the clinical recommendations in the management of infectious diseases focusing on the current practices, recent advances in diagnostic approaches and therapeutic strategies. The books also discuss progress and challenges in the development of viral vaccines and discuss the application of viruses in the translational research and human healthcare.

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Foreword 1

As a way to mitigate the negative economic and social consequences of the current COVID-19 pandemic, artificial intelligence (AI) holds great promise for humanity to adapt and chart a path forward in a social environment in it. Social distancing and working from home and strict restrictions on group gathering have become the norm. The COVID-19 disease, rooted by the SARS-CoV-2 virus infection, has been declared a global menace by the WHO. AI techniques can play a significant role in each pandemic's juncture, starting from its prediction, detection, analysis, generating awareness, and preventive measures to powering robots that can replace humans in hospital wards. As a precursor to the strategic opportunities associated with the shocks brought about by COVID-19, this book explores the enormous potential of artificial intelligence in COVID-19 diagnosis, detection, and prediction, prognosis, and knowledge representation. It will also appeal to a broad readership, including academics, researchers, and medical industry professionals and provide a comprehensive review of AI and ML's role as one effective method in the arena of screening, predicting, forecasting, contact tracing for SARS-CoV-2 and its related epidemic. The book introduces 31 chapters divided into four parts that discuss many interesting and recent ideas that show how AI is helping to tackle COVID-19 including the impact of COVID-19 on the manufacturing and operational ecosystem and machine learning solicitation for COVID-19.

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Foreword 2

We are witnessing an extraordinary test of the human spirit as governments and institutions worldwide take steps to protect people and prevent the spread of the global pandemic resulting from COVID-19. The world as we knew it has changed; forever. Artificial Intelligence and machine learning technologies coupled with the ubiquitous development and deployment of IoT devices are already playing a vital role in helping us control the spread of the disease by supporting testing and tracing. On a broader scale, these technologies enable professionals from multiple disciplines to work collaboratively as we race to find a vaccine that can be deployed widely. It will require interdisciplinary collaboration, and professional organizations like the IEEE (Institute of Electrical and Electronics Engineers)—the largest professional technical organization in the world, with over 400,000 members and a mission of ‘Advancing Technology for Humanity’ will have a vital role to play.

As we all work to learn the impacts on our global economy, two constants remain certain—innovation and economic development—which will remain critical drivers of regional and human success. Organizations like IEEE will play a vital role in this redeveloped world. With the switch to telework and telehealth, the technologies created by IEEE members are clearly making a difference and will continue to play an important role in the new world economy when we emerge from this pandemic. IEEE has the power to support our members worldwide and hold our profession together during these uncertain times.

This collection of articles is intended to provide a framework for anyone interested in the application of AI techniques in healthcare. It is also a bellwether for the future of telehealth as we strive to protect and serve our globally dispersed communities with varying levels of access to healthcare. An important consideration going forward is the ethics of autonomous and intelligent systems and their implementation in telemedicine. Many organizations including IEEE are already working hard to ensure inclusion, diversity, and equity on several fronts from ‘Ethically Aligned Design’, to the ‘Brain Initiative’ to name a few. I applaud the editors for this timely contribution and expect that it will provide a good framework for students and practitioners in the years ahead.

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S. K. Ramesh

Preface

Artificial Intelligence (AI), a practicable assisting tool to bring benefits to society, has been accepted by almost all healthcare disciplines. As technological evolution and transition have transformed the world around us, AI is exercised in almost all junctions of research and development along with other evolutionary developments of the digital age like the Internet of Things (IoT), Machine Learning (ML), Deep Learning (DL), Artificial Neural Networks, and Big Data. Since the potential impact of AI applications in healthcare is increasing day by day from treatments, image analysis, diagnosis, clinical decision assistance to overall healthcare management as well as empowerment of the doctor's skills, such technology can be thought to be an augmented tool to the existing healthcare facility in the fight against COVID-19 and similar pandemics. The COVID-19 disease, rooted by the SARS-CoV-2 virus infection, has been declared as a global menace by the WHO. AI techniques can play a major role in each juncture of the pandemic, starting from its prediction, detection, analysis, generating awareness as well as preventive measures to powering robots that can replace humans in hospital wards. This book is edited to attract a broad audience interested in the employment of Artificial Intelligence techniques in healthcare applications like disease prediction, diagnosis, prognosis, treatment as well as prevention and further research in a similar field.

This book comprises 31 chapters in total. Chapter 1 discusses the AI-powered devices for healthcare as well as provides a review of all research works going for a battle against COVID-19 with a goal that various areas of AI can be further explored and analysed by researchers so that it can be an assisting tool for healthcare industries in different areas to fight back COVID-19 menace. Chapter 2 focuses on a few things about how technologies can help diagnose and contain COVID-19. In Chap. 3, based on the success of AI tools, the authors predict that the AI-based diagnostic will soon come bundled with the X-ray and CT operating software. Chapter 4 highlights how AI technology is used in the medical diagnosis and the early prediction of COVID-19 infection. Chapter 5 used combinatorial (quick), stepwise forward selection, stepwise mixed selection, and GMDH neural network to predict the spread of disease in India. Chapter 6 focuses on symptom analysis and evaluation for COVID-19 patients by adopting random forest machine learning algorithms and at the same time made use of cloud events for putting an insight of region tracking into different colour zones when the patient symptom is captured through a graphical user interface. Chapter 7 presents a brief outline of fundamentals and generic design issues of the expert system and proposes an expert system, ESCOVID, with a set of 43 rules. In Chap. 8, an attempt is made to intimate a healthy normal person about the danger of infection of novel COVID-19. The objective of Chap. 9 is to analyse the current worldwide prognosis scenario (diagnosis and control) along with available technology-based preventive strategies. Chapter 10 presents a clinical knowledge-based system (CKBS) based on a clinical multi-agent case-based reasoning system (CMACBRS). In Chap. 11, the use of various AI with machine learning models to predict the pattern of the disease based on various parameters has been analysed and listed. Chapter 12 starts with a brief discussion on drug discovery with a general expenditure overview and extends with pipeline techniques for automated drug development. Chapter 13 analyses COVID-19 with linear and polynomial regression intending to consider its everyday exponential behaviour along with predicting COVID-19 future reachability across nations by using the real-time dataset. Chapter 14 recommends ML as well as DL as a worthwhile tool to model the COVID-19 outbreak. Chapter 15 proposes a system that will collect the database available on government websites related to statistics of COVID-19, and it will ease the traveller to make decisions for travelling. Chapter 16 proposes a model significant to recognize the features that add further in identifying the heart disease stage level of a patient by employing machine learning algorithms. Chapter 17 discusses the mental health challenges during this COVID-19 pandemic and the possible role of artificial intelligence to combat mental health issues. In Chap. 18, an attempt is made for effective diagnosis of ASD using machine learning and AI techniques during the pandemic. Chapter 19 recounts the different mobile phone apps for contact tracing to control the COVID-19 pandemic worldwide. In Chap. 20 pragmatic analysis of data presented focuses on the role of IoT and social networking in uplifting mental healthcare among the transgender community by minimizing panic and anxiety in the pandemic situation. Chapter 21 aims at analysing contributing factors to the use of technology by people during the COVID-19 pandemic. The fight against COVID-19 by using AI methods, namely Extreme Learning Machine and Long/Short Term Memory (LSTM) of DL, has been emphasized in Chap. 22. In Chap. 23, a wide literature survey is done on the databases such as PubMed, Scopus, and Google scholars by using the code word COVID-19 and the role of potent technologies to mitigate the virus and at the same time impact of technologies on isolation and quarantine. Chapter 24 focuses on the impact of isolation and quarantine on COVID-19 patients with artificial intelligence applications. The objective of Chap. 25 is to determine the factors affecting the behavioural epidemic of loneliness among individuals of all age groups during the lockdown period of the COVID-19 pandemic. Chapter 26 analyses the psychological and economic impact of compulsory job switching on switchers during the pandemic. Chapter 27 determines the important key points to be considered for formulating the utility and traceability of Artificial Intelligence in making the availability of essential goods. Chapter 28 tries to understand the overall effect, as well as the specific change in the pattern the way these companies are managed, operated, and end with a simple model that can be incorporated by any industry and reduce the need to appoint specialists and researchers to get insight. Chapter 29 aims at unfolding the problems to be cropped up in rural India, particularly in the Banpur Block of Odisha State, and devising the way out to address agricultural problems during the COVID-19 pandemic. In Chap. 30, the interaction of nicotine with the SAR-CoV-2 target site suggests the potentiality of nicotine against COVID-19. Chapter 31 describes how all the above applications lead to legal conundrums and the imminent need of bringing amendments to existing legislations or drafting new policies and encouraging the government to bring up initiatives for innovations and research and development on the same.

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Sachi Nandan Mohanty received his postdoc from IIT Kanpur in the year 2019 and PhD, from IIT Kharagpur, India, in the year 2015, with MHRD scholarship from the Government of India. He has edited 24 books in association with Springer and Wiley. His research areas include data mining, big data analysis, cognitive science, fuzzy decision making, brain-computer interface, cognition, and computational intelligence. Prof. S N Mohanty has received 3 Best Paper Awards during his PhD at IIT Kharagpur from International Conference at Beijing, China, and the other at International Conference on Soft Computing Applications organized by IIT Roorkee in the year 2013. He was awarded best thesis award first prize by Computer Society of India in the year 2015. He has guided 6 PhD scholars. He has published articles in 60 international journals of repute and has been elected as a FELLOW of the Institution of Engineers and the IETE and is a senior member of the IEEE Computer Society Hyderabad chapter.

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Part I

AI as a Source of Prides for Healthcare

Comprehensive Claims of AI for Healthcare Applications-Coherence Towards COVID-19

1

Suneeta Satpathy, Sachi Nandan Mohanty, Jyotir Moy Chatterjee, and Anasuya Swain

Abstract

Health care Industries as well as clinical and public health sectors has seen a paradigm shift from a long-established approach to an assimilated advancements in gathering, investigating and testing of ordered and shapeless healthcare data for overall health defensive and safeguarding goals with application of computing technologies. Artificial intelligence (AI) with its enabled cognitive knowledge has proved itself a powerful assisting tool with progressive analysis techniques to the existing healthcare domain. A vast development of AI in the healthcare sphere has become an active assisting instrument for the clinical assistants to derive a better conclusion in many functional medicinal areas like cancer, neurology and cardiology. The powerful techniques of AI include machine learning and deep learning to handle prearranged healthcare data whereas unstructured healthcare datasets are managed by text mining and Natural Language Processing. Also rapid increase of healthcare data leading in the formation of outsized data as well as automated healthcare tools are easily managed by AI-supervised Big data and IoT-based methods. We have made a systematic review of AI application for various medicinal areas keeping an eye on its early hour's assessment of detection, prediction, diagnosis, treatment, as well as prognosis based on data, information, and knowledge retrieved from evidence-based research analysis of

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healthcare tools, publicly available medicinal data and biomedical databases. The chapter also progresses with an acknowledgement of challenges and opportunities in using such tools to map, merge and integrate clinical and public health domain dataset to deal with COVID-19 pandemic. We propose that the clinical, public health community as well as computing technology research should come together and gradually evolve and progress from data and information to translational knowledge so that prevailing AI-based techniques can be a powerful assisting tool for the human physicians to unchain the relevant information of the current pandemic.

Keywords

Artificial intelligence · Machine and deep learning · Healthcare · Public health · IoT · NLP · Big data · COVID-19

1.1 Orientation of Artificial Intelligence in Healthcare Research

Healthcare science has gone through major improvements with applications of AI around the globe with a rising demand for more technically improved, accurate and timely services along with customer satisfaction (Chouard and Venema 2015; CB Insights 2017; Fleming 2018). To give a primer to AI, The technology was coined in the year 1950 with a focus to employ machines to act and behave like humans. It can be defined as a bunch of algorithms and programs that can act like a human brain and carry out the reasoning tasks automatically with the ability of self-learning and adaptability. Artificial intelligence applications in healthcare industries make use of refined algorithms which are designed with cognitive intelligence to adapt and learn the complex features from the voluminous data and perform the tasks automatically and assist in clinical decision-making. The possibility of human error that may arise in diagnostic and curative as well as remedial analysis is being reduced to a great extent with AI-assisted tools in medical sciences (Dreyer and Geis 2017). Such tools also help in making real time disease risk predictions along with outcome of risks. The applications of AI has also brought the latest and in depth information from various medical journals, biomedical databases and real-time clinical practices. Moreover the applications of AI for healthcare are endless.

The current pandemic originated due to new corona virus disease (COVID-19) has tremendously impinged on people's lives and caused countless deaths all over the world. In order to deal with this menace many strategic policies and steps have been formed and implemented over the globe along with employment of Robert and drone technology for sanitization and food delivery. Medicinal technological research is also in progress for discovering drugs and vaccines for COVID-19 disease prevention (Beck et al. 2020). The researchers with AI-enabled applications are also able to analyze X-ray images and CT scan images to detect the COVID-19 infected patients (Rosebrock 2020). So the need of the hour is to have more technological applications for healthcare as well trained healthcare professionals ensuring timely detection and caring of the patients. Artificial intelligence with its automated cognitive knowledge has the potential to make a difference in dealing with the challenges being put forth by the novel COVID-19 virus (Bullock et al. 2020; Petropoulos 2020).

Further the chapter flows with a review of technological application areas of AI in healthcare till date as well as its subfields or sub-domains that can be explored for its demanded application towards medical sciences for a battle against COVID-19.

1.2 Correlated Investigational Analysis of AI Appliances in Healthcare System and Various Clinical Diseases

Artificial intelligence (AI) is the subdiscipline of computer science capable of behaving intelligently to handle complex computational tasks there by exceeding human involvement in many domains including health care (He et al. 2019; Kent 2018). The application of AI has allowed improved identification, anticipation, uncovering and cure of disease like cancer, heart diseases, nerve problems and its related diseases as well as diabetes on time. Moreover application of AI is also being done for various health care data management and its safety efficiently. The following correlated literature review is grouped into four sections that explore the applications of AI acting efficiently in various fields of healthcare and helping the doctors as well as medical research to serve mankind in a better way.

1.2.1 Disease Detection and Diagnosis

AI has been used in different types of disease diagnosis and treatment processes in healthcare. The efficient management of various diseases like cancer, heart disease and other tropical diseases are also done with AI-based techniques. Application of AI has developed talented tools that have enhanced the identification, diagnosis and prognosis of lung cancer by simplifying the complex analysis of CT scan images. Deep learning applications have simplified the screening of lungs cancer disease from chest computed tomography (Ardila et al. 2019; Lakshmanaprabu et al. 2019). The diagnosis of cancerous tissues in mammography images has been simplified with application of AI techniques (Jaleel et al. 2013). Even the survival rate of the cancer patients are also able to be predicted by application of AI. Gene expression data are analyzed and interpreted by machine learning algorithms and AI-based techniques respectively for abnormality detection and classification. Even genetic data is also used for diagnosing cancer cells with AI applied techniques (Venet et al. 2011; Van Ooijen et al. 2018). The genetic turmoil in patients is also identified from their face images with application of various machine learning algorithms (Ko 2018; Sreevatsan et al. 2004) along with supervision of the healthcare providers. Children of 12–40 months old are able to be diagnosed with ASD (Autism Spectrum Disorder) with the help of AI-assisted eye-based tracking technique that studies the healthiness of the brain with a variety of face images (Sumathi and Poorna 2016;

Erguzel and Ozekes 2014). Intelligent AI algorithms have been adopted in Derma Care (Er and Abakay 2015; Al-shamasneh 2017) to analyze different melanoma moles. The algorithms can extract various features from the mole images that are not feasible to be extracted by human eyes. AI supervised imaging techniques are able to detect dimensional, voluminous anal figurical differences in tumour cells that can be used to forecast the further medical decisional results (Er and Abakay 2015). Various heart-related diseases in its primary stage can be detected with biosensors and related point-of-care testing (POCT) systems in augmentation with AI (Vashistha et al. 2018). Similarly diabetes being a chronic disease is normally categorized into two types, Type-I and Type-II can lead to different disorders like neuropathy, nephropathy, retinopathy and cardiomyopathy (Sg et al. 2017; Buch et al. 2018). Such life threatening disease is also construed with AI automated optimized systems named as Rhythm that can auto manage and predict blood sugar levels of the diabetic patients (Malanda et al. 2013). According to the research in radio diagnosis procedure of healthcare is going to augment AI in their routine based examination. The complex radio diagnosis processes have been improved with various modern imaging techniques (Imison et al. 2016). Radio diagnosis branch of healthcare has been super powered with the arrival of ultrasound, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), and Positron Emission Tomography (PET) scanning technologies. These data are being used by various AI-based intelligent algorithms to assist the medical practitioners in drawing concluding remarks. Deep learning application like convolutional neural networks (CNNs) has been done in various medical imaging tasks and proved to be effective in identification and localization of various objects (Lundervold and Lundervold 2019; Choe et al. 2019) as well as in analyzing the brain MRI images. The research in (Lakhani and Sundaram 2017) shows deep learning algorithms are also used in the detection of tuberculosis (TB) from X-ray images of the chest and results obtained proved to have substantial accuracy levels. AI mediated algorithms are also designed to act as augmentation tools for nephrologists to draw decisional conclusions for clinical examinations. The intelligent AI mediated algorithms also built with ultrasonic machines so that ultrasound examination can be carried out even by the naive medical assistants. The AI-based techniques has also improved various dimensional imaging analysis and techniques for getting better quality images (Imison et al. 2016). The intelligent AI algorithms are also adopted by ophthalmologists in diagnosing eye related diseases by giving a brief report of Google brain project where deep learning-based AI systems are employed for the identification of diabetic retinopathy (DR) and diabetic macular edema in fundus photographs. AI mediated techniques are also used for forecasting of epileptic seizure and size of bladder. Recent research reveals that AI has been used for forecasting of functionality changes related to urinary bladder control (Tantin et al. 2020), epileptic seizures (Bou Assi et al. 2018), and stroke predictions (Sakai and Yamada 2019). The techniques of AI are also seen in extracting useful features from biomedical signal data like electroencephalography (EEG) (Hamada et al. 2018), electromyography (EMG) (Kehri et al. 2016), and electrocardiography (ECG) (Rai and Chatterjee 2018).

The treatment practices and strategies are also getting enhanced with AI-based modern treatment design techniques and control monitoring. Even the time span of diagnosis procedures of various medical imaging tasks are getting speeder and accurate with intelligent algorithms being adopted in the process leading to more treatment choice options and patient satisfaction (Imison et al. 2016). Applications of AI also enable doctors to correlate disease related information from public databases as well as from other doctors so as to provide best of the services for the patients (Salman et al. 2017). So application of AI-based techniques along with existing healthcare facilities are able to make the patient's life more radiant by providing more accurate and error free identification and prediction as well as decision-assisted strategies.

1.2.2 Automated Robert Treatment and Drug Design, Discovery

Robots with inbuilt AI capabilities are becoming useful to work along with doctors to do the desired task. The first ever robot used for assisting the surgery related work like gynaecologic surgery, prostate surgery and head and neck surgery thereby improving the competence of the doctors was granted by USA in the year 2000. Medical surgeons and their surgical procedures are now being assisted with Roberts and AI oriented robotic systems (Juza et al. 2014; Prabu et al. 2014) like telemanipulator or through computer control (44) thereby improving the traditional method of surgery in terms of time as well as limitations and restrictions of operating procedure and capabilities of surgeons (Prabu et al. 2014). Da Vinci Surgical System (Bluma and Langley 1997) is a good example that has worked with the Johnson & Johnson pharmaceutical company to plan new surgical robot system. Even the constraints with respect to capabilities and size of da vinci to work for delicate tissues are expected to be overcome by AXSIS robot (Narula et al. 2014). Along with the physical robots being used for surgery, varieties of administrative tasks are also automated through Robotic process automation. Such type of systems are able to intelligently carry out healthcare tasks like keeping the patients information up to date and billing related activities, aforementioned approval as well as retrieving the data from the images for transaction processing (Zaidi 2018).

Design and discovery of healthcare drugs is a time consuming and tedious task. AI technologies as well as machine learning techniques are being adopted to make the things done quickly and safely with accuracy. The research work (Agrawal 2018) in reviews that AI may not be the complete replacement of drug design or discovery rather can act as an assistance to the existing technology for inventing new compounds and find the effectiveness and usefulness of previous medicines. The study in (Svetlana et al. 2009) also reflects that AI-based programs are being adopted to read and learn the existing medicines and suggest the possibilities of restructuring the medicine to fight against the 2014 Ebola virus pandemic. So the research study (Agrawal 2018) justifies that AI-based technologies can speed up the drug discovery and design process to suggest the new drugs for the diseases. The unfavourable reactions of drugs can also be forecasted by the applications of AI-based algorithms.

1.2.3 Healthcare Data Management Supported by Digital Managerial Application

There are various chat bots applications and mobile apps for catering to the needs of the patients like Babylon (Coiera 2006). Such types of apps engage the patients with health oriented questions and can suggest few medications to an extent (Cowie 2018). Even the patient's mental conditions and telehealth can be tracked with chatbot applications. There are also varieties of health auto monitoring systems which are currently being used extensively to remotely monitor the patient's health. There are wearable devices like wrist watches and fitness tracking devices which can keep a record of the number of steps being walked, run and other health related information like weight, calories, etc. that is used for remote patient monitoring (Horner et al. 2011).

Many health care administrative related activities can be organized under the supervision of AI-based technologies and thereby reducing the time being spent manually and increasing the efficiency of the task. The RPA technology is adopted in the healthcare system to automate different tasks like documentation, billing, organizing medical records (Hussain et al. 2014). The technology enabling applications with NLP are able to track the prescriptions and refill it as well as can schedule appointments for the patients (Utermohlen 2018). Another AI-based machine learning application are also able to track many insurance claims being done by the insurers.

1.2.4 AI in Public and Clinical Health

AI is also considered as the budding technology to handle and control various pandemic disease outbreaks in the past. Such technology is also used to find the medium of spread of the epidemic.

1.3 Motivational AI Devices for Healthcare

Today artificial intelligence is a buzzword and its importance is growing day by day due to the role to create the motivation among the users, doctors/healthcare experts by its assistance in certain way and with easy decision making in some functional areas which develop automation system with better speed, reliability and cost minimization than the human beings .The importance of this system has shown its 30% usage all over global companies. The accuracy and acceptance of the changes and challenges grow the importance of AI and its motivation among the various users for its application in different sectors in general and health care sector in particular. Artificial intelligence mainly has its three major categories (Fig. 1.1).

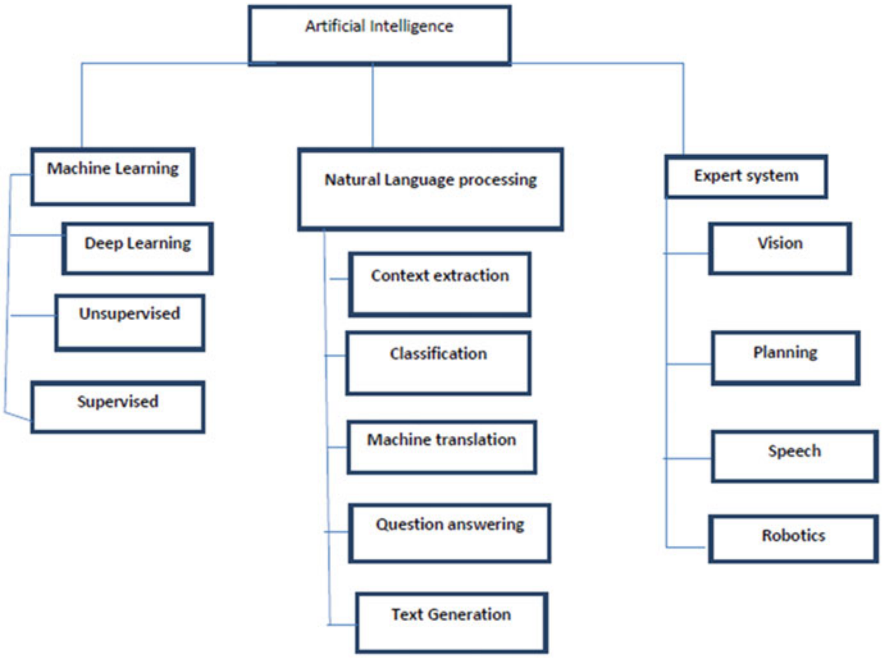

Fig. 1.1 Twigs of AI

1. Machine Learning (ML) and Deep Learning
2. Natural Language Processing (NLP)
3. Expert System

1.3.1 AI-Administered Devices with Machine Learning and Deep Learning

This artificial Intelligence tool defines the objectives of the machines with the learning being held with coding of speed details with a goal to retrieve insights into the resources and detailed information for more futuristic decisions. Machine learning is a statistical design to fit the data in the model and learn it through training. Health care systems use machine learning-oriented AI approaches in many of its applications to make precision decisions with the estimation and evaluation of the available protocols on patient attributes, treatment and its application on current situations. Machine learning's success demands the training with the data set for which the result variable is called as supervised learning. Similarly, neural network technique has been applied in the healthcare sector since 1960 (Lei et al. 2018) for the usage of categorization of applications like determining whether a patient will acquire a particular disease or not with the recognition of inputs, outputs, features, etc. On the same note, deep learning is an artificial intelligence technique composing of neural network models with many levels of features/variables that can predict the result. Deep learning applications on Health care are famous for identification of potential cancerous lesions in radiology images (Sordo 2002). Its major applications are in radionics or in the detection of clinically relevant features in imaging data beyond what can be perceived by the common human being (Vial et al. 2018). It is also used for the speech recognition and is a form of natural language processing.

1.3.2 AI Attributed Devices with IOT

Internet of Things (IOT) and artificial intelligence (AI) are very powerful technologies and combination of both develops AIOT (AIOT) which is a system composed of an artificial person where artificial intelligence works as the nervous system and internet of things works as the brain. AI-based IOT application helps to get the real-time data and create new opportunities for the interpretation. IOT is a network of any objects/software embedded with technologies connected with devices through the internet. This system has its usage from general household items to sophisticated industrial tools. According to Michel today the world is attached with 8.3 billion IOT devices. On the basis of end user, IOT-based artificial intelligence is segmented into healthcare, BFSI, energy and utilities, government and defence, telecom, manufacturing and others. The health care sector is expected to grow its maximum share due to the application of IOT-based artificial intelligence like robot-assisted surgery, virtual nursing of dosage errors, identification of participants in clinical trials, automatic image diagnosis and preliminary diagnosis (Bresnick 2016). Further AIOT has its usage in controlling the traffic activities; teacher's helping aid, smart households, oil industries and security tasks in airlines.

1.3.3 AI Supervised Devices with Big Data and Data Science

Rapid growth of technology and its importance has developed the usage of artificial intelligence and Big data. Artificial intelligence and Big data both are complementary to each other as AI interprets the data whereas big data provide a large volume of usable data for its interpretations but they are different in nature and purpose (Bresnick 2016). Both the technology help the data scientists to be involved with their emotional and cognitive intelligence to take proper decisions for Fault detection/anomaly detection, calculating the likelihood of pattern of interest in the different application areas, Pattern Recognition etc.

1.3.4 AI-Based Mining and NLP

This part of artificial intelligence started its application in the year 1950. Natural language is a process of automatic manipulation of natural language of speech and text technique which examines huge amounts of data patterns and its requirement for a defined process with the regulating speed and accuracy tasks. This technique can answer common customer queries, promote specific products, provide instant quotes, conduct surveys as well as collect customer data. It can strengthen the internal corporate knowledge base with the content generation capabilities and a helping aid to the various aspects of healthcare systems and other sectors by recognising the text speech and conversion of speech to text with the available facility of machine translation. Due to the current pandemic situation caused by corona virus outsized volume of data is produced in academics world. To deal with this amount of data and blend the researchers and scientists with knowledge the Berkeley National Laboratory, Lawrence have developed a COVID Scholar (https://www.hpcwire.com/2020/05/01/supercomputer-powered-text-mining-tool-combs-through-covid-19-studies/) text mining tool powered by NLP, supercomputing and machine learning that can make a scan of papers and articles on COVID-19 with an intention to extract information on it.

1.3.5 AI-Enabled Expert System

Such artificial intelligence device helps the experts for easy and effective decision making and works with various aspects like vision, robotics and autonomous vehicles. Machine vision not only collects but also analyses visual information using the camera and converts analogue to digital to get the best possible results. It can help the business to identify/recognise objects after scanning those and can be augmented in the reality fields that can work on conversion of images and videos into useful insights. Robotics is also considered as another tool of AI that helps to design and develop the robots to perform tasks consistently.

1.4 Demand of AI for COVID-19

WHO has declared CoronaVirus disease (Galeotti and Surico 2020) to be a global pandemic on March 11, 2020 and originated from China in December, 2019. Artificial Intelligence is said to be composed of intelligent algorithms that are built around machine learning, deep learning, natural language processing and expert systems with a purpose to carry out functionalities like prediction, diagnosis, pattern recognition, treatment and assist in drawing decision making strategies for healthcare industries. It has proved its potentiality in various areas of healthcare and medical applications. The pandemic outbreak of COVID-19 has also necessitates the potential use of AI and other suitable computing tools to fight against it (Broad 2020; Hollister 2020; Taulli 2020).

The demand of AI for a battle against COVID-19 can be summarized under few application areas of medical sciences like (1) prior alert generation: early warnings and alerts, (2) continuous tracing and following the COVID-19 symptoms and (3) diagnosis and prognosis, (4) treatment and possible drug design and discovery and (5) control over Society and people with guidelines.

1.4.1 Prior Alert Generation

There are various AI-based models like BlueDot (https://bluedot.global), which has been proved to have potential to forecast the communicable pandemic diseases. It also forecasted the COVID-19 menace well before WHO declared it towards the end of December 2019 (Kreuzhuber 2020). Another AI-based model HealthMap (http://www.diseasedaily.org/about) also able to raise an early warning of COVID-19 pandemic on Dec 30, 2019. Even the research work by the scientists of BlueDot also raised an early alarm for the outbreak of the disease which got published in the Program for Monitoring Emerging Diseases (PMED). Even though AI-based models gave an early warning of the disease outbreak, the prediction was required to be supported by human scientist elucidation. So AI based in time disease outbreak warning generation can act as an assisting tool to the existing healthcare professionals as well as systems to successfully deal with the current COVID-19 outbreak (Hollister 2020).

1.4.2 Continuous Tracing and Following COVID-19 Symptoms

AI-based intelligent algorithms can be trained to continuously follow up the symptoms for COVID-19 disease and do the tracing in the region being spread as well as forecast the future prediction in the society. The similar type of prediction was being done for Zika virus in the year 2015 (Akhtar et al. 2019) with the development of dynamic neural networks. Such types of AI-based prediction models can be reworked for COVID-19 data sets. The research work in (Hao 2020) tries to retrain the developed model to fight with the current situation. The work (Rowan 2020) also highlights that AI models used for retraining with COVID datasets are being hampered with the huge datasets consisting of noisy data from social media. As AI-based prediction models purely rely on historical datasets can result in mis-prediction because of such global outlier of the noisy data created with the panic behaviour of the people. AI-based approaches are starting to be adopted by the social media sites to put a check on their contents (Ortutay and Klepper 2020). So continuous tracing and following up the COVID-19 symptoms and simultaneous prediction of its spread can be effectively done with valid input data sets so that decision making strategic plans can be undertaken by public health and clinical industries. John's Hopkins University's CSSE prediction database is the best example to justify the above cited statement as COVID-19 total affected patients in the Netherlands was less in number than its predicted value.

1.4.3 Diagnosis and Prognosis

According to the research assessment done by Bullock et al. (2020) (Khadidos et al. 2020), AI-based techniques are useful to be used in the diagnosis of COVID-19 from CT scans as well as from X-ray images. The research study by Rosebrock (2020) also shows how deep learning techniques can be adopted to investigate COVID-19 accurately from the X-ray image of the affected patients and can substantially save time. COVID-Net is built with deep convolutional neural network application by Wang and Wong (2020) can investigate chest images for COVID-19 symptoms. CAD4COVID is a remodelling by the scientists of Dutch University of Delft for the old AI model developed by university of diagnosis of tuberculosis, can identify and track the COVID-19 viruses from chest X-rays. So AI-based diagnosis can be accurate, time saver for the radiologist and life saving for the patient if trained with a proper amount of valid datasets. The impact of virus effect may be of different percentages in different patients so, depending on the impact of virus effect various machine learning algorithms are also used by researchers (Yan et al. 2020; Jiang et al. 2020; Suneeta et al. 2021) to model mortality risk of a person as well as the respective treatment to be taken by prognostic modelling. Such AI-based prognostic modelling can be more trained with COVID-19 data driven data sets.

1.4.4 Treatment and Possible Drug Design and Discovery

Discovery of medicinal drugs is a challenging task while it is assisted with the appliance of Artificial Intelligence. AI techniques can help to draw the drugs design outlines by identifying the compositions & compounds with the probability of effective therapies and desired properties in a cost and time effective manner (Coldeway 2019; Fleming 2018; Segler et al. 2018; Smith 2018). Implementation of AI in drug design is strategic in nature due to the lack of limited data sets whereas AI methods used for the drugs design may not discard any known information rather can take the help of all. It can be integrated with Big data and machine learning and can be developed as computational chemistry tools with limited and inconsistent data. Since 1960 AI has been applied to design the drug compounds (Butina 1999). Novel chemical compositions and structures as well as its deployment layout can be generated by AI-based generative models (Seghr et al. 2018). The design and discovery procedure of new drugs with effectiveness and potentiality is costly as well as time consuming (Chang et al. 2012). Structure-based drug design (SBDD) approach forms the basis for designing the industrial drug assignments and scientific researches. Such approach is considered to be vigorous optimization process that deals with the 3D simulation structure of a target protein and knowledge of a disease at the molecular level (Chang et al. 2012). Automated SBDD process has no doubt shortened the time line but Big data dependency will likely increase as the perception of personalized medicinal improvement is considered as the starter of computation oriented medicinal chemistry. The statistical methods are used as a learning technique in AI-based technology for drug development process.

Result oriented Drug Design process supervised by artificial intelligence can be achieved through following steps.

1. Develop a model for the drug—The model development can be undertaken with the utilization of recently deep recurrent neural networks that can make an ease to learn the constitution of drugs.
2. Train the recurrent neural network—The Recurrent neural network can be trained to capture the constitution of a large set of known bioactive compounds.
3. Specification of the model—The model can specify the molecular features from small—target focused collected activities and can transfer learning to drug design and generation.
4. Produce novel chemical entities—Novel chemical entities can be produced within the training data domain to design AI model.

The numbers of research labs are adopting AI to develop treatment for COVID-19 as well as its vaccine and drugs. Even Google's DeepMind, has adopted AI for forecasting the proteins structure of the virus information. Machine Learning algorithms have been adopted by the researchers (Beck et al. 2020) for identifying atazanavir as a potential medicine for the treatment of COVID-19. Also the research by Regalado (2020) outlines that the actual vaccine for COVID-19 treatment will take its time of 18 months.

1.4.5 Control over Society and People with Guidelines

AI-based thermal imaging machines are being adopted in various places to scan the people for potential infection and put a control to it by declaring the social distancing guidelines and lockdown rules (Rivas 2020). The research in (Petropoulos 2020) says that AI enabled mobile apps can provide in time medical advice and updates about the disease being spread so that they can take precautionary measures. Moreover AI controlled machines or robots can also be developed to control the people with the government guidelines for the pandemic.

1.5 Conclusions and Future Work

In comparison to previous eras, the age of digital technology has blessed us with its power and application to deal with every need of society and human live. Looking at to the current tremendously affected situation around the world caused due to COVID-19, there is a need to constantly explore and deploy AI-based techniques in medical science to fight against the pandemic. This chapter outlines the AI devices and its current ongoing research works in the field of radio diagnosis, forecasting of the disease symptoms, prediction of COVID-19 cases as well as necessary drug design and discovery. AI has the potential to play major role in diagnostic analysis, epidemiological tasks, and pharmaceutical manufacturing and research in the battle against COVID-19 provided it is supplied with valid datasets with less outliers or noisy data. This chapter concludes that valid datasets is vital to decide the effectiveness of AI-based tools for current as well as future epidemics. So AI with machine learning, deep learning, NLP and computer vision for forecasting, pattern identification, analysis, interpretation can be an effective tool to be more explored and deployed to make a diagnosis, envisage, and attempt to make a cure as well as can enrich the researchers with knowledge about the different signature pattern of the COVID-19 virus and to deal with socioeconomical impacts.

1.6 Executive Summary

This chapters outlines the AI-powered devices for healthcare as well makes a review of all research works going for a battle against COVID-19 with a goal that various areas of AI can be further explored and analyzed by the researchers so that it can be an assisting tool for healthcare industries in different areas to fight back COVID-19 menace.

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Artificial Intelligence-Based Systems for Combating COVID-19

2

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Abstract

The world has faced and overcame lots of viral and bacterial infections and diseases like Chikungunya, Cholera, Crimean-Congo haemorrhagic fever, Ebola virus disease, Hendra virus infection, Lassa fever, Nipah virus infection, Plague, SARS but currently, the world is under the impact of the very recent and much severe novel COVID-19 (2019n-CoV) which is said to have devastating effects on humans and has affected the highest number of population in the history of mankind (https://www.who.int/emergencies/diseases/en/). To help contain the virus from further spread various approaches are being followed across the world as currently, no vaccine is available for the treatment of COVID-19 so the nations are following various preventive measures. Technology can now be seen as a game-changer in this outbreak as it has made things easier for us since the beginning. Some of the advanced technology like AI, IoT, Big Data, Cloud, etc. can make our fight against corona easier, as they can be utilized in healthcare and research effectively to generate astonishing outcomes so as to contain the pandemic. This paper shall focus on describing a few things about how technologies can help diagnose and contain COVID-19.

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Keywords

COVID-19 · Artificial intelligence · Thermal scanning · Robotic system

2.1 Introduction

The first appearance of the virus was noted in the Wuhan city of China in December 2019 (Phan 2020). It is a new form of the virus of the corona family known to cause respiratory infections of which SARS (Severe Acute Respiratory Syndrome and MERN (Middle East respiratory Syndrome) are also the members. The virus that was found in animals now shows human-to-human transmission with the period of incubation ranging between 2 and 10 days. Some of the major symptoms include pneumonic lungs, shortness in breathing, dry and painful with mild to severe fever, etc. The virus also shows asymptomatic (patient is carrying the infection/virus but shows no symptoms) and due to which WHO was informed on 31st December a few weeks after the spread of the virus until then the virus was spread across the city and among various migrants who visited the city.

Its infectious nature was seen after the continuous rise in cases found in the country and the hospitals being flooded with the patients for the treatment. As the virus was new, WHO also took some time on researching it and at last declared it pandemic but it was too late, by that time the virus had spread across all the continents.

The continuous rise in cases and unavailability of any vaccine has put tremendous pressure on the government, researchers (https://spectrum.ieee.org/news-from-around-ieee/the-institute/ieee-member-news/researchers-spain-blockchain-ai-app-flatten-the-curve), and health workers to find a rapid solution for the cause. As per report a COVID-19 affected person can transmit this virus to 406 people in 30 days if there is no lockdown in that city, but if social exposure is reduced by 75% then one affected person will only be able to infect 2.5 people (https://economictimes.indiatimes.com/news/politics-and-nation/icmr-study-suggests-1-covid-patient-can-infect-406-people-in-30-days-in-absence-of-self-isolation-govt/articleshow/75028122.cms?from=mdr).

As currently there is no medicine or vaccine for COVID-19, researchers and doctors are working day and night to control the pandemic so everyone is asked to follow some preventive measures that can help prevent the spread of the virus and everyone across the world is following the guidelines by their government and concerning authorities.

2.2 How Technology Can Help in Containing the Pandemic?

Technology can act as a great weapon to conquer this pandemic and with the help of these effective and efficient technologies, we can arrive at the solutions quickly without wasting too much time in manual methods as about 1.5 lakhs deaths have happened so far due to corona.

Computers are meant for their efficiency and they can perform computational tasks optimally way better than human beings. The graph below depicts how efficiency changes over time by using technology and without using technology i.e., manual methods. And it is very clear that human efficiency degrades over time and thus humans take more time to process things (Fig. 2.1).

Various technologies can work together to make things easier, as Artificial Intelligence is known for mimicking human intelligence (https://spectrum.ieee.org/tech-talk/artificial-intelligence/machine-learning/yoshua-bengio-revered-architect-of-ai-has-some-ideas-about-what-to-build-next) by use of which we can perform effective predictions based on past data (Vaishya et al. 2020). Apart from this as this pandemic has put a lot of pressure on health workers like nurses and doctors so AI (https://www.computer.org/publications/tech-news/research/initiative-to-defeat-covid-19-thanks-to-artificial-intelligence) can be used to build robotic systems to mimic the behavior of those health workers without risking their own lives.

IoT makes us accessible with lots of sensors and devices that can be utilized to make effective healthcare systems by use of healthcare sensors available to us like temperature sensors, piezo-electric sensors, heartbeat sensors, humidity sensors, etc.

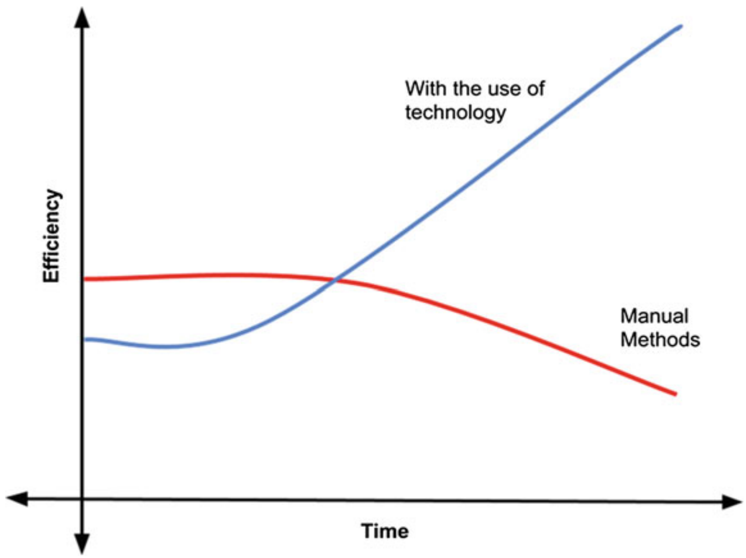

Fig. 2.1 Describing the efficiency of using manual methods over the computational method

Apart from these various data visualization techniques are available to us that make statistical analytics easier and time-saving by visualizing the data in the form of graphs, charts, etc. (Callaghan 2020)

Other technologies like Big Data, Cloud, and blockchain can be utilized together to make things easier and simpler for all that are involved in combating the battle against COVID-19.

From these, we can foresee that the use of technology can be very effective and time-saving as every second is important in this tough time of health emergencies.

2.3 Technological Approach Vs Non-technological Approach of Treatment of COVID-19

It is clear from the above diagram (Vaishya et al. 2020) that the technological approach is far more promising than the conventional it is due to the fact that humans are slow at processing facts and figures as compared to machines as they can process millions of instructions at a time and are way more efficient than us. Talking about accuracy and precision again, machines dominate. So, effective treatment lies in the use of more technological means as they are fast, efficient, and accurate. Also, the use of machines can lead to less human interaction thereby preventing them from being infected while working. As time is critical in these times, the use of technology can also help in reducing the exponential time of detection and diagnosis of COVID-19. Although in some cases, computers are also not that much advanced and we cannot fully rely on systems when the condition of a patient is worsening, In that case, doctor's supervision is necessary for further treatment as computers still are not very effective decision-makers as humans (Fig. 2.2).

2.4 Existing Technologies to Detect/Diagnose the Virus

Technology has woven the world we live in without which our life would have been really tough and challenging. In this pandemic situation, the use of technology is our eminent weapon to contain and cure the corona. Some of the technological equipment that countries are using for the detecting COVID-19 are:

2.4.1 Non-contact Infrared Thermometers

Temperature is vital signs for assessing the illness of a person, the ill person shows higher temperature reading than a normal healthy human. With the use of Non-Contact Infrared Thermometers, one can easily detect someone's body temperature reading from a distance without making any contact with the person's body and this is an effective tool nowadays for detecting ill persons without touching anyone as coronavirus shows human-to-human transmission. The device measures the rise

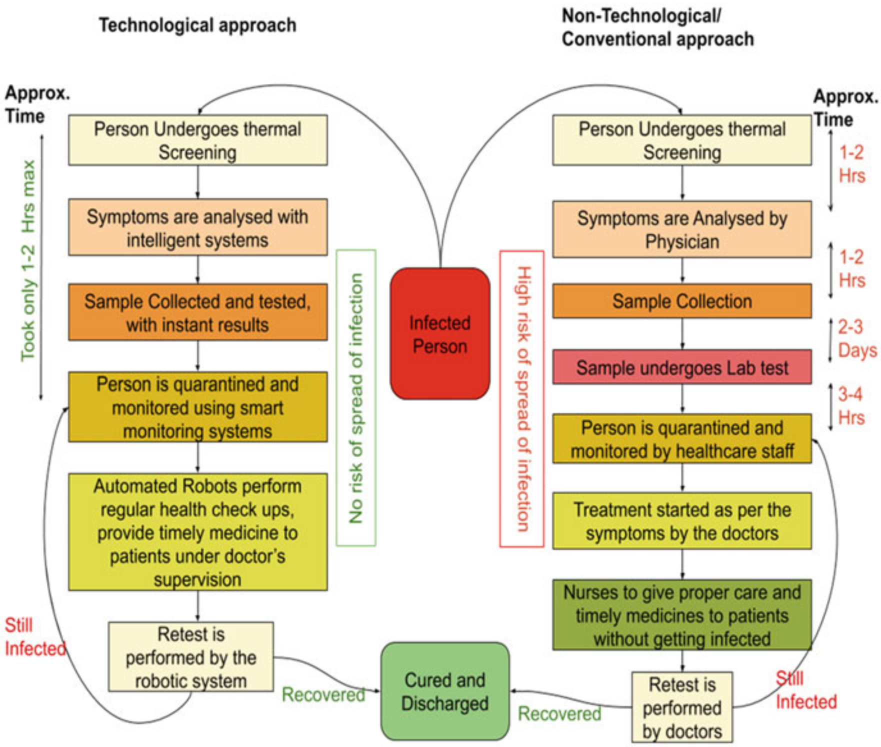

Fig. 2.2 Depicting the technological approach vs conventional approach of treatment

in body temperature due to some viral infections. The basic phenomenon behind the working of Infrared thermometer is black body radiation. Anything at a temperature above total zero has particles within it moving around. The higher the temperature, the quicker the atoms move. As they move, the atoms discharge infrared radiation—a kind of electromagnetic radiation underneath the obvious range of light. As they get more sizzling, they transmit progressively infrared, and even begin to emanate obvious light. That is the reason warmed metal can gleam red or even white. Infrared thermometers distinguish and measure this radiation.

Infrared light works like noticeable light—it very well may be engaged, reflected, or assimilated. Infrared thermometers ordinarily utilize a focal point to center infrared light from one item onto an identifier called a thermopile. The thermopile assimilates the infrared radiation and transforms it into heat. The more infrared vitality, the more sweltering the thermopile gets. This warmth is transformed into power. The power is sent to a finder, which utilizes it to decide the temperature of whatever the thermometer is pointed at. The greater power, the more smoking the item is (https://sciencing.com/infrared-thermometers-work-4965130.html).

2.5 Thermal Screening via Thermal Cameras

Also called thermography is the method in which thermographic cameras are used to detect the radiation evolving from anybody with a temperature greater than absolute zero. Thermal imaging is a very powerful remote sensing technique for a number of reasons, particularly when used to elucidate field studies relating to animal ecology. Thermal imaging data is collected at the speed of light in real time from a wide variety of platforms, including land, water, and air-based vehicles. It is superior to visible imaging technologies because thermal radiation can penetrate smokes, aerosols, dust, and mists more effectively than visible radiation so that animals can be detected over a wide range of normally troublesome atmospheric conditions. It is a completely passive technique capable of imaging under both daytime and nighttime conditions. This minimizes disruptions and stressful disturbances to wildlife during data collection activities. It is capable of detecting animals which are colder, warmer, or the same as their background temperature because it does not compare temperatures but rather the emissivity of the animal against its background (https://www.sciencedirect.com/topics/earth-and-planetary-sciences/thermal-imaging).
These cameras are used in airports and some public places to monitor the passengers and if any person found affected by their temperature reading (https://web.archive.org/web/20120229061442/http://www.applegate.co.uk/b2b-news-articles/more-detail-regarding-infrared-camera-0020792.htm?view=NEWS_105027), they are held by the officials for further screening procedures (de Carvalho and Nogueira 2020). The upside of this technique is that the time taken to get an exact evaluation of the travelers is extremely speedy without making additional postpones travelers showing up or leaving, as they are as of now standing by to experience visa control, this makes warm imaging useful for everybody (https://satir.com/application/thermal-imaging-and-fever-detection).

2.5.1 Symptom-Based Diagnosis

As Corona shows multiple symptoms at a time, the medicine for each symptom is given to patients like hydroxychloroquine is given to patients who have a deficiency in breathing and unable to breathe properly. Indian Council of Medical Research (ICMR) released a research that shows 80% of corona patients only have mild cold and fever (https://economictimes.indiatimes.com/industry/healthcare/biotech/healthcare/80-coronavirus-patients-will-only-have-mild-cold-and-fever-icmr/articleshow/74760035.cms?from=mdr).

2.5.2 Ventilators

Ventilators are used as a piece of life-saving equipment for the patients who have difficulty in breathing due to the hardness of their lungs (condition of pneumonia), the ventilator acts as an artificial respirator through which they can breathe easily and their immune system helps in recovering faster. A ventilator frequently is utilized for brief periods, for example, during medical procedure when you're under general sedation (AN-es-THE-ze-ah). The expression "sedation" alludes to lost inclination and mindfulness. General sedation incidentally takes care of you.

The drugs used to actuate sedation can disturb typical relaxing. A ventilator helps ensure that you proceed with breathing during medical procedure. A ventilator likewise might be utilized during treatment for a genuine lung sickness or other condition that influences typical relaxing. A few people may need to utilize ventilators long haul or for the remainder of their lives. In these cases, the machines can be utilized outside of the medical clinic—in long haul care offices or at home. A ventilator doesn't treat an infection or condition. It is utilized distinctly for eternal support.

A ventilator utilizes strain to blow air or a blend of gases (like oxygen and air) into the lungs. This weight is known as positive weight. You typically breathe out (inhale out) the air all alone, however once in a while the ventilator does this for you as well. A ventilator can be set to "inhale" a set number of times each moment. At times it is set so you can trigger the machine to blow air into your lungs. Be that as it may, on the off chance that you neglect to trigger it inside a specific measure of time, the machine consequently blows air to keep you relaxing. Once in a while, specialists suggest a ventilator called a chest shell. This sort of ventilator works like an iron lung—an early ventilator utilized by numerous polio patients in the only remaining century. In any case, the chest shell isn't as massive and keeping as the iron lung. The chest shell fits cozily to the outside of your chest. A machine makes a vacuum between the shell and the chest divider. This makes your chest grow, and the air is sucked into your lungs. No breathing cylinder is utilized with a chest shell. At the point when the vacuum is discharged, your chest becomes alright and the air in your lungs comes out. This pattern of vacuum and discharge is set at an ordinary breathing rate (https://www.nhlbi.nih.gov/health-topics/ventilatorventilator-support) (Fig. 2.3).

2.6 Means of Prevention from COVID-19

2.6.1 Masks

It is advised to use all sorts of prevention measures so as to contain the spread of Coronavirus, we should use masks and gloves whenever we are near to the infected person and dispose of it properly after every use (for prevention of the spread of virus).

In the market, several types of masks are available but all masks are not capable of preventing COVID-19 virus infection. Mainly three types of masks are available in market these are explained below:

- Homemade Cloth Face Mask: To keep the spread of the infection from individuals without manifestations, the Centers for Disease Control and

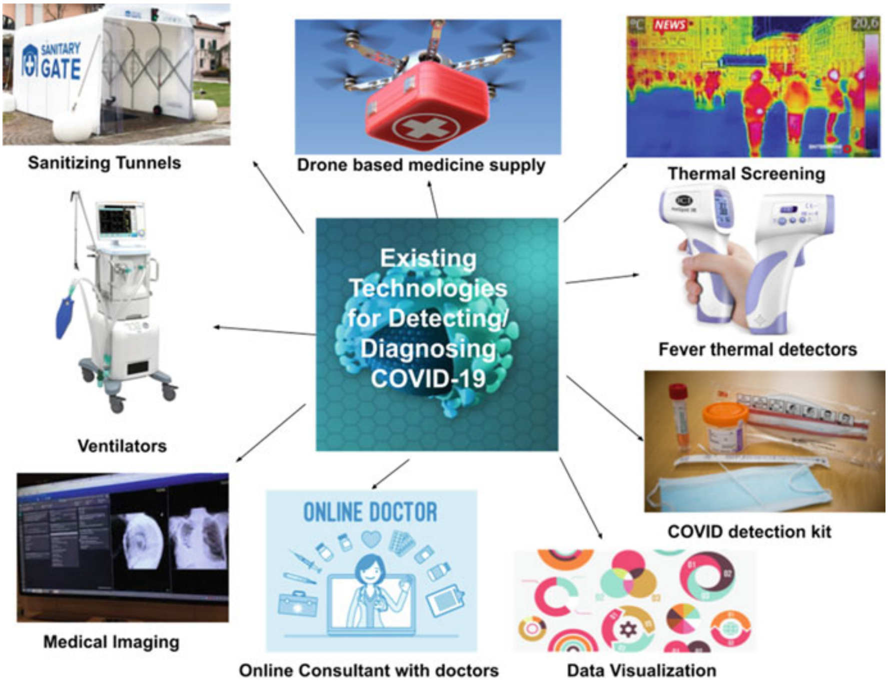

Fig. 2.3 Existing technologies for detecting and diagnosing COVID-19

Prevention (CDC) is currently suggesting that everybody wears material face veils, for example, custom-made face masks Trusted Source, while out in the open spots where it's hard to keep up a 6-ft good ways from others. This proposal is notwithstanding proceeded with social separating and appropriate cleanliness rehearsals.

- Surgical Mask: Careful covers are dispensable, baggy face veils that spread your nose, mouth, and jaw. They're regularly used to shield the wearer from showers, sprinkles, and enormous molecule beads and forestall the spread of possibly irresistible respiratory emissions from the wearer to other people. Careful covers can shift in plan, however the veil itself is regularly level and rectangular fit as a fiddle with creases or overlap. The highest point of the veil contains a metal strip that can be framed to your nose.
- N-95 Mask: An N-95 respirator is an all-the-more tight-fitting face veil. Notwithstanding sprinkles, showers, and enormous beads, this respirator can likewise sift through 95% of little particles. This incorporates infections and microscopic organisms. The respirator itself is commonly roundabout or oval fit as a fiddle and is intended to frame a tight seal to your face. Flexible groups help hold it immovably to your face. A few sorts may have a connection called an exhalation valve, which can help with breathing and the development of warmth and mugginess.

- N-99 Mask: Veils that accompany a N95 rating can channel up to 95% of the particulate issue 2.5 from the air you relax. PM 2.5 will in general remain the longest noticeable all around and can prompt plaque stores in your nose, throat, lungs, or even the courses and can prompt a coronary failure.
- P-95 Mask: The significant distinction between P-evaluated and N-appraised air veils is their capacity to sift through oil-based poisons, which the previous can while the last cannot. Notwithstanding getting out oil-based poisons, these air covers can sift through 95% of the particulate issue from the air. The P-evaluated veils are more effective just as more costly than their N-appraised partners and must be supplanted after around 40 h of use as well (https://www.healthline.com/health/coronavirus-mask#types-of-masks; https://www.guidingtech.com/62349/whats-difference-n95-n99-p95-air-masks/).

2.6.2 Sanitizers/Hand Rub

Use of alcohol-based sanitizer and hand rub is recommended. It can be used in the replacement of soaps but it's good practice to wash hands with soap. The World Health Organisation suggested washing hands on a regular basis at least for 20 s, and using an alcohol-based sanitizer having at least 70% alcohol (https://www.who.int/gpsc/clean_hands_protection/en/).

2.6.3 Sanitizing Tunnels for Public Areas

Sanitizing tunnels are an effective way of disinfecting the whole body in one go, there are overhead sprinklers attached in the tunnel that sprays the disinfectant over our body in a matter of seconds (https://medicalfuturist.com/how-digital-health-technology-can-help-manage-the-coronavirus-outbreak/).

2.6.4 Washing Hands with Soap for 20 s

Washing hands is a good habit and helps in removing 90% of germs of our hands and preventing us from getting sick. As we use our hands to eat and perform activities and sometimes we even touch our face that leads to the spreading of germs inside our body and eventually we get sick, so we should opt for this habit in our daily hygiene to safeguard us from various viruses and bacteria.

2.6.5 Avoiding Handshakes

Handshakes acts as a great medium of spreading virus and germs from one human to another thereby infecting another healthy person also, so everyone should avoid handshakes so as to prevent the spread of corona.

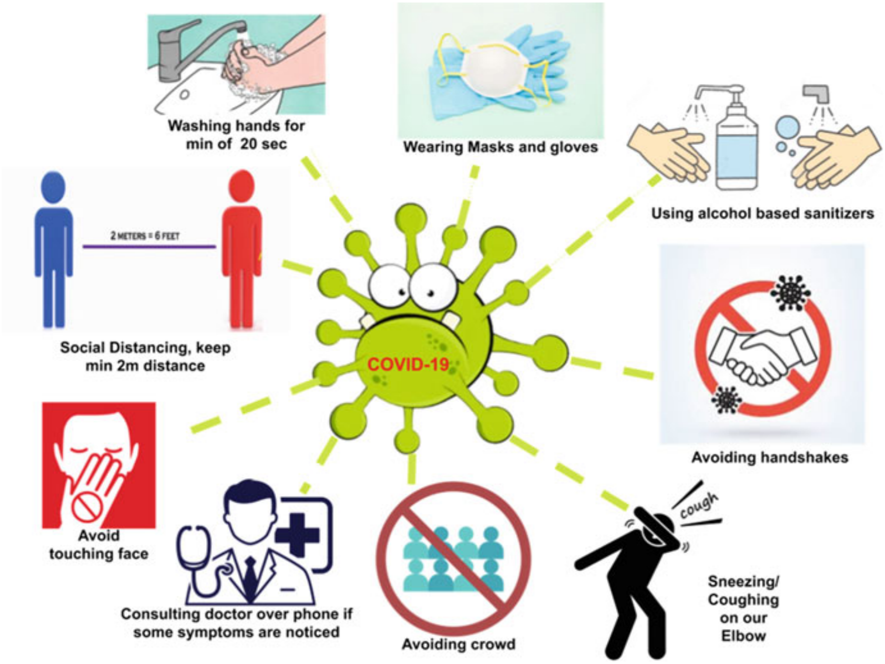

Fig. 2.4 Preventive measures to take to prevent the spread of COVID-19

Social Distancing Up to 2 m/Avoiding Crowd As Coronavirus shows human-to-human transmission and can spread by the infected person within the range of 1 m. So social distancing is an effective way to prevent ourselves from the spread of Corona.

Coughing and Sneezing in Elbow (Folded) In this way, the tiny droplets containing viruses when we sneeze or cough do not move far away and remain with us only, which can easily be washed off. Doing so will help in the spreading of the corona.

Other measures include Opting for E-Healthcare (Kapoor et al. 2020), shopping online, working from home, doing online meetings, etc. (Fig. 2.4).

2.7 Use of Modern Technologies for Making Diagnosis Faster, Easier, and Effective

Thermal cameras can be installed in public places and continuously monitored through AI-based systems to detect the COVID suspects based on their thermal readings, and thereby raising a notification to the concerned officials via the use of IoT for faster action in terms of further screening processes and eventually isolating them from others (Table 2.1).

Table 2.1 Use of modern technology for various applications during this pandemic to prevent it's further spreading

Technology	Can be used for (purpose)	Picture
Robotics	1. In replacement of nurses and caretakers of patients 2. Monitoring patient's health and give them timely medicines 3. Perform routine checkups to know the improvement of patient	
Drones	1. To supply medicines and important kinds of stuff to the public 2. For monitoring and surveillance of hotspot regions of the corona 3. As a sanitizing vehicle to spray disinfectant in isolated areas 4. As a carrier to supply goods	
E-Healthcare	1. Seeking doctor's advice over video calls 2. For online medicine prescription 3. For health counseling, like to gain expert advice on a healthy diet, personal hygiene and relieving stress, etc. 4. Online pharmacy and services 5. Video-based live monitoring of patients (https://spectrum.ieee.org/the-human-os/artificial-intelligence/medical-ai/ai-can-help-hospitals-triage-covid19-patients)	
E-Services	1. Online shopping 2. Online education 3. Reading E-books and papers 4. Using digital money than cash 5. Online meetings, etc.	

Cost-effective and portable medical kit to instantly check the suspect for the contamination.

AI-based systems for classification of diseases based on symptoms to avoid confusion and filter out the public according to diseases (https://spectrum.ieee.org/the-human-os/artificial-intelligence/medical-ai/companies-ai-coronavirus).

Effective data visualization techniques for real-time visualization and updation of data according to a number of confirmed, death, and recovered cases around the world. And also used for making heatmaps to visualize the outbreak and performing data analysis tasks accordingly (Callaghan 2020).

A computerized system for monitoring and providing timely medicines to patients via video under the supervision of doctors without any visit to the isolation ward. The doctors will be looking at the patients via video (Li et al. 2020; https://spectrum.ieee.org/the-human-os/artificial-intelligence/medical-ai/ai-can-help-hospitals-triage-covid19-patients).

Use of AI-based and data science techniques to predict the rise in cases over time and also for the detection of the spread of corona (https://www.thehindubusinessline.

com/opinion/how-technology-helps-in-the-fight-against-coronavirus/article31160578.ece).

Usage of advanced medical equipment and imaging devices (https://www.embs.org/articles/ai-driven-informatics-sensing-imaging-and-big-data-analytics-for-fighting-the-covid-19-pandemic/) for performing researches for COVID-19, and for making vaccines and also to study the genome sequencing of the virus (https://spectrum.ieee.org/the-human-os/biomedical/imaging/hospitals-deploy-ai-tools-detect-covid19-chest-scans).

Other things include robotic systems (McCall 2020) in replacement of nurses and other healthcare staff, telemedicine, video conferencing, autonomous vehicles, and drones for medicine supply, virtual biometrics (Li et al. 2020), etc.

2.8 Proposed Techniques to Effectively Control the Rise in Cases of COVID-19

2.8.1 Crowdsource-Based Applications

Use of crowdsourcing based applications to find suspected cases and make diagnosis easier. Crowdsource refers to, using the crowd as a source for information, as it is not possible for the government to arrange for door-to-door checkups for each and every house in the country during this emergency. So by using a crowdsourced application, the people can inform the officials about suspects in their locality, which saves some time for the government to focus on other localities in spite of approaching suspects for their testing.

One of the recent implementations is in "**Arogya Setu**" **app** by Indian government that keeps track of the individuals whether they are at lower risks or higher risk of infection and warns the phone carrier about the nearby suspects in their locality. The data about the current health status and their medical and travel history is given by the user itself from which it is predicted that the person is at lower risk or higher risk...if the user found to have the symptoms the app triggers alert to government to conduct further tests in this way the app is helping in the testing/prevention process from COVID-19.

Satellite System for Tracking Purpose Satellite-based (https://spectrum.ieee.org/view-from-the-valley/artificial-intelligence/machine-learning/satellites-and-ai-monitor-chinese-economys-reaction-to-coronavirus) tracking for suspected cases using GPS of their phone. It can be effective as everyone is using smartphones nowadays. So based on the past data of a person the government can track him down and prevent further spread of the virus. And also get to know about his contacts and whom that person met or where he went so as to detect and diagnose easily. As the satellite systems now have become more precise and accurate that can take the pictures from just 10/50 m above the ground (https://www.businessinsider.in/science/space/news/heres-how-the-gisat-1-will-add-to-indias-space-power/articleshow/74451883.cms). They can be used to track the person seeking some medical or travel history based on the date from crowdsourced application. So the government has to invest less effort in detecting the corona suspects. Thereby giving more time to look into further diagnosis options.

CCTV Monitoring by AI System Continuous monitoring of hotspots via CCTV via AI-based systems on the basis of collected data. As it is not practical to manually monitor day and night for the hotspot areas over CCTV so AI-based systems can be employed that are capable of detecting the people coming out of their homes despite lockdown and warn them to go back. AI techniques are becoming more and more advanced day by day one such technique is anomaly detection that can be effectively used in CCTV based systems to record the behavior or human whether he/she is spitting someware or trying to spread the infection etc. Apart from that, human detection systems can detect the crowd density and alert the officials about the situation also with the additional support of speakers the system may warn the people about the risks of crowds in the present scenario. This implementation will be very beneficial in terms of containing the further spread of corona.

AI-Based Robotic System Use of AI-based robotic devices to keep track of medications and other aspects. It can be an effective way that can be used in the replacement of some healthcare staff like nurses, housekeeping, etc. (McCall 2020) That can be used to mimic (https://spectrum.ieee.org/tech-talk/artificial-intelligence/machine-learning/yoshua-bengio-revered-architect-of-ai-has-some-ideas-about-what-to-build-next) the activities performed by them so as to reduce the human intervention with the infected person and thereby preventing the spread. AI-based robotic systems can be smart enough to do the fuzzy tasks that are done by human as its algorithms were devised on the basis of human activities and behavior, basically every AI algorithm tries to mimic the human behavior like neural networks mimics the biological neurons, NLP inspired from human talk just like we use grammar and words to speak. So these advanced algorithms that mimics our behavior can be utilized for various purposes like artificial nurses that can take care of the patients. Systems that can check and detect corona can be easily made by use of these algorithms.

Simple block diagram depicts how AI-based system will work (Fig. 2.5):

Voice Assistant Usage for Better Outcome Voice assistants to get information and suggestions and also timely notifications for taking medication. Voice User Interface is a very new technology that can also be termed as Voice AI is the application of advanced AI techniques like NLP and Predicate Logics, etc. Nowadays these find applications in our popular smart speakers like Google Assistant, Siri, Alexa, Cortana, Watson, etc. Through the use of them, some functionality can be added so that they can give advice and suggestions and can act as a personal counselor during the emergency period so as to deal with boredom and stress.

The below figure depicts the various technologies that can be used to contain the corona (Fig. 2.6).

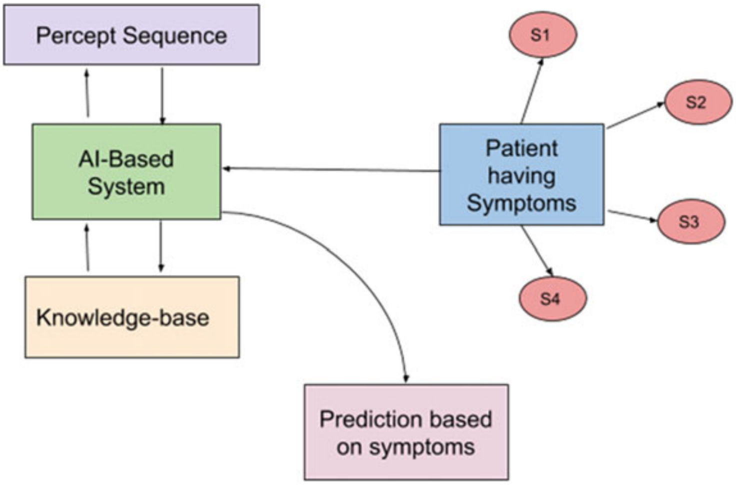

Fig. 2.5 Diagram depicts the working of AI-Based COVID detection system

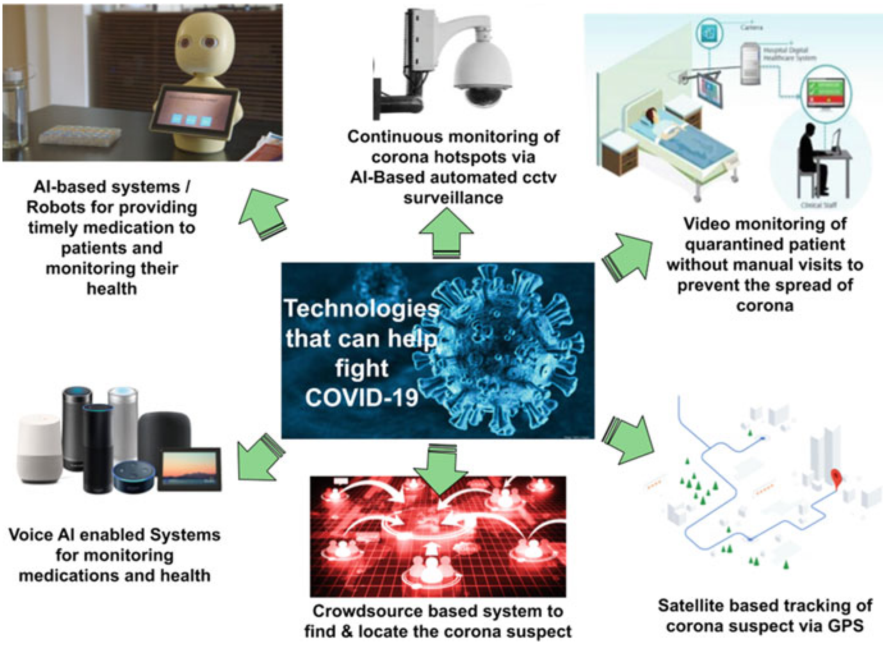

Fig. 2.6 Technologies that can help to fight against COVID-19

2.9 Conclusion

Due to the recent outbreak of COVID-19, the countries across the world are in trouble and they are working day and night and doing their best to contain the virus. As the virus is new and its symptoms are displayed after 2–10 days after getting infected, so it has become really tough to contain it. Due to which almost all the countries across the world with some cases are in lockdown mode. Without worrying about their economy, every country just wants to contain the virus as fast as they can but the situations are getting worse. This is due to the fact that conventional methods and approaches are not enough to contain this dangerous virus, so there's the need for something more advanced and powerful.

Today, technology has evolved and now we have more advanced technologies that can be used in a wide range of applications in preventing the spread and containing the COVID-19.

They can reduce human interaction for the treatment of patients, like robots to perform repeated tasks. Reducing human interaction in healthcare reduces the risk of being affected by this deadly virus during treatment which will lead to the reduction in death cases and prevent the health workers from being affected. They can be used to supply medicines and other important items to the public and also can monitor the areas that act as hotspots for the spread of corona.

There is the limitless application of the technology. The only thing needed is the exploration of how to take help from them so as to prevent, detect, diagnose, and contain the COVID-19.

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Part II

AI Warfare in COVID-19 Diagnosis, Detection, Prediction, Prognosis and Knowledge Representation

Artificial Intelligence-Mediated Medical Diagnosis of COVID-19

3

Malaya K. Sahoo, Prashant Khare, and Mukesh Samant

Abstract

The scale and magnitude of the current SARS-CoV2 or COVID-19 pandemic caused enormous burden to healthcare in addition to the socioeconomics of people and countries. The diagnosis is a key part of the strategies to prevent further spread of the infection and patient treatment. The viral infection can be detected by RT-PCR or by antibody testing for specific IgM. The chest X-ray and CT scan often diagnose the COVID-19 earlier than the laboratory tests. However, when radiologists are overburdened with too many cases it is very difficult to review them accurately and timely. The artificial intelligence (AI) based tools can assist at this step with faster detection of abnormality with comparable accuracy. The AI using neural-network-based models can distinguish COVID-19 from other pneumonia, based on the presence of ground glass opacity (GGO) and other features in X-ray and CT scan images. In addition to the interpretation of the radiological data, AI technology can also help with the optimization of data acquisition, preprocessing of initial slices, restructuring of a 3D image, and augmentation. Combining radiological information with the clinical symptoms and other vital measurements can increase the speed and accuracy of COVID-19 diagnosis. Based on the success of AI tools, we predict that the AI-based diagnostic will soon come bundled with the X-ray and CT operating software. In addition to radiology, the AI can be applied to other related data types from

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simple PCR data to complex high-dimensional cytometry data for automation and extraction of relevant information.

Keywords

SARS-CoV2 infection · COVID-19 diagnosis · CNN · Artificial intelligence

3.1 Introduction

The SARS-CoV2 infection causing the COVID-19 pandemic started at the end of 2019 and spread very rapidly all over the world within a very short time. This caused enormous chaos to healthcare as well as the socioeconomic status of many people and countries.

With 27–32 kb of single-strand positive-sense RNA genome, the coronaviruses have the largest genomes among RNA viruses. The name is attributed to the presence of tall surface glycoproteins or spikes which look like small crown or coronet (Lai and Cavanagh 1997). Phylogenetically, the human coronaviruses (CoV) form seven clusters represented by the strains 229E, NL63, OC43, HKU1, MERS-CoV, SARS-CoV, and SARS-CoV-2. The first four strains cause common cold and are also called the seasonal coronaviruses. The SARS-CoV reported in November 2002 was the first to cause severe acute respiratory syndrome and caught global attention due to its large-scale infection, disease severity and high death rate with almost 9000 reported cases, 88% recovery and 12% deaths by July 2003 (WHO n.d.-a). Later it caused several outbreaks at much smaller scale. In 2012, the MERS-CoV was first reported from Saudi Arabia which remained the epicenter and caused about 2500 laboratory confirmed cases with 34% deaths worldwide (https://applications.emro.who.int/docs/EMROPub-MERS-SEP-2019-EN.pdf). Then in December 2019 the new corona virus causing severe pneumonia was named Wuhan virus based on the origin and first epicenter, 2019-novel-CoV and later SARS-CoV-2 due to its genetic similarity to SARS-CoV. The scale and magnitude of the current pandemic dwarf the Ebola and Zika epidemics in the recent past and is comparable or more deadly than the 1918 Spanish Flu. It has caused 18 million reported cases worldwide and over half a million deaths in just 7 months (WHO n.d.-b). Although SARS-CoV2 is highly transmissible, the fatality rate of COVID-19 is 1–3% which is lower than that of SARS (9.5%) and MERS (34.4%), but higher than that of influenza (0.1%) (Rajgor et al. 2020).

The SARS-CoV2 infection affects people in various ways and a wide range of severity. Walsh et al. (2020) have reviewed 113 studies from 17 countries and compiled the viral load and infectivity over the course of infection. Majority of infected persons experience no symptoms or mild symptoms like fever, cough, sore throat, runny nose or congestion, body aches and diarrhea. Among the symptomatic cases, ~20% develop hyperinflammation in the lungs, leading to acute respiratory distress syndrome (ARDS), multiorgan failure and high mortality rate (Cao 2020). Due to the similarity with other febrile illnesses, it is not possible to diagnose the infection just from the symptoms but suspected based on the potential exposure and context. Only a subset of the patients develops shortness of breath, pneumonia and pain in chest due to the clogging of airways in the lungs with infiltration of excessive immune cells and fluids. The acute manifestation is termed COVID-19, short for Corona Virus disease of 2019.

Because of the differences of the two distinct phases, different approaches are taken to diagnose (1) SARS-CoV2 infection, and (2) COVID-19 disease. The infection status is most commonly tested using real-time reverse transcription–polymerase chain reaction (RT-PCR) assays to detect the presence of viral RNA, as well as antibody tests to detect IgM and IgM produced specifically against the SARS-CoV2 proteins. The COVID-19 or acute state is diagnosed by radiography (X-rays) as well as computed tomography (CT) scans.

The swift and exponential increase in number of cases worldwide poses a huge challenge to the access to healthcare facilities with proper radiological tools and personnel even in developed countries with relatively more available healthcare resources. The use of artificial intelligence (AI) can really help in this situation to complement and make the limited facilities to cater more patients without affecting the quality of service. The field of AI has been evolving rapidly and has reached to the point where it can be used in real-life problems beyond experiments in laboratories. The most prominent advancements have been in image classification due to their suitability in internet-based applications using billions of images by millions of users on thousands of business or recreational aspects. Though the application of AI such as neural network in radiographic diagnosis dates back to at least three decades for example, the ranking of 110 radiographs of bone tumors for possible diagnoses by Piraino et al. (1991), the current mature state has been attained due to improvements of hardware enabling faster and cheaper computing power and software algorithms due to interest of the interest business community.

In this chapter, we discuss the application of AI in COVID-19 diagnosis and its potential for further use in similar situations. The discussion focuses on the medical diagnosis and excludes the other aspects like disease management, infection control, epidemiological and other socioeconomical predictions.

3.2 Pathogenesis and Diagnostic Windows

The entry of corona viruses into the body is mainly mediated through respiratory droplet and potentially by fecal-mediated from close physical contact with the infected person (Amirian 2020). The CoV infections establish in the nasopharyngeal epithelium by attaching to the goblet and ciliated cells, which are rich with Angiotensin-converting enzyme 2 (ACE2) receptor. The phylogenetic proximity of SARS-CoV2 to SARS-CoV cluster initially suggested that both of viruses have the same human receptor (Qiang et al. 2020) and the infection can proceed to other tissue and organ bearing ACE2 receptors. The CoV spike proteins (S) binds to ACE2 and facilitates viral attachment and fusion of host and viral membranes followed by endocytosis mediated internalization and cathepsin and TMPRRS2-mediated cleavage of S protein. The ACE2 receptor is widely distributed in upper respiratory tract, alveolar cells, nasal mucosa, heart, kidney and intestinal cells makes them the ideal candidate of CoV (Donoghue et al. 2000; Sungnak et al. 2020). The cleavage of S protein leads in formation of a 6-helix antiparallel bundle directing the fusion of virus with host cell membrane and finally emancipate of viral genome into cytoplasm of host cell for its replication (Bosch et al. 2003). Once the viral RNA is released, the formation of poorly defined vesicles provides protection to the replicating RNA from the antiviral immune response (Knoops et al. 2008). Primarily, the replication of SARS-CoV2 starts in the mucosal epithelium of the upper respiratory tract that includes nasal and pharynx region and after that, it reaches to lower respiratory tract and gastrointestinal mucosa (Xiao et al. 2020). The CoV genome replication starts with the translation of replicase gene. The formation of replicase-transcriptase complex by the assembly of non-structural proteins (nsp) from ORF1a and ORF1b takes place in double-membrane vesicles which activate the transcription of plus-strand RNA. The RNA-dependent RNA polymerase (RdRp) is encoded by nsp12 (te Velthuis et al. 2010). The nsp13 functions as 5′-triphosphatase and RNA helicase (Ivanov and Ziebuhr 2004) and nsp14 functions as Guanine-N7-methyltransferase and 3′-5′ exoribonuclease for capping of viral mRNA (Becares et al. 2016). This produces the entire viral genome for replication as well as shorter chunks called sub-genomic RNA. The formation of nested sub-genomic RNAs (sgRNAs) take place by joining 5′ leader and 3′ body sequences of mRNA due to discontinuous transcription of RTC (Zuniga et al. 2004). During the synthesis of negative-strand viral RNA RdRp switches the template leading to discontinuous transcription where the sub-genomic RNA is fused to the leader sequence (Kim et al. 2020). This is a distinct ability of Coronaviruses to undergo homologous and non-homologous recombination due to strand switching ability of RdRp (Lai et al. 1985; Maier et al. 2015). The translation of structural proteins like spike (S), membrane (M) and envelope (E) takes place which transported to endoplasmic reticulum and then an intermediate compartment of endoplasmic reticulum and Golgi complex. Here, the N protein mediated nucleocapsid formation occurs, creating mature virus particles, which are released by exocytosis (Krijnse-Locker et al. 1994). The time period between onset of infection and presentation of symptoms called incubation period ranges between 2 and 14 days with median 5.2 days which is consistent with other human coronaviruses (Lauer et al. 2020). Majority of the infected individuals develop some kind of symptoms but close to 40% of cases may not develop any symptom. The nature or degree of the symptoms do not correlate with the viral load (Lavezzo et al. 2020). During this stage the SARS-CoV2 infection can be detected by testing the presence of viral RNA by RT-PCR (reverse transcriptase polymerase chain reaction), isothermal PCR, TMA (transcription mediated amplification), hybridization probes or deep sequencing using targeted or metagenomics approach. The viral proteins can be detected using antigen specific antibodies by ELISA (Enzyme linked immunosorbent assay), lateral flow assays, or IFA (Immuno-fluorescence assay). The nasopharyngeal swab is the most commonly used sample for molecular tests due to the localization and enrichment of infection in the nasopharynx (Fig. 3.1a). While the nasal, oral, or throat

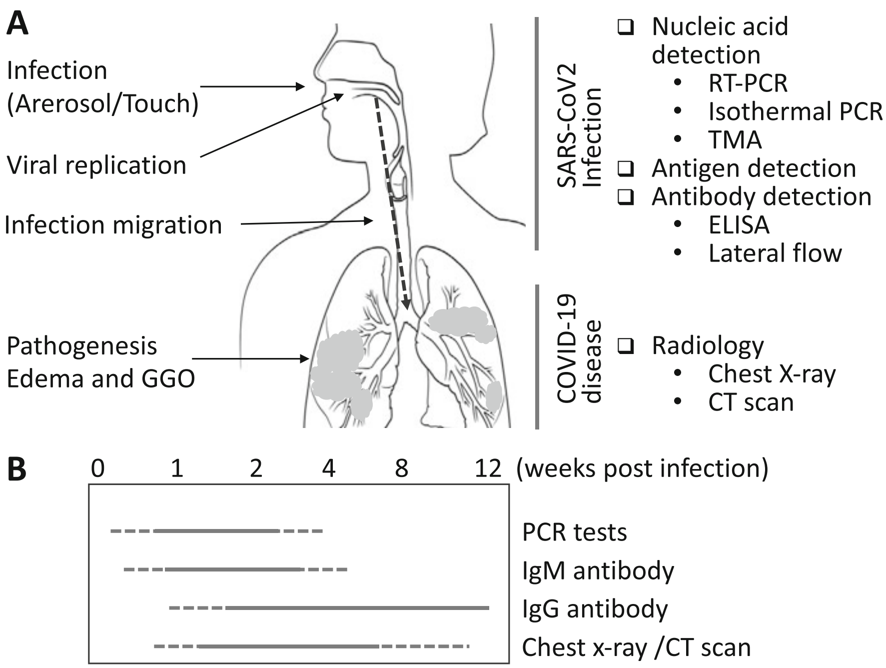

Fig. 3.1 The Course of SARS-CoV2 infection and progression to COVID-19 disease presenting opportunities for diagnosis of different targets by various detection methods (**a**). RT-PCR is the most common and considered the gold standard. TMA, Transcription mediated amplification, and isothermal PCR amplify nucleic acid without thermal cycling. Radiology is the most common and reliable method for detection of the pathology. The different diagnostic methods have different but overlapping time windows (**b**) depending upon the analytes or signatures. For example, a CT scan can be negative in the early stages of disease when RT-PCR and IgM can be detected easily; while toward late stages, the RT-PCR and IgM might be negative, but CT scan shows abnormalities

swabs are also used either as alternative site or for the convenience of sample collection by self. The SARS-CoV2 viral RNA can also be detected in fecal samples for about 28 days after symptom onset in about 55% of the patients (Wu et al. 2020). The other most important diagnostic specimens are plasma or serum from blood collection after infection. SARS-CoV2 specific immunoglobulin (Ig) antibodies present in the serum or plasma indicate current or past infection by the presence of IgM or IgG respectively. The viral RNA can also be detected in blood or derived products which may indicate a correlation with the severity of disease (Chen et al. 2020b, c; Hogan et al. 2020d).

The second phase of infection progression from upper respiratory tract to the lower respiratory tract and then into the lungs using the same ACE2 receptors present on the endothelial cells of lung capillaries is critical to the development of COVID-19 disease. When the infection reaches deeper into the alveoli and lung parenchyma the host immune system produces several proinflammatory cytokines in large amounts and alveolar macrophages and other immune cells are recruited to the clear the infected cells. The vascular lumen loses anticoagulant function due to apoptosis of the endothelial cells which is triggered by rapid viral replication (Iba et al. 2020). The increased vascular permeability, constriction of blood vessels by dysregulation of ACE2 pathway due to competitive inhibition by S protein, and finally the accumulation of edema fluid in alveoli due to dysregulated cellular immunity causes the important COVID-19 symptoms namely shortness of breath and pneumonia (Subbarao and Mahanty 2020). About 15% require supplementary oxygen supply due to low oxygen level and 5% require ventilation due to critically impaired respiratory system, while about 80% of symptomatic SARS-CoV2 infected patients only present mild symptoms (Rokni et al. 2020). The severity of pneumonia related symptoms may also be aggravated by secondary infections due to the malfunction of regulatory cellular immunity. At this stage, the plasma and serum samples can also be tested for tissue specific pathological markers and molecular markers of immune response against SARS-CoV2. The difference between asymptomatic and symptomatic the blood cell counts of severe and critical COVID-19 patients have different levels of cell counts compared to other non-SARS-CoV2 Pneumonia. COVID-19 patients show elevated levels of white blood cells, neutrophils, platelets, C-reactive protein, troponin-I, creatinine, and blood urea nitrogen, while displaying decreased levels of lymphocytes and albumin causing increased neutrophil or platelet ratio over lymphocyte counts, (Zhou et al. 2020b). In addition to the cellular markers, various cytokines and chemokines can also serve as marker for the severity of disease. The levels of IL2, IL7, IL10, GMCSF, IP10, MCP1, MIP1A, and TNFα in plasma are significantly higher in critical patients in ICU compared to less severe non-ICU patients. However, the most important diagnosis of COVID-after the presentation of pneumonia or shortness of breath are based on direct visualization of the tissue damage and edema in lungs using radiological methods like chest X-ray, CT- scan because of the easier and better accessibility of equipment and expertise to medical care systems. From a radiologist's perspective, the COVID-19 is a subset of pneumonia cases with some unique characteristics to differentiate from other community-acquired pneumonia. After all, the COVID-19 was initially characterized as a pneumonia outbreak (Zhou et al. 2020a).

Overall, there are several molecular markers which can be used by laboratories to identify infection, track progression and predict severity of the COVID-19 disease. Of these the RT-PCR and IgM or IgG antibody or SARS-CoV2 antigen testing are useful for the first phase of infection where the outcome mostly indicates the infection, its persistence and the potential immunity against infection. In the second phase of severe pathogenesis in lungs, caused by the infection itself or the overt and dysregulated immune response, the radiological diagnosis methods are more direct to assess the damage and recovery. The molecular markers at this step can guide the treatments strategy to reduce the damaging components.

Methods of AI-Based Analysis The steps of machine learning and deep learning are illustrated in Fig. 3.2. The traditional AI using machine learning relies on extraction of predefined features or based on expert knowledge. Each of the feature

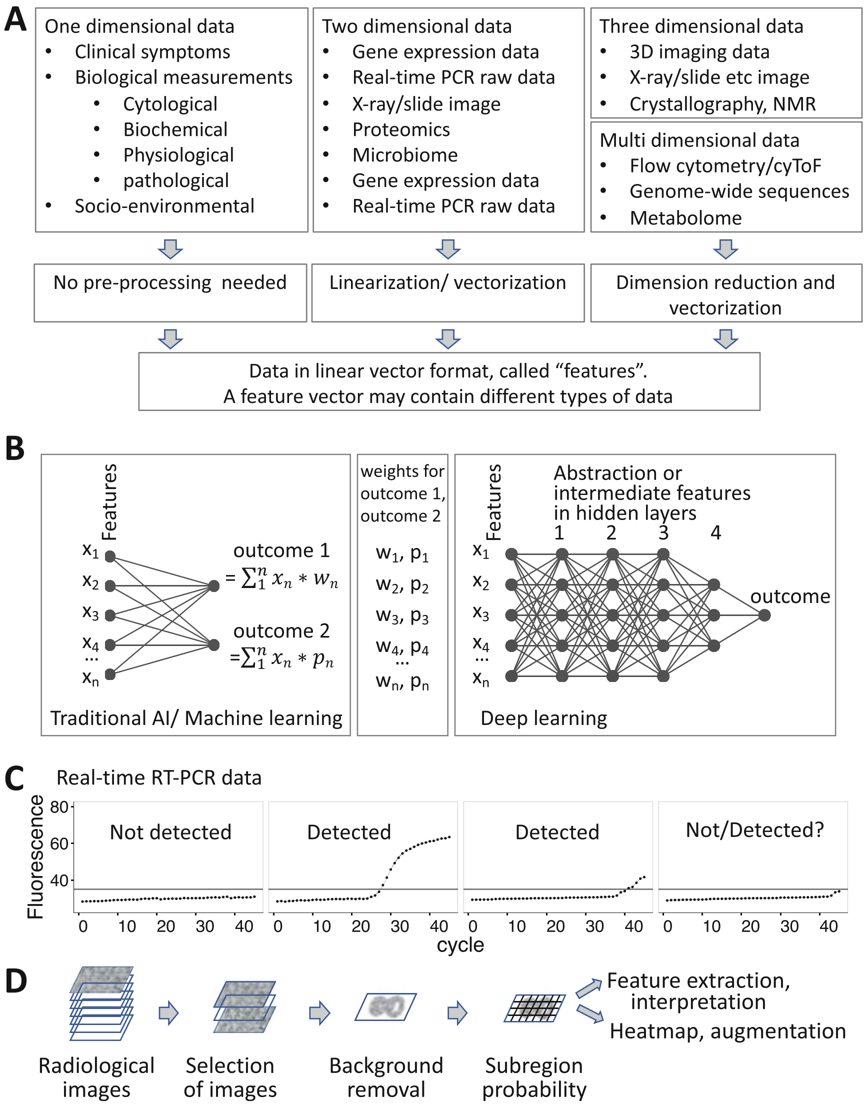

Fig. 3.2 Computational steps in AI. (**a**) The raw data need some preprocessing before they can be fed into AI model. (**b**) With simple data and cleaner features the outcomes can be calculated using a set of weights, which is the central element of any AI model. The weights are initialized with random values and gradually improve with several input data tested over hundreds of iterations. In more complex data several intermediate hidden layers are present. These layers help transform data into features in steps by using one set of weights with the data from the previous layer. The set of weights is gradually corrected by modifying them according to the difference and direction of error. The final model is a set of weight-sets for each node of all layers, which can be applied to data outside the test set. (**c**) The RT-PCR data is a simple linear series of fluorescence signals over thermal cycles or time. (**d**) For complex radiological data, the analysis of each outcome may need deep learning approach. Convoluted neural network (CNN) is the most common in image analysis field. Several modules of CNN or similar models can be used to assist different aspects of the analysis. These deep learning modules require a very large training dataset and large number of iteration to attain good performance. All the steps and modules can be packaged as one single AI application for end users

is either directly from standardized/preprocessed raw data, or a smaller number of features statistically extracted by dimension reduction or derived by selection of top determinants. For PCR data, these features are the set of raw or normalized fluorescence intensity over thermal cycles or time typically represented as an amplification curve, or the derived set of base line, increments, and slopes (Rao et al. 2013). Due to simplicity of the data, the analysis is a straightforward mathematical calculation. AI approach can take a significant amount of computing during training to achieve the same interpretation. However, some of the hidden features might not be captured by the mathematical calculation, particularly when the curve does not fit the sigmoid curve very well (for example an exponential curve which did not cross the threshold, Fig. 3.2c). In proteomics and mass spectrometry data, the features can be the set of peptide or ion counts. The gene-expression data contain the signal intensity or read counts from microarray or RNA-seq respectively. Similarly, datasets from flow cytometry (FACS or cyTOF) contain 5 to 40+ cellular markers on a few thousand to millions of cells from a single sample. In these high dimension data, the features are extracted as abstract summaries, which is a smaller subset of key dimensions, or top eigenvectors. In images, the features can be the color and intensity values of the pixel or extracted features from the pixel in the context of surrounding pixels such as density distribution and diversity. Overall, each element of the data set, raw or calculated, is taken as a feature. The feature set is multiplied by a matching set of parameters (also called weights, to denote the relative importance of a specific features among the whole set) and the sum represents the probability of a specific binary outcome as 0 or 1. Initially the weights are random numbers, used to calculate the probability of outcome as the sum of all features multiplied with the respective weights. Based on the difference between the real outcomes (as 0s or 1s) of all training dataset and the calculated probabilities the weights are adjusted. The process is repeated with the new set of weights. After a large number of iterations, the overall differences between the calculated probabilities and real outcomes become minimal. In deep learning, this involves more steps, where each calculation generates one node in the next layer. So there are $n \times m$ ($n =$ number of features in previous layer, $m =$ number of nodes in the current layer; $m < n$ or $m = n$ or $m > n$) sets of weights while calculating each of the next layers in succession. This is called forward propagation, implemented on each of the training data (one image at a time). Based on the overall difference between outcomes and calculations, the weights are adjusted in steps form right to left, called backward propagation. After many iterations over a large number of training images, the last parameter-set to produce minimum overall difference between the calculated outcome and assigned outcome is taken as the AI model. Any new data set will be calculated using the parameter-set in the AI model and the outcome is predicted from the probability based on a threshold. The set of images initially used to derive the AI model is called training data set. A second smaller dataset with known outcomes is analyzed using the AI model to cross-validate the accuracy of prediction at different probability thresholds using sensitivity, specificity and area under receiver operating characteristic curve (AUC). If the accuracy is inadequate, then the parameter-set needs further adjustments using more training data. A separate model is generated in the same way for each of the desired outcomes.

The AI methods for image processing usually involve more preprocessing compared to other datasets with numeric or logical values. This includes normalization of image size, selection of a subset of most informative images from the CT scan set, removal of area outside the focus organ, and analysis of smaller segments of the images for extraction of additional features with additional machine learning to augmented features. The development of AI model requires the most intense computational resources while the real application based on the final model can be applied in regular computer. The most commonly used statistical machine learning algorithms for image processing are support vector machine (SVM), random forest (RF) and k-nearest neighbor (KNN) (Thanh Noi and Kappas 2017). In deep learning algorithms based on neural networks, several hidden layers consisting of hypothetical features are included in the model before reaching the final set of hypothetical features and calculation of outcome. The hidden layers also help extraction of features from the raw data, so a separate feature extraction step is not necessary. Each of the features in the hidden layers are calculated as the sum of all the features in the previous layer multiplied by respective set of factors for that layer. Similar to machine learning, the factor set is corrected in each iteration based on the error observed in the next layer backward starting from the outcomes (Fig. 3.2b). Convolutional neural networks (CNN) is the leading algorithm used for computer vision and medical imaging (Montagnon et al. 2020).

3.3 AI Assisted COVID-19 Diagnosis

3.3.1 Potential Application for Infection Detection

So far, the RT-PCR is most commonly used molecular approach for the detection of SARS-CoV2 infection and prediction of potential COVID-19 disease manifestation. This is primarily due to the abundance of the technology in molecular laboratories, its high sensitivity and specificity in addition to the simplicity and robustness of the assays. At the current state, the assays do not need much assistance from AI because of the simple and straightforward interpretation of results by well-established algorithms in the field. However, AI can increase the accuracy at the borderline level of detected/not-detected decision-making which is the primary source of error to call false negative or false positive. For example, when sample-pool-based tests are adopted to increase efficiency of testing-resource use and rapid turnaround time for mass testing, the potential false negatives can be significant. Laboratories attempt to use pool-based testing in a population with low prevalence of infection or surveillance scenario (Lohse et al. 2020; Hogan et al. 2020c). While the samples with higher viral load (lower Ct values) can be reliably detected in the pools, the borderline positive samples with viral loads close to the respective assay's limit of the detection may be missed and called negative falsely. Similarly, isothermal PCR-based assays call a relatively higher proportion of false negatives in 20–32%

of samples when a significant portion of the specimens have lower viral load (Hogan et al. 2020a, b) which is expected from a population level distribution. The isothermal amplification methods use time as the X-axis factor instead of number of the temperature cycles in RT-PCR to track the increase in fluorescence signal and calculate a cycling threshold (Ct). These assays perform very well compared to RT-PCR when relatively higher viral load samples are tested. In both the cases of isothermal-based or pool-based tests, a subset of these false negative samples displays an amplification curve which just missed the threshold bar. The thresholds are preset above observed levels of background signal or noise to facilitate simplistic human interpretation. Machine learning can improve this point of interpretation by integrating multiple composite equations from higher order derivatives for the curve, and dynamic threshold in addition to the human interpretation criteria (Fig. 3.2). This has been demonstrated by application of machine learning implemented on quantitative PCR data for optimum Ct prediction (Gunay et al. 2016), interpretation of melt curve data for genotyping sequence variants, and identification of bacteria and prediction of antimicrobial susceptibility (Athamanolap et al. 2014). Overall, AI has potential to improve the accuracy of RT-PCR-based assays by increasing assay sensitivity and reducing false negatives, but it is in the early stage of being utilized by the field.

3.3.2 Application of AI on 'Omics' Big-Data

The most inevitable application of AI in the molecular diagnosis is in multiple 'omics' data such as proteome, transcriptome, and metabolome. These assays analyze a large number of molecules present in samples and generated big data sets, which can only be analyzed using some kind of machine learning algorithms. In general, the metabolomics studies include mass spectrometry (MS) or nuclear magnetic resonance (NMR) to profile all molecular signatures detected in a biological sample, and then use multivariate statistics to compare levels of metabolites between sample groups (Quinn 2017). This is an emerging field with improvements in both the equipment hardware and techniques, better databases of annotated molecules, along with development of deep learning algorithms. Trivedi et al. (2017) have compiled a large number of metabolomic studies identifying smaller list of biomolecules or genes which can serve as diagnostic markers linking to a specific infection or risk of severe disease. AI can make this process more useful and robust by integrating all the dimensions of big-data to train and predict cases instead of ignoring majority of data due to difficulty in interpretation of the whole, and can be used in multiple aspects in the infectious diseases field (Agrebi and Larbi 2020). These datasets can also integrate diverse data sources and types, like cellular and genetic markers, one or more 'omics' data and clinical symptoms in the machine learning model (Fig. 3.2). The nasopharyngeal and serum sample metabolomes have been shown to predict bronchiolitis severity among infants (Stewart et al. 2017, 2019), tuberculosis (Saybani et al. 2015), fungal infection (Lima et al. 2020), respiratory virus infections (Hogan et al. 2019) and the discovery of metabolic markers of complex diseases (Lee and Hu 2019). Using serum sample from healthy versus non-severe and severe COVID-19 patients Shen et al. (2020) demonstrated the application of AI on metabolomic and proteomic data. The application of AI could classify severe cases based on the metabolites and protein signatures in serum samples collected 1–4 days before the actual clinical diagnosis as severe patients. The overall accuracy of predicting severity was 93.5% in the training set and 84.2% in validation. Several studies have analyzed multi-omics data for classifier molecules or parameters for COVID-19 and the severity of the disease. Messner et al. (2020) used a high-throughput semi-automated pipeline for serum proteomics which detected about 3000 peptides representing quantitative data out of that about 200 proteins with minimal missing data. Using DIA-NN, a deep neural network software for proteomic spectral data, 27 potential biomarkers which are differentially expressed to enable gradation of severity based on WHO criteria.

In addition to classification of the severity, the study also identified key molecules for as potential markers of severity and insights for therapeutics. Though the data set was small the results represent encouraging prospect of this approach. Similarly, using RNA-Seq and high-resolution mass spectrometry data from 128 blood samples from patients with diverse COVID-19 severities Overmyer et al. (2020) mapped 219 molecular features with strong correlation with COVID-19 status. The data set comprised of quantitative data for over 17,000 parameters including transcripts, proteins, metabolites, and lipids associated with patient prognoses and clinical outcomes in a curated database. Manny of the key molecular features indicate the involvement of complement and neutrophil activation, and dysregulated lipid transport in the pathogenesis of COVID-19. These studies indicate the complexity of multi-omics data for which the application of AI is a key factor. This aspect is beginning to be demonstrated in actual healthcare setting and the potentials of AI is very promising.

3.3.3 Use of AI on Radiology Data

The majority of AI application on COVID-19 diagnosis has been applied on the radiological images during the severe phase of the disease. The two important factors for this are, (a) information of radiological images match very closely to the severe or critical conditions of patients, compared to RT-PCR data which only diagnoses infection and a majority of infected show no symptom or mild symptoms, (b) the radiological images have a large amount of data worth analyzing with assistance of AI because manual analysis is time consuming, subjective, and error-prone in a hurried situation.

Chest radiographs are well-established part of the routine follow-up of patients with suspected COVID-19 or other pneumonia because of its ability to accurately diagnose quickly compared to laboratory tests. The quick diagnosis of pneumonia in patients is critical to direct early isolation precautions and administration of life-saving supportive therapies. The initial study on clinical characteristics of COVID-19 (Chen et al. 2020a) described the chest X-ray and computed tomographic scans

(CT scan) showing about 75% patients with bilateral, and 25% with unilateral pneumonia, multiple mottling and ground glass opacity (GGO). The bilateral GGO or patchy shadows in the lungs of all COVID-19 patients has been the most common observation by several studies (Caruso et al. 2020; Ng et al. 2020; Wang et al. 2020; Zhang et al. 2020). The CT scan is typically performed by acquiring volumetric CT images of the thorax at 1–1.5 mm slices without administration of intravenous contrast. The conventional chest X-ray is acquired in the posteroanterior projection at initial presentation and followed up in the anteroposterior projection. All available CT and chest X-ray images are commonly reviewed by more than one thoracic radiologist and classified as having GGO, consolidation, cavitation or nodular opacities, and the distribution of lung abnormalities. The CT findings also correlate to the time course of infection: early disease is represented by GGO and similar abnormality, followed by development of crazy-paving and consolidation later in the disease course (Bernheim et al. 2020; Pan et al. 2020). While the RT-PCR and antibody results indicate the SARS-CoV2 infection which correlate with COVID-19 lung pathologies, the time windows for each diagnosis overlap partially (Ai et al. 2020) affecting detection in one platform and not the other (Fig. 3.1b). The CT scan has been widely used as the primary tool of diagnosis for patient with fever and a suspicion of SARS-CoV-2 in several countries including China and Korea, mostly because of its speed and availability (Mei et al. 2020). However, the interpretation of radiological images is complex and subjective, which can be augmented, automated and better standardized using additional AI applications. The application of AI in recognition of complex patterns in images and providing quantitative as well as qualitative assessments of radiological features for the diagnosis of various types of cancer is well established (Hosny et al. 2018). The early application of machine learning on radiological images used supervised learning with manually selected set of features from the images. The recent advances incorporate deep learning techniques in nested steps to automatically extract features to analyze and predict diagnosis.

The AI assisted analysis of CT scans to diagnose COVID-19 was first demonstrated by Li et al. (2020) using a multicenter retrospective study. A deep learning model based on RestNet50 named COVID-19 detection neural network (COVNet) was created by training on 1165 COVID-19, 1396 other pneumonia and 1173 non-pneumonia CT scans. The 3D CT scan images were first preprocessed, and the lung regions were extracted as the region of interest by using a U-net-based segmentation. Then COVNet was used to predict pneumonia from the preprocessed images. The COVNet was able to identify COVID-19 in chest CT scans with AUC 0.96. The differentiation between COVID-19 from other pneumonia despite shared features like GGO is an impressive performance by the model. In addition, a localization map was generated to visualize the important regions in images with a pseudo-colored heatmap of the suspected regions. A similar approach using multiple instance learning (MIL) with a RestNet34 backbone architecture could predict the risk of progression to severe disease in addition to the current severity status (Xiao et al. 2020). Another study (Mei et al. 2020) used AI with multiple deep learning modules for rapid diagnosis of COVID-19 and correlated the results with RT-PCR.

The first module used a CNN model to rank the slices by the probability of containing abnormal parenchyma. Then a second CNN module analyzed the abnormal slices and predicted diagnosis. Finally, a third machine learning module used the diagnosis from abnormal CT scans along with other clinical data to classify COVID-19 positivity. The combination of models along with RT-PCR data were more sensitive at detecting SARS-CoV2 infected cases compared to the radiologists, likely because several positive patients had normal CT. The other possibility of asymptomatic but abnormal CT images were also observed with unilateral and focal to diffused bilateral GGO that gradually progress to consolidations within 1–3 weeks (Shi et al. 2020b). This study also demonstrates the fact that AI can be applied to the entire pipeline including collection of images at correct angle and radiation dose, selection of abnormal slices, and COVID-19 diagnosis of scan images (Shi et al. 2020a). Similarly, CNN with transfer learning strategy can be used to extract COVID-19 specific biomarkers from X-ray images and effectively distinguish COVID-19 cases from other viral and bacterial pneumonia with 96–98% accuracy, sensitivity, and specificity (Apostolopoulos and Mpesiana 2020). With training using 22,000 radiologist-annotated images, an application of a U-Net-based deep learning model produces a probability heatmap of pneumonia overlaid onto an input radiograph to highlight key areas for further confirmation by radiologists. This model used jpeg images of frontal chest radiographs downloaded from research journal publications and found consistent marking of localized area of pneumonia and overall diagnosis (Hurt et al. 2020). In addition to the yes/no answer for COVID-19, AI can catalog the common signs including pleural effusion, halo, vascular thickening, crazy-paving, and can calculate the volume of pneumonia lesions (Ren et al. 2020).

3.4 Future Directions

Due to the availability of easily accessible AI models that have already been developed and demonstrated to work on CT scan and X-ray images they will be more widely used. The deep learning on image data typically required a very large set of data to serve as the training sets need more images for training. This step will improve very soon with larger set of annotated images from collaborative repositories for training, optimization or fine-tuning. In addition, AI assisted image acquisition workflows will make scanning procedures more efficient and can protect medical staff effectively from contracting COVID-19 infection. Then multiple deep learning-based modules will perform specific tasks to preprocess images and extract features which can be directly interpreted by radiologists or physicians. Due to sufficient reliability in the performance of AI models, the CT scanner system's software will be provided as preloaded tools from vendors. For example, Thoracic VCAR software (GE Healthcare) has a tool to generate a concise report of the quantitative measurements of the lung involvement, which can convey the key vital information to referring physicians directly (Belfiore et al. 2020). With the continual refinement of the best deep learning modules and packages, and sufficient computational capability of the existing instrument setup the AI tools will prove to be more accurate and reliable over time. The availability of such AI-based tools in the instrument's own operating software will make its use more routine, less time consuming for radiologists and others, while other more efficient AI algorithms still continue to develop. Finally, some of the tools developed for COVID-19 can also be applied in the other similar diagnostic situations.

Conflicts of Interest The authors declare no conflicts.

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Artificial Intelligence (AI) Combined with Medical Imaging Enables Rapid Diagnosis for Covid-19

4

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Abstract

Recent worldwide pandemic flare-up, Coronavirus disease (Covid-19), an infectious disease that is caused by novel Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). Early diagnosis is the only way to control Covid-19 during this difficult situation. There are many methodologies currently available to test and diagnose Covid-19. For the etiologic diagnosis of this viral infection, standard molecular test such as real-time reverse transcription polymerase chain reaction (rRT-PCR) assay plays a vital role in which nasal swab, bronchoalveolar lavage samples or tracheal aspirate can be used. To identify the mutation in SARS-CoV-2 genome, nucleic acid sequencing can be done. Molecular tests and serological assays can intensify SARS-CoV-2 diagnosis. However, supply shortages of test kits, possibility of false-negative results and consumes up to 48 h to render the results and this may delay the isolation of suspected cases or there will be a chance of spreading infection to others. Artificial Intelligence (AI) has high potential to analyze huge amount of clinical data in a minimal amount of time and contributes a large impact to handle this pandemic outbreak. This technology has been widely used in the field of radiology and medical imaging for research and development. Nowadays, AI plays a significant role in medical

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sciences by detecting or diagnosing various diseases as early as possible and even helps in treating the diseases. In this context, we highlight how AI technology is used in the medical diagnosis and in the early prediction of Covid-19 infection. We extracted data from various research reports, WHO guidelines and other articles. It is important for the readers to know that new data is updated nearly every hour regarding the diagnosis, treatment strategies and outcomes of the disease.

Keywords

Artificial intelligence · Covid-19 · Pandemic · SARS-CoV-2

4.1 Introduction

The novel coronavirus inflicting Covid-19, later denominated SARS-CoV-2 was aboriginal to account for initial human cases in 2019 December at Wuhan City, China. The complete SARS-CoV-2 genetic sequence acquired from initial human cases and in addition to the isolated sequences of various similar viruses from former and all other places around the world exhibits the ecological inception of SARS-CoV-2 in bat populations. The evidence obtained in totality displays the zoonotic source in coronavirus along with entire genetic sequences of SARS-CoV-2 isolated from human cases that are akin. A laboratory expert involved in the rapid collection and appropriate testing of patient specimens confronting the suspect case definition for Covid-19 could be supremacy for outbreak control and clinical management. Based on Johns Hopkins University statistics, besides 14.1 million positive cases recorded across 188 countries, there were more than 602,000 deaths, meanwhile 7.89 million people had recovered. Due to the severity and also the extent of Covid-19 throughout the world, on March 11, 2020, the pandemic outbreak declaration was made by the World Health Organization (WHO). Although the WHO and government of many countries have enforced numerous strategies to reduce the further SARS-CoV-2 spread, various countries were experiencing more cases and deaths. Meanwhile, some countries have controlled and decreased the speed of infection and eventually increased the recovery rate of infected patients. Till now, there is no availability of vaccines to forestall the Covid-19 and this led to the greatest challenge among people, doctors, and health care professionals. Nevertheless, several human clinical trials were commenced for evaluation of the potential treatment based on safety and efficacy. Studies have proved that some drugs against virus like Favipiravir, Remdesivir, Chloroquine/Hydroxychloroquine, Ritonavir/ Lopinavir has a potential to hinder SARS-CoV-2 replication, thus recommended for the Covid-19 patients according to their severity of disease (Malarvizhi et al. 2020). Laboratories' attempt for Covid-19 virus testing should abide by suitable biosafety practices. Infected patients have clinical symptoms including pyrexia (fever) and tussis (cough). Current approaches to diagnose Covid-19 include:

4.1.1 Reverse Transcription–Polymerase Chain Reaction

Reverse transcription–polymerase chain reaction analyses' shorter DNA segment thereby converted from RNA which has a pivotal role in the diagnosis of the SARS-CoV-2, which contains solely RNA (Globe Newswire News Room 2020). Methods of sample collection differ accordingly as throat and nasopharyngeal swabs, sputum, saliva, or airway lining fluids via a suction catheter (Bustin et al. 2009). According to Drosten et al. for diagnosis, swabs samples of throat and nasal are less appropriate than sputum, as these contain less viral RNA and throat swab samples were reliable only at first week while in the consecutive week, the virus multiply within the lungs (Drosten et al. 2003). Henceforth, sputum, or deep airway collection is recommended regardless of sampling saliva which reduces physical interactions and risk of professional's health. The probability of virus detection depends on the sample collection methods and the time elapsed from infection (Merck Manual 2020).

4.1.2 Isothermal Amplification Assays

Isothermal nucleic acid amplification assay amplifies the viral genome quicker than PCR as no long continuous varying temperature cycles are involved while detection is solely through fluorescent tags. The modification in CRISPR gene-editing technology was carried out for detection purposes, wherein the CRISPR enzymes attach with the nucleic acid sequence to colour the paper strips. This is considered as a low-cost alternative and easy to use, where this test involves directs RNA amplification leaving behind the reverse transcription conversion strategy (Joung et al. 2020).

4.1.3 Antigen Tests

An antigen is the part of a pathogen or a foreign substance that activates the host system's immune response thereby producing antibodies. Antigen tests check viral surface proteins or spikes form which is vital for diagnostic purposes. The aforementioned RT-PCR tests are time-consuming with limitation of trained professional, despite with higher accuracy. The White House Coronavirus Task Force head, Deborah Birx stated that 'We can nevermore able to perform PCR tests for 300 million patients per day. However, there might be with these antigen tests'. These tests make use of a nasopharyngeal swab subjected to antibodies coated paper strips intended to captivate the coronavirus antigens. This evaluation will take not more than 30 min, providing visual inveigh. The respiratory sample swabs lack required antigens for detection specifically for asymptomatic patients. The Food and Drug Administration (FDA), states that antigen tests provide greater accuracy of positive results indicating contrast to false negatives which is a limitation. Further validation of those negative can be made through a PCR test (Office of the Commissioner 2020).

4.1.4 Serological Tests

Serology tests are used to test the blood samples and can be used to identify once the infected person has recovered. The host immune systems counter-attack to infections by producing antibodies. After several days of initial infection, IgM antibodies of SARS-CoV-2 are generally detectable despite the antibodies amount are not well characterized even during infection (FDA n.d.). The SARS-CoV-2 IgG antibodies are detectable 10–14 days after the infection and after 28 days of onset of infection; remarkable peaks were detected leading to the late emergence of antibodies to function as acute infection markers. The memory of some pathogen and antibody produced remains in the bloodstream for specific time duration but the efficiency of SARS-CoV-2 antibodies remains unexplored.

4.1.5 Rapid Diagnostic Tests (RDT)

Rapid Diagnostic Test uses a handy, precise, negative, or positive lateral flow assay which treats blood or saliva samples as well as swab samples of infected individuals. This rapid test results in coloured lines for differentiating positive from negative results (Johns Hopkins Center for Health Security [JHCHS] 2020).

4.1.6 Enzyme-Linked ImmunoSorbent Assay (ELISA)

ELISA tests use blood plasma or serum samples and detected by either quantitative or qualitative analysis. The SARS-CoV-2 protein is priorly coated in a 96-well titre plate; subsequently samples are introduced and incubated for antibodies to bind forming an antigen-antibody complex. These complexes will be exposed to antibody wash following colour or fluorescence emission (JHCHS 2020).

4.1.7 Neutralization Assay

The assessment of antibodies in samples for viral infection prevention in culture cells can be done by neutralization assay with blood, plasma, or serum as samples. The cells in culture allow the virus to reproduce (e.g. VeroE6 cells), and to visualize and quantify the number of antibodies blocking virus replication, altering the concentration of antibody can pave the way (JHCHS 2020).

4.1.8 Chemiluminescent Immunoassay

The quantitative analysis of blood, plasma, or serum samples was accomplished with Chemiluminescent Immunoassays, wherein samples were treated with buffers, known viral protein, and enzyme-linked specific antibodies resulting in luminescence. This assay uses micro particles that are protein-coated and magnetic in nature. Initially, the antibodies adhere to this viral protein to form complex, proceeding to binding of secondary enzyme-linked antibodies addition. As a result of an enzymatic reaction, it produces light and the radiance emitted helps in calculating the number of antibodies including IgA, IgM and IgG were identified.

Johns Hopkins Medicine team have reported that to find quicker solutions in detecting and treating Covid-19, AI has the potential to influence and reinforce the role of chest imaging and large-scale data (JHCHS 2020). Several studies had reported that CT findings may be associated with severity of duration of illness, symptoms and yet recovery too. Moreover, CT abnormalities might predate positive results in RT-PCR test in symptomatic and asymptomatic patients. The final diagnosis relies on rRT-PCR positivity for the presence of infection but to rule out the possibilities of false-negative results, serial testing may be needed. Due to the shortage of RT-PCR test kits, there is an urgent need for alternative methods for exact and rapid diagnosis of Covid-19 patients. As SARS-CoV-2 has strong infectivity, optional methods are immediately required to identify, isolate and treat the patients without any delay, which could reduce the risk of public contamination and mortality rates. CT examinations results can be obtained quickly whereas rRT-PCR results require 5–6 h. In addition, it is not clearly understood whether rRT-PCR is the gold standard, and whether its false-positive or false-negative results are common. A retrospective study among the patients in Yichang Yiling Hospital were confirmed and diagnosed with Covid-19 pneumonia and they have compared the CT imaging sensitivity with rRT-PCR testing.

4.2 AI-Based Diagnosis

Early diagnosis and effective screening processes play a vital role to combat the infection spread. Real-time RT-PCR is known to be a standard diagnostic tool from nasopharyngeal swab specimens for Covid-19 (WHO 2020; Guan et al. 2020). Rapid diagnostic test kits detect the viral proteins of SARS-CoV-2 presence (Antigens) in the respiratory tract samples. These test kits were also able to detect the presence of antibodies in the blood samples after the entry of antigens (World Health Organization 2020). Because of the shortage of test kits in most populated areas, the possibility of the false-negative rate as high as 1 in 5 means alternative and taking 6–48 h to generate the results and the suspected patients will have a chance of spreading the disease to the healthy individuals (Guan et al. 2020). Artificial intelligence (AI) enables rapid and accurate diagnosis of Covid-19 (Mei et al. 2020). The focus on using an alternative method for rapid and accurate diagnosis by researchers at Mount Sinai leads to the usage of the Artificial Intelligence (AI) technology with the combination of CT findings and clinical assessment (patient's age, sex, comorbidities, showing any abnormalities in blood cell counts, etc.) to analyze the Covid-19 patients. And they integrated the data from the medical findings with clinical information to develop a unique AI algorithm (Genetic Engineering and Biotechnology News 2020).

SARS-CoV-2 is known to cause lung tissue damage and in a clear accurate way that doctors were now seeking new diagnostic approaches. The most easily noticed abnormalities in the chest CT scans were cloudy lesion patterns or ground glass opacities with consolidations which occur particularly around the peripheral lobes of both lungs. AI mimics the flow of work used for diagnostic purposes by a physician in predicting accurately conclusive diagnosis either positive or negative (Genetic Engineering and Biotechnology News 2020). Already CT scans were used as a diagnostic tool in China when a patient arrives with symptoms like fever and cough (Nishiura et al. 2020; Song et al. 2020). For the evaluation in highly suspected patients, a Chest CT scan acts as an effective diagnostic tool (Genetic Engineering and Biotechnology News 2020). However, in some asymptomatic and early diagnosis patients, the chest CT imaging were unfavourable for prediction as there prevails chance of negative predictive value to completely expel infection which emphasize the need to include the clinical data in the analysis. The same diagnostic method can be used to predict the large number of diseases pertaining to the respiratory system. The use of AI technology enables much higher precision than what radiologists can achieve. This testing system will be a great achievement in any country where there is a shortage of test kits, radiologists, and affordable diagnosis. Hospitals and lab technicians may have heavy workload and facing many consequences due to the faster human-to-human transmission and limited to hospitalize or isolate the suspected patients with this viral disease. Hence effective and large-scale screening tools were necessary to avoid the delayed treatment of suspected cases (Ai et al. 2020).

4.2.1 Chest CT or X-ray CT Scans

Chest computed tomography (CT) or X-ray computed tomography (CT) or computerized axial tomography (CAT) scanning combines the application of computer technology with a X-ray device that rotates to develop detailed cross-sectional images or ‘slices’ of the chest. CT can provide the diagnostic information, thus the computer processes these images and displays it on a monitor. Amid the other assorted imaging techniques, the unique ability to picturize a combination of soft tissues, bones, and blood vessels is present in CT. Many people may experience only mild symptoms in the early stage of an infection, with prolonged time after the onset of clinical symptoms, CT findings were more frequent in order to identifying advanced-phase disease of Covid-19 correlated with a significantly elevated frequency of Ground glass opacification (GGO) in addition to a reticular pattern (Crazy paving), Consolidation, Vascular dilation, Pleural effusion, Vacuolar sign, Thoracic lymphadenopathy (lymph node size of $\geq$10 mm in short axis dimension), Air bronchogram, Bronchal distortion, Subpleural line or Subpleural transparent line, Reverse halo sign, Fibrotic streaks, and Bilateral and peripheral disease. Initially Chest CT findings of Covid-19 patients has evaluated the presence of bilateral, multilateral ground glass opacification (GGO) which is mainly distributed in the peripheral lower lobes and very less frequently in the middle lobe (Li and Xia 2020)

Table 4.1 CT findings in patients with Covid-19 at different stages (The Radiology Assistant n.d.)

Early stage	0–14 days	Presence of GGO, partial crazy paving, lower number of involved lobes
Progressive stage	5–8 days	Extension of GGO, increased crazy paving pattern
Peak stage	10–13 days	Presence of consolidation
Absorption stage	≥14 days	Gradual resolution

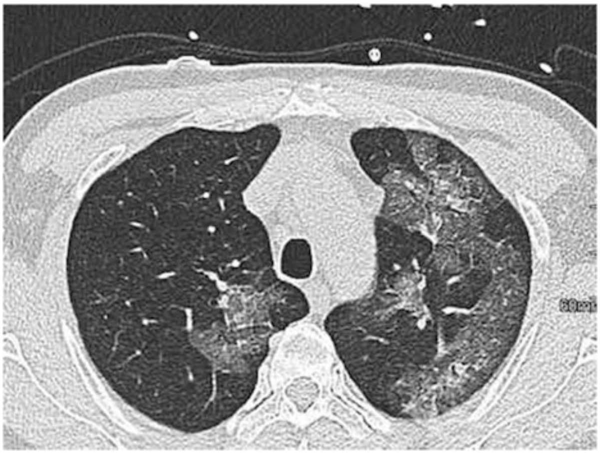

Fig. 4.1 CT findings of a juvenile male, who had symptoms like fever for 10 days, with progressive cough and breath shortness. At the time of admission, Saturated Oxygen level of blood was 66%. PCR test for Covid-19 was obtained as positive (The Radiology Assistant n.d.)

and it also examines the presence of consolidation, interlobular septal thickening, vascular enlargement, air bronchogram sign and air trapping which were alike to the CT findings of MERS and SARS (Kanne 2020; Kong and Agarwal 2020). The alveolar and interstitial pulmonary injury and edema are root cause for lung abnormalities. Angiotensin- converting enzyme-II is a key molecule which was involved in the development and progression of acute lung failure (Imai et al. 2005), by the involvement of angiotensin-converting enzyme-II, SARS-CoV-2 bring about direct lung injury thus it leads to diffuse alveolar damage (Koo et al. 2018). This pathological mechanism of GGO and consolidation including rapid changes in abnormalities occurred in the Covid-19 cases can be easily identified in the chest CT imaging. These findings can change over time in patients into different stages as shown in the following table (Table 4.1).

'Ground glass opacification (GGO)' indicates an extent of smoky increased lung opacity whereby bronchial and vascular structures may still be seen and it is less opaque than consolidation as the CT findings of ground glass patterns shown below (Fig. 4.1). 'Consolidation' is an opacification with obscured margins of vessels and airway walls because the alveoli is replaced with pus, fluid, blood, cells (as well as tumour cells) or other substances instead of air resulting in lobar, diffuse or multifocal ill-defined opacities. Vessels widening typically found in the area of ground glass

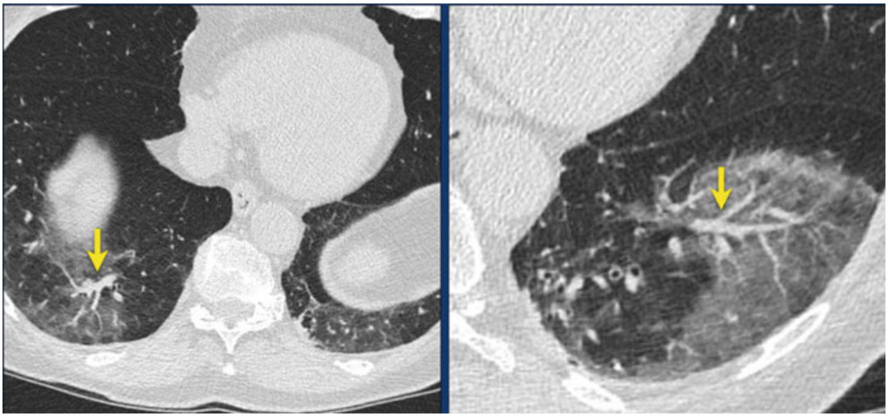

Fig. 4.2 Widening of vessels in the area of ground glass opacities (The Radiology Assistant n.d.)

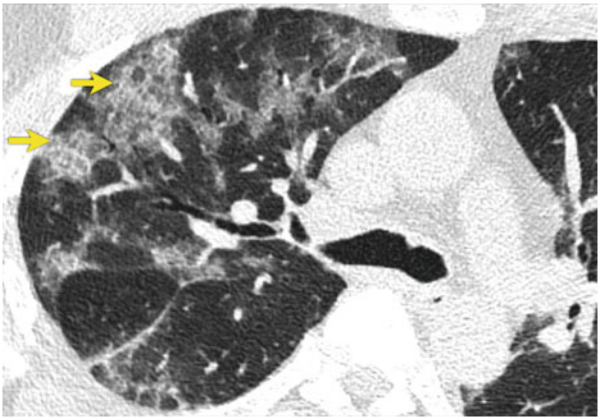

Fig. 4.3 Images of thickened intralobular and interlobular lines in combination with ground glass lesions, these patterns could be seen in a somewhat later stage (The Radiology Assistant n.d.)

is known as 'vascular dilation'. In the later stage CT may find the combination of thickening of interlobular and intralobular lines with GGO pattern is known as 'crazy paving' which is shown in (Figs. 4.2 and 4.3).

The CT involvement score correlates the severity of the lung engrossment on the CT with the disease severity. Some of the CT findings such as pleural effusion, crazy paving and consolidation are less common that may occur in the next stages of the disease (Xiong et al. 2020; Schmitt and Marchiori 2020). As the above mentioned lung abnormalities may differ in the initial CT findings of 919 severely affected cases which are tabulated below (Table 4.2).

Chest CT provided through a new Artificial intelligence (AI) based software that detects by a programmed quantification of abnormalities cohort with Covid-19. A set of rules or instructions given to an AI program or Convolutional neural network

Table 4.2 Common initial CT findings and distribution in 919 Covid-19 patients (Salehi et al. 2020)

CT-findings	Total no. of patients/No. (%) of reported cases
Ground glass opacification(GGO)	88% (346/393)
Bilateral involvement	87.5% (435/497)
Posterior distribution	80.4% (41/51)
Multilobular involvement	78.8% (108/137)
Peripheral distribution	76% (92/121)
Consolidation	31.8% (65/204)

(CNN) is known as an algorithm which helps it learn on its own, hence it can identify and quantify the abnormalities in the lungs from CT imaging automatically (Mei et al. 2020). The methodology of AI involve few steps that the system takes non-contrast chest CT as input, segments the regions of three dimensional CT abnormalities with Covid-19 and estimates the severity of lobe involvement, quantifies and identifies the distribution of high opacities by deep learning or deep reinforcement learning. Then the method outputs dual severity measures of the disease (i.e.):

1. Percentage of opacity, Percentage of high opacity (or) PO, PHO and
2. Lung severity score, Lung high opacity score (or) LSS, LHOS.

The initial measure of PO and PHO is universal which implies the overall spread of abnormalities like GGO, consolidation and crazy paving relative to the volume of the lungs, while the LSS and LHOS is a collective measure of the lobe-wise distribution of involvement and high opacities distribution area of involvement of each lobe respectively (Chaganti et al. 2020).

Multiple studies and research stated that CT findings may equate with the increased symptoms as well as time taken to recover from illness. Bilateral, multilobar ground glass opacities with asymmetric, peripheral, posterior distribution and partial crazy paving were common in early chest CT findings. Extension of GGO, consolidation, subpleural dominance, crazy paving and bronchus distortion may appear in the advanced stage of disease (Xiong et al. 2020; Schmitt and Marchiori 2020). The ability to categorize into mild and severe illness accordingly with patients clinical information by using AI and machine learning was made easy, thus allowing them to reveal more clinical data about the impact of SARS-CoV-2. Recent research explored that CT sensitivity for 51 Covid-19 patients of 98% which is comparatively more than the RT-PCR analysis sensitivity of 71% (Fang et al. 2020) (Fig. 4.4).

About 81% of 1014 Covid-19 cases reported RT-PCR false-negative results but positive chest CT scans as extremely probable patients were then reclassified by accounting their clinical symptoms (Ai et al. 2020).

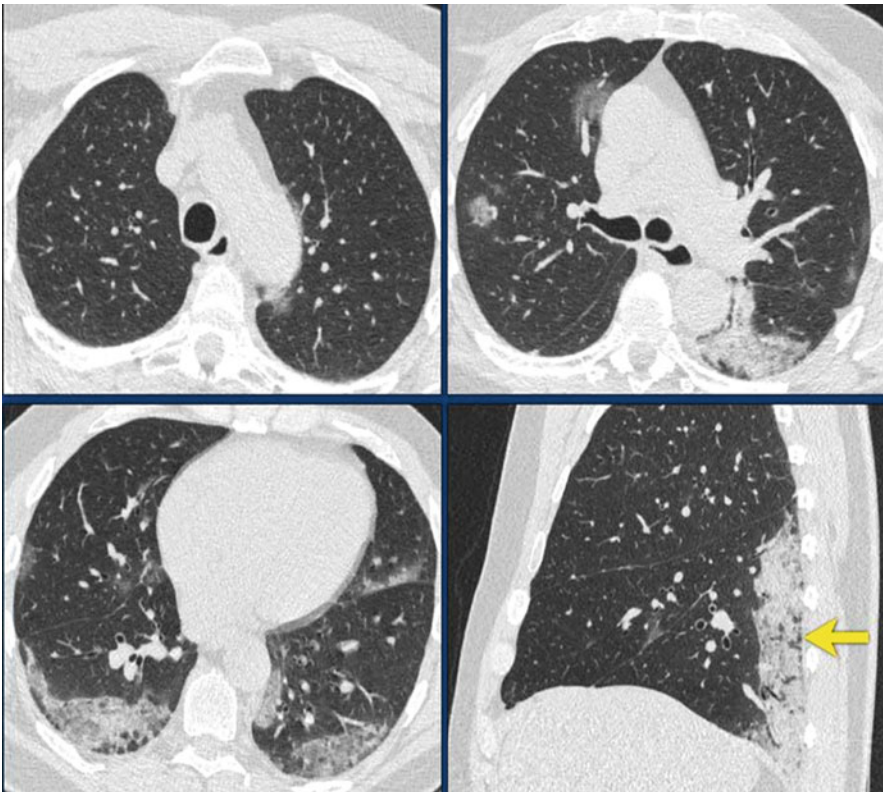

Fig. 4.4 Visualization of a 59-year-old male with fever for 1 week with non-productive cough. Due to the high clinical suspicion CT, some areas of ground glass opacities (GGO) and massive consolidation in the posterior parts of the lower lobes (yellow arrow on sagittal reconstruction) were observed and the results of RT-PCR were negative. A sputum test was performed after 2 days which resulted as positive (The Radiology Assistant n.d.)

4.2.2 Chest Radiography

Chest radiography is fast, rapid, comparatively economical imaging modality that are accessible in several resource restrained healthcare settings. An Artificial Intelligence system could also be a helpful tool to radiologists or, other professionals where radiological expertise are not available. CAD4COVID-X-Ray is an AI system that used to detect Covid-19 characteristics on frontal chest radiograph (Murphy et al. 2020). Technical University of Munich (TUM) researchers have developed a very ingenious X-ray methodology for lung diagnosis which they currently decided for testing the diagnosis of Covid-19 (Scientist Live 2020). The method could evidently identify the illness abnormalities and involves a dose with less radiation than the CT methods. X-rays, in addition to the biochemical tests, can be used to diagnose the changes in pathology of the lungs caused by this viral infection. These

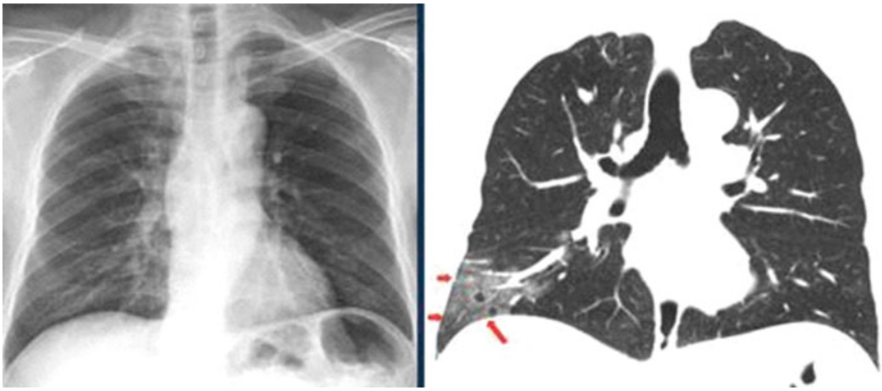

Fig. 4.5 X-ray and CT report of a patient with Covid-19 infection

X-ray method makes it feasible to examine a great number of Covid-19 patients within a brief period of time, which provides results without any delay after the examination (Cozzi et al. 2020). While standard X-ray imaging exhibits the attenuation of the X-rays on the tissue whereas the dark-field method focus on the small share of the scattered X-ray light. Standard X-ray images ignore the X-ray light that are scattered. Therefore, the new method uses natural phenomenon of scattering which are similar in a way where dark-field microscopy technology using visible light. In Covid-19 infected patients, lesions in the lung initially resembles like a spider web or cotton wadding and spreads throughout the lung, later fills with fluid. In addition to other similar symptoms, these structures clearly indicate Covid-19 infection. The lungs with lesions could be noticed clearly in dark-field images. However chest film is inset during the early stages of the disease.

Below reports are a comparison of Chest Radiograph with Chest CT (Salehi et al. 2020). The ground glass opacities (GGO) in the right side lower lobe on the CT with red arrows are not observable on the chest radiograph, which was taken an hour prior to CT study (Figs. 4.5 and 4.6).

Seventy-two years old woman having acute respiratory failure, mild fever (38 °C), dyspnea was admitted and series of her chest films were picturized (Fig. 4.7). She was tachypneic (30 bpm), with lymphopenia and low level of oxygen saturation (SpO_2 85%). The patient was discharged from the hospital since she did not present alarm criteria at that time. She required mechanical ventilation. So she was admitted to intensive care but she died 24 h later.

Imaging Finding

- During the time of admission patient had ill-defined bilateral alveolar consolidation with peripheral distribution.
- After 4 h, there was radiology reports showed worsening, with affectation of lower lobes. Endotracheal tube and central venous line were required.
- There was bilateral alveolar consolidation, later 24 h.

Fig. 4.6 On the day of admission to the hospital normality of the chest film was observed. On mechanical ventilation after 4 days, visible bilateral consolidations on chest film were picturized

- 48 h later, the radiology reports of her were declining. Bilateral alveolar consolidation with pan lobar affectation.
- 72 h later, bilateral alveolar consolidation with pan lobar affectation, with typical radiological findings of ARDS. After this, 24 h later, she passed away.

4.2.2.1 Limitation

Because Covid-19 can spread to the lungs and can cause serious respiratory complications, doctors may be inclined to use chest X-rays to assist them in the diagnosis of coronavirus infection. According to a study from Wexner Medical Center, The Ohio State University, doctors should be cautious of relying on chest X-rays for Covid-19 diagnosis. After reviewing chest X-rays of 630 symptomatic and confirmed Covid-19 patients, research team found that more than half of the chest X-rays looked normal and a majority of them looked either normal or mildly abnormal. 'Doctors must not be confident by a negative chest X-ray', said lead researcher Michael Weinstock, according to a press release about this investigation. Chest films can be used in the proceedings of the disease (Palmer 2020).

4.3 Other Predictive Measures for Covid-19 Diagnosis

4.3.1 Pulse Oximetry

Pulse oximeter is a noninvasive test which is used to measure the oxygen level or oxygen saturation of the blood. It operates on a battery and supply real-time results on small LED display on the device itself. It sends wavelengths of light through the finger to measure the pulse rate (Kannan 2020). Normal oxygen saturation level for an average person without any pulmonary pathology are ranges between 75 and 100 millimetres mercury (mmHg) and typically shows reading between 94 and 99%

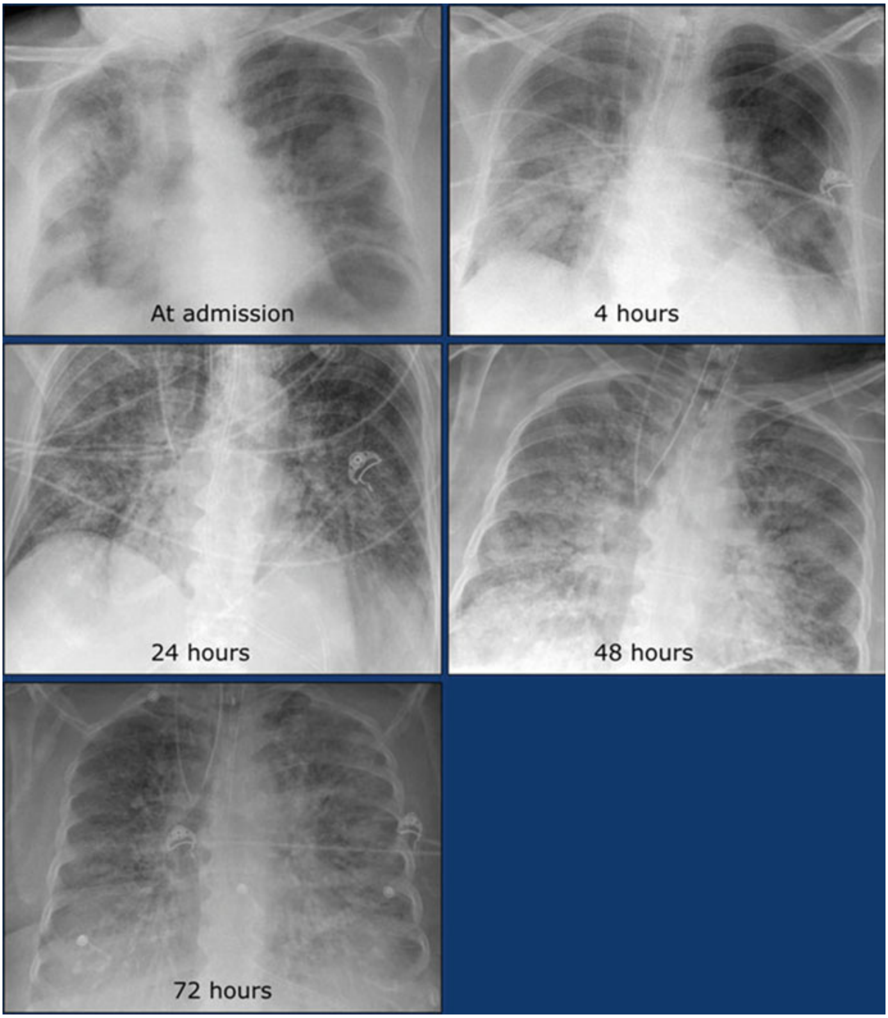

Fig. 4.7 Seventy-two-year-old woman's chest films. At the time of admission: peripheral distribution observed in ill-defined bilateral alveolar consolidation. Four hours later: lower lobes affectation. Bilateral alveolar consolidation at 24 h. Bilateral alveolar consolidation with pan lobar affectation at 48 h and same result was observed 72 h later and after this patient died

(Times of India 2020), but Covid-19 patients has oxygen sea level as low as 50% (Hindustan Times 2020). A level below indicates that there is a lung problem and would recommend that the person is seriously ill and might need supplemental oxygen or should be hospitalized. It would reveal the SpO_2 level (peripheral oxygen saturation) or blood's oxygen level as well as heart rate depending on the light absorption in the blood and also detect the movement of blood cells and colour. Blood cells in bright red colour denotes a good amount of oxygen (oxygenated) while in dark red colour denotes the deoxygenated blood thus to calculate oxygen saturation percentage, comparison of the number of bright red cells and dark red cells is carried out with the pulse oximeter (Kannan 2020; Jubran 1999). This also helps in detecting 'silent hypoxia'. It is a condition where the body is deprived of adequate supply of oxygen (Hindustan Times 2020; Kannan 2020). According to health experts, patients with Covid-19 having lower oxygen rates can make use of this small device that plays a vital role. Its significant role in patients exhibiting Covid-19 is health monitoring especially patients whoever has comorbidities. Although many doctors reported that patients affected by SARS-CoV-2 were presenting with dangerously low saturation levels, these lowering of saturation levels is notably present in coronavirus disease as well as in other diseases like asthma, chronic obstructive pulmonary disease (COPD) and other lung infections too (Mathur 2020). So without any further testing we weren't able to conclude for SARS-CoV-2 positive only with the pulse oximeter results. Some nail polish or false fingernails may cause false readings in pulse oximeters and this has been considered as a limitation (Biggers 2019). Thus, the pulse oximeter is recommended and suggested for the early detection of 'COVID pneumonia' which is potentially a fatal condition which is observed among the most severe cases.

4.3.2 Thermal Screening

Thermal screening systems use infrared (IR) technology which detects the quantity of emitted radiation by an object that elevates the temperature; these temperature variations are noted by thermography. This infrared body temperature monitoring is enough for large-scale screening and plays a significant contribution in controlling the spread of pandemic especially in highly crowded areas (e.g. airports, supermarkets, factories) (Unni 2020). According to WHO, after exposure to the virus, an individual acquires fever which is a common symptom of Covid-19 that typically appears within 2–14 days. Due to this, telethermographic systems were largely used for the detection of body temperature. This system determines the surface skin temperature, and assesses the initial temperature for triage use which is potentially helpful in heavy populated areas (FDA n.d.). Though thermal scanners cannot spot a virus or infection, it can lead to further testing if a scanned person has elevated body temperature (EBM). However thermal scanning was great at sensing the general body temperature, they were far less precise at monitoring temperature for clinical assessment. The proper way to handle thermal scanners is to distant the person or object at 1–3 cm from the scanner and scanning beyond this limit may lead to false readings since the temperature of air is also considered by the device during reading (Mishra 2020). Even those limitations, the systems were still regarded as one of the few ways to quickly detect the infection risk.

4.4 Conclusions

As world battles to combat the spread of Covid-19, artificial intelligence started up in every country were developing and enhancing their tools and solutions to help the frontline workers in order to control the crisis. Artificial intelligence (AI) helps the health care representatives and clinicians by patient triaging, diagnosis (in combination with RT-PCR analysis results and epidemiological risk), faster identification of clinical characteristics and response to treatment/therapy in patients exhibiting Covid-19 symptoms. Chest CT with AI tool is very easy to use, consuming less time than manual annotations, and has more sensitivity than other tests. So in this difficult time, AI needs to get more attention as this technology can process large-scale clinical data in a minimal amount of time. Robots were also used in screening and diagnosis to assist physicians and healthcare workers to avoid exposures from infected Covid-19 cases. Screening robots helps in recording data of patients (name, sex, age, and clinical characteristics), and evaluation (temperature check) in a contactless manner. Those who have a high body temperature with symptoms of the virus, or those members who have tested positive in their family can make use of the diagnostic robot, which have a video conversation with a doctor who is in a remote location, and procures a prescription thereafter forwarded to the patient. AI can be used in vaccine development and treatments at a faster rate than usual ones and also in clinical trials.

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5 Role of Artificial Intelligence in COVID-19 Prediction Based on Statistical Methods

R. Sujatha and Jyotir Moy Chatterjee

Abstract

Coronavirus disease 2019 (COVID-19) is a respiratory ailment that can spread from individual to individual, first recognized during an outbreak in Wuhan, China. Possibility of getting COVID-19 is greater for people who are in contact of someone known to have COVID-19, for example clinical professional, or family member. Peoples at higher peril for sickness are the those who live in or have starting late been in a zone with advancing spread of COVID-19. A few patients have pneumonia in the two lungs, multi-organ failure and sometimes death. In this work we are predicting the impact of COVID-19 cases in India based on time series analysis, correlation analysis, Granger Test, and Group Method of Data Handling (GMDH). We have compared the prediction of four algorithms namely combinatorial (quick), stepwise forward, stepwise mixed, and GMDH neural network (GMDH-NN) for predicting the future of India. Out of that stepwise mixed method gives good prediction for confirmed cases but GMDH-NN gives better prediction in case of death and recovered cases. As this disease is declared as an epidemic, the present study will help researchers to understand the impact of this outbreak. We have used combinatorial (quick), stepwise forward selection, stepwise mixed selection, and GMDH neural network to predict the spread of disease in India.

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Keywords

COVID-19 · Time series analysis · Combinatorial (quick) · Stepwise forward selection · Stepwise mixed selection · GMDH neural network (GMDH-NN)

5.1 Introduction

The viral infection that causes COVID-19 most likely rose out of a creature, but is currently spreading from individual to individual. Overall, COVID-19 is a challenge faced by multiple disciplines like medicine, defense, finance, telecommunication, information technology, and so on. The contamination is thought to spread chiefly between people who are in close contact with one another (inside around 6 ft) through respiratory globules conveyed when a infected individual hacks or sniffles. It also may be possible that an individual can get COVID-19 by reaching a surface or article that has the disease on it and a short time later reaching their own mouth, nose, or conceivably their eyes, yet this isn't accepted to be the essential way the contamination spreads. Patients with COVID-19 have had delicate to genuine respiratory malady with impacts of:

- Fever
- Cough
- Shortness of breath

The World Health Organization (WHO) announced the 2019–20 coronavirus epidemic a Public Health Emergency of International Concern (PHEIC) on 30 January 2020 (WHO 2020; Mahtani 2020) and a pandemic on 11 March 2020 . Proof of neighborhood spread of the ailment has been found in numerous nations over each of the six WHO districts (World Health Organization 2020a, b).

5.2 Related Work

Xu et al. (2020) examined the neurotic characteristics of a patient who passed on from severe infection with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) by postmortem biopsies.

Novel (2020) reported outcomes of a descriptive, experimental investigation of all cases identified as of February 11, 2020.

Chen et al. (2020) expected to assess the clinical characteristics of COVID-19 in pregnancy and the intrauterine vertical transmission capability of COVID-19 infection.

Liu et al. (2020) audit the basic reproduction number (R0) of the COVID-19 virus. R0 means that the transmissibility of a virus, representing the normal number of new infections created by an infectious person in an absolutely innocent populace.

Pan et al. (2020) studied the adjustment in chest CT findings associated with COVID-19 pneumonia from beginning diagnosis until understanding recuperation.

Sujatha et al. (2020a, b) utilized linear regression, vector autoregression and multilayer perceptron technique for COVID-2019 cases prediction in India using Kaggle dataset.

Iwendi et al. (2020) applied boosted random forest algorithm for COVID-2019 prediction.

5.3 Dataset Description

We have used the COVID-2019 (KP 2020) dataset from kaggle where data from January 22, 2020 to March 26, 2020 are present. The dataset is having data of more than 180 countries with their attributes such as Province/State, Country/Region, Latitude, Longitude, Date, Confirmed, and Deaths. Out of this dataset we have concentrated on India's data. The dataset is having 65 instances for India. As we have taken only India's data so with have discarded the latitude and longitude by only considering the corresponding dates followed by the confirmed, death, and recovered cases. We anticipated the future effects of COVID-19 pandemic in India through time series analysis, correlation analysis and Granger Test and GMDH.

5.4 Experimental Results

For experimentation purpose we have incorporated Group Method of Data Handling (GMDH) strategy. This method was started by Ivakhneko in 1966 and it has been improved and advanced in the course of recent years. The GMDH calculation interfaces the inputs to outputs with higher sequential polynomial networks which are principally feed-forward and multilayered neural networks (NN) (Onwubolu 2009). Right now, nodes are shrouded units and the activation polynomial coefficients are weights which are evaluated by standard least square regression (Ghanadzadeh et al. 2012). Lately, be that as it may, the utilization of such self-composed networks has prompted fruitful use of the GMDH-type computation in a wide scope of zones in engineering and science (Ahmadi et al. 2007; Abdolrahimi et al. 2014; Pazuki and Kakhki 2013; Atashrouz et al. 2015; Najafzadeh 2015). The GMDH is a polynomial-based model. As indicated by the GMDH approach, each layer can be acquired from a quadratic polynomial function. In this manner, the input variables are anticipated to the yield variable. The primary objective right now is finding of function, f, which ventures the input variables to the yield variable. In this way, the output variable (X_i) can be composed from the input variables as the accompanying structure:

$$X_i = f(Y_{i1}, Y_{i2}, Y_{i3} \ldots Y_{in}), \quad i = (1, 2, 3, \ldots, M) \tag{5.1}$$

where, Y_s are input variables. The structure of the GMDH can be obtained using the minimization of an objective function. The objective function ω can be written as:

$$\omega = \sum_{i=1}^{M} [(\mathrm{X}(Y_{i1}, Y_{i2}, Y_{i3} \ldots Y_{in})) - X_i]^2 \tag{5.2}$$

where, in the above equation X_i is actual data (Naderpour et al. 2019).

GMDH (Ivakhnenko 1971; Dorn et al. 2012) is known as a self-sorting deep learning technique for time-series analysis issues. It is broadly utilized in numerous fields, for example, forecasting, data mining, optimization and pattern recognition and so on. GMDH-based NN can be considered as a polynomial NN. As a distinction with different networks, the GMDH network changes persistently during the preparation procedure. A few favorable circumstances of GMDH network can be referenced as: self-association in the preparation procedure, high exactness in forecasting, findings for high-request nonlinear frameworks and so forth (Nguyen et al. 2019).

GMDH comprises of parametric, clusterization, analogs complexing, re-binarization and likelihood calculations. This inductive methodology depends on sifting through of bit by bit entangled models and determination of the ideal arrangement by least of outer standard trademark. Polynomials as well as nonlinear, probabilistic methods or clusterizations are utilized as essential models.

GMDH methods can be valuable in light of the fact that:

- The number of layers and neurons in hidden layers, model structure and other ideal hyperparameters are resolved consequently.
- It ensures that the most precise or impartial models will be found—technique doesn't miss the best arrangement during arranging everything being equal (in the given class of functions).
- As input variables can be utilized nonlinear functions, that may have effect on output variable.
- It naturally finds interpretable connections in data and chooses compelling input factors.
- GMDH sorting calculations are fairly basic for developing software (GMDH n.d.) .

We have used the GMDH software and Orange Data Mining software (Bioinformatics Laboratory 2020) for conducting our experiments. Granger test and correlation analysis is conducted using and time series analysis is conducted using (NNS 2020). Data science begins with collecting the data followed by consolidating, investigating, understanding and finally presenting it with valuable information. In data consolidating and investigating phase, as a part of knowledge gain, should know the nature of attributes and the nature of values make up the dataset. Data visualization helps in getting great insight of the data set followed by applying the required process of classification, association, clustering based on the problem scope

Table 5.1 Statistics of INDIA COVID-19

Variable	Date	Confirmed	Deaths	Recovered
Numeric values	0	65	65	65
Text values	65	0	0	0
Missing values	0	0	0	0
Unique values	65	28	10	13
Zero values	0	8	49	25
Most frequent		3	0	0
Min. value		0	0	0
Max. value		727	20	45
Median		3	0	3
Mean value		73.72	1.35	6
Std. deviation		157.60	3.43	10.52
2σ outliers		5	4	4
3σ outliers		2	2	3
4σ outliers		1	1	0

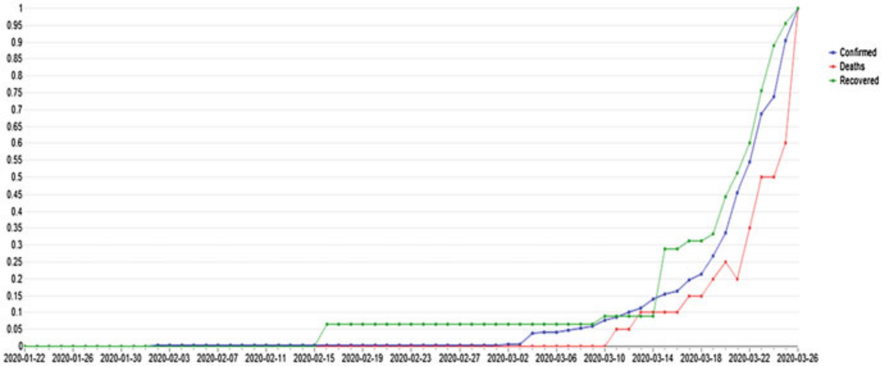


Fig. 5.1 Time series plot of INDIA COVID-19

(Van Der Aalst 2016; Keller et al. 1994; Sui 2019; Mirkin 2019a). Table 5.1 provides the statistics of the considered dataset for the forecasting purpose. No missing value is the added advantage that helps in good prediction (Evans et al. 2007; Peat and Barton 2008).

Time series plot depicts the nature of the variable considered for the experimental purpose. It helps to recognize drifts in the data over spell. Intuitive in nature and provides faster insight about the changeover of the data over the time span. Line chart representation is used often that as higher clarity and informative in nature (Wen 2019). In the line chart representation parallelly visualize the changeover of the multiple variable of the dataset over the time at single shot.

Figure 5.1 shows the data connected for the variable like confirmed cases, death cases, and recovered cased of INDIA COVID-19 dataset on the normalize pattern. On applying the correlation over the dataset in orange data mining too we obtain the light of the correlation among the attributes. Higher correlation and minimum false

Table 5.2 Correlation of INDIA COVID-19 features

Data instances: 6				
Features: 2				Meta attributes: 2
	Feature 1	Feature 2	Correlation	FDR
1	Confirmed	Date	0.949	1.521012e − 30
2	Recovered	Date	0.937	4.52186e − 28
3	Confirmed	Recovered	0.847	1.43853e − 17
4	Deaths	Recovered	0.736	2.123428e − 11
5	Confirmed	Deaths	0.731	2.74335e − 11
6	Deaths	Date	0.694	5.7187e − 10

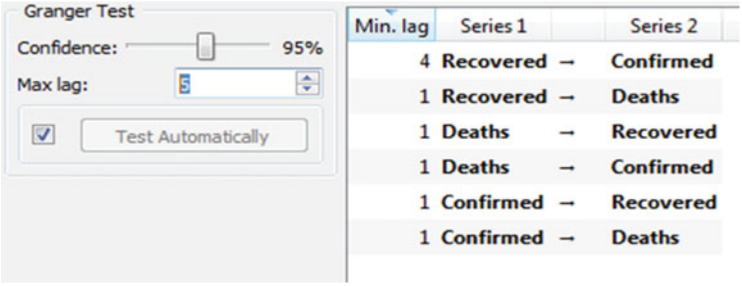


Fig. 5.2 Granger test on INDIA COVID-19

discovery rate is the pattern that is visualized in this dataset (Mirkin 2019b). It's very obvious date plays great role in time series representation. Table 5.2 provides insight about correlation between two features along with measures.

Granger test is the statistical method for determining the influence of one time series with another time series feature considered for the experimental part. Famously it is called as granger causality since provided by academician Clive Granger. Find application in various fields like economics, neuro science and so on. With confidence 95%, for the dataset it's interpreted that confirmed cases four times ahead of recovered cases. Similarly as of now for the 2 months of time series dataset lag is not much inferred but as the length of data grows the lag may be skewed positively or negatively (Wen et al. 2019; Ghysels et al. 2016). Figure 5.2 shows the granger test with max lag as 5.

Curve fitting is the method of fabricating a curve based on the mathematical function. Obviously, that will make the perfect fit for the given data points with constraints. Fitted curve assist in the data visualization (Mudelsee 2019; Guest 2012; Maddams 1980). It helps in inferring values when data is missing with the generated function. Best fit can form in either straight manner or curve. Criterion value provides the insight about best fit. Figures 5.3, 5.4, and 5.5 illustrates the curve fit for the selected variable confirmed, death, and recovered, respectively.

Various measures help in understanding the accuracy of the fitted curve. Mathematical function for each variable is responsible for setting values in any part of

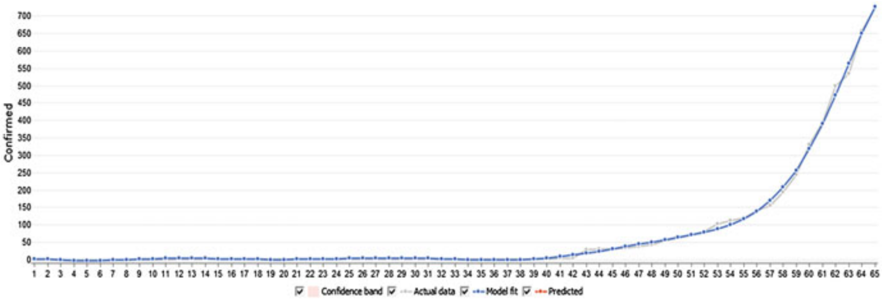


Fig. 5.3 Curve fitting of confirmed cases in INDIA COVID-19

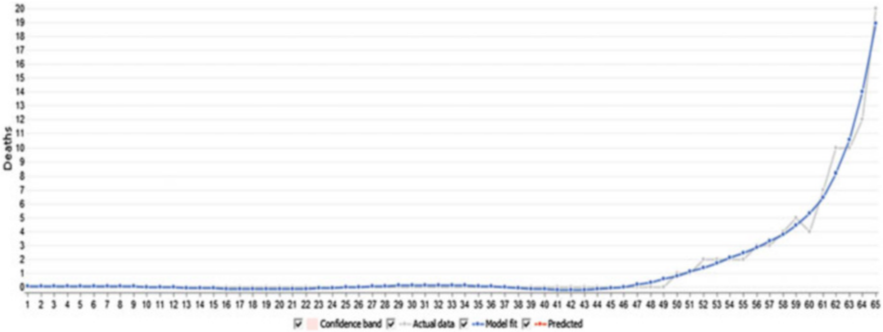


Fig. 5.4 Curve fitting of death cases in INDIA COVID-19

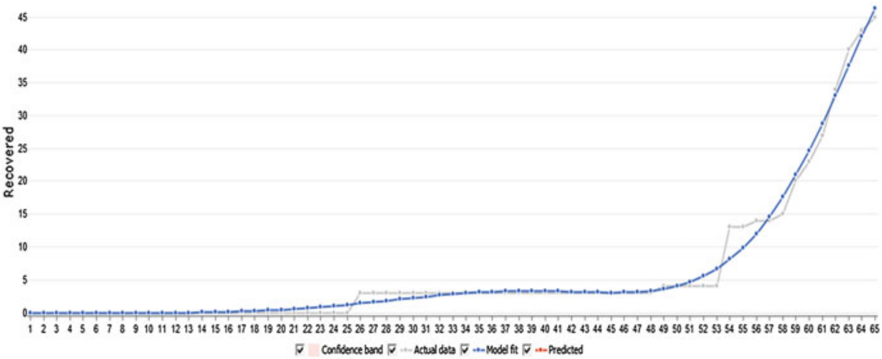
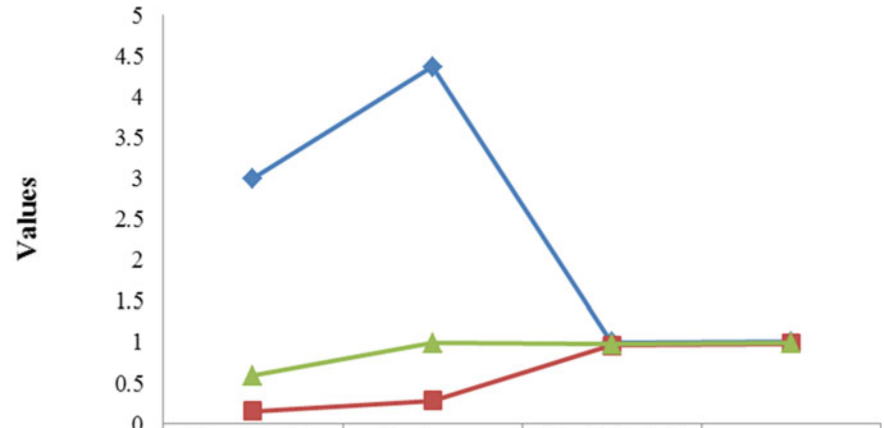


Fig. 5.5 Curve fitting of recovered cases in INDIA COVID-19

curve. Based on this perspective equations 5.3, 5.4, and 5.5 represents function of the confirmed, deaths, and recovered features, respectively.



	Mean absolute error	Root mean square error	Coefficient of determination	Correlation
Confirmed	2.9972	4.367	0.996	0.9985
Death	0.1489	0.2815	0.959	0.9798
Recovered	0.5841	0.9895	0.9708	0.9853

Fig. 5.6 Accuracy of model fit

$$\begin{aligned} Y_1 = {} & 2.51235 + \text{time}^{2*(-1.52766)} + \text{time}^{3*0.515268} + \text{time}^{4*(-0.0698097)} \\ & + \text{time}^{5*0.00501064} + \text{time}^{6*(-0.000210204)} + \text{time}^{7*5.31865e-06} \\ & + \text{time}^{8*(-7.98039e-08)} + \text{time}^{9*6.531e-10} + \text{time}^{10*(-2.243e-12)} \end{aligned} \tag{5.3}$$

$$\begin{aligned} Y_1 = {} & -0.0657009 + \text{time}^{5*3.21508e-07} + \text{time}^{7*(-3.58273e-10)} \\ & + \text{time}^{9*1.77937e-13} + \text{time}^{10*(-1.67276e-15)} \end{aligned} \tag{5.4}$$

$$\begin{aligned} Y_1 = {} & 0.0795093 + \text{time}^{4*(-1.35655e-05)} + \text{time}^{6*1.22536e-07} \\ & + \text{time}^{7*(-7.69865e-09)} + \text{time}^{8*1.98941e-10} + \text{time}^{9*(-2.38232e-12)} \\ & + \text{time}^{10*1.09322e-14} \end{aligned} \tag{5.5}$$

Ranking of the best fit in the ascending order begins with deaths, recovered, and confirmed variable with criterion value as 0.0406, 0.0297 and 0.01181 for the mentioned functions respectively. Figure 5.6 graphical represents the plot of the mean absolute error (MAE), root mean square error (RMSE), coefficient of determination and correlation of model fit for the three variables of dataset.

We have conducted our experiment in GMDH based on four core algorithms namely Combinatorial (quick), Stepwise forward selection, Stepwise mixed selection, and GMDH neural network.

5.4.1 Combinatorial (Quick) Approach

The traditional combinatorial GMDH method produces models of all conceivable input variable mixes and chooses best model from the created set of models as indicated by a picked choice standard (Anastasakis and Mort 2001). Here for the experimental part with combinatorial (quick) method, the parameters used are reorder observation as Pseudo-random, validation strategy as *k*-fold validation, twofold, validation criteria as RMSE.balance, variable ranking as correlation, drop variable as rank 5, additional variable as *xi.xj* with return best model as 100 with time series mode.

$$Y_1(t) = -1497.69 + \text{``Confirmed}[t-8]\text{, cubert''} * 413.182 \tag{5.6}$$

With the help of mathematical function (5.6) and system generated criterion value of 0.00153, the system is predicting the confirmed cases. Figure 5.7 shows the predicted values for confirmed cases.

$$\begin{aligned} Y_1[t] = 1.84925 &+ \text{``Deaths}[t-5]\text{, cubert''} * (-2.82812) \\ &+ \text{``Deaths}[t-9]\text{, cubert''} * (-2.50114) + \text{cycle} * 1.17415 \end{aligned} \tag{5.7}$$

With the above mathematical function (5.7) and system generated criterion value of 0.11036, the system is predicting the death cases. Figure 5.8 shows the predicted values for death cases.

$$Y_1[t] = -98.82 + \text{cycle} * 1.44 \tag{5.8}$$

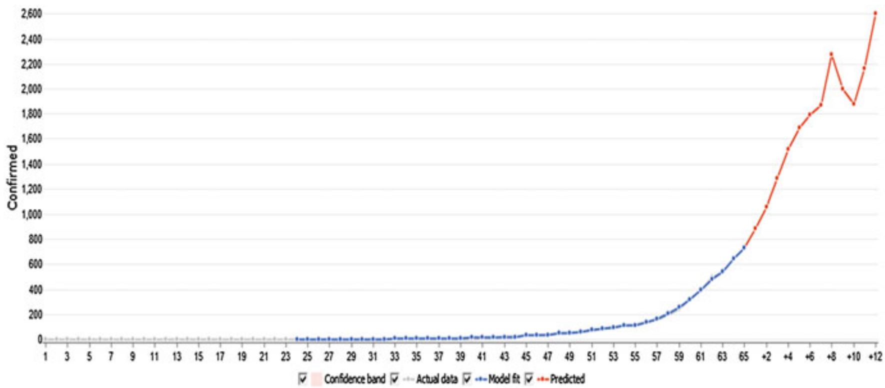


Fig. 5.7 Confirmed case prediction graph plot

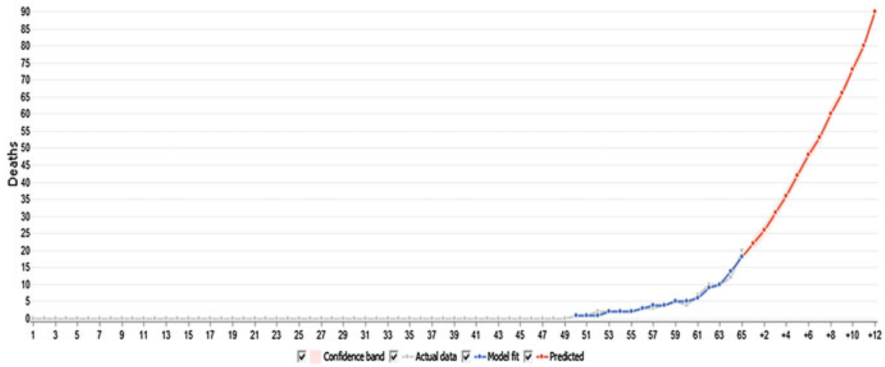


Fig. 5.8 Death case prediction graph plot

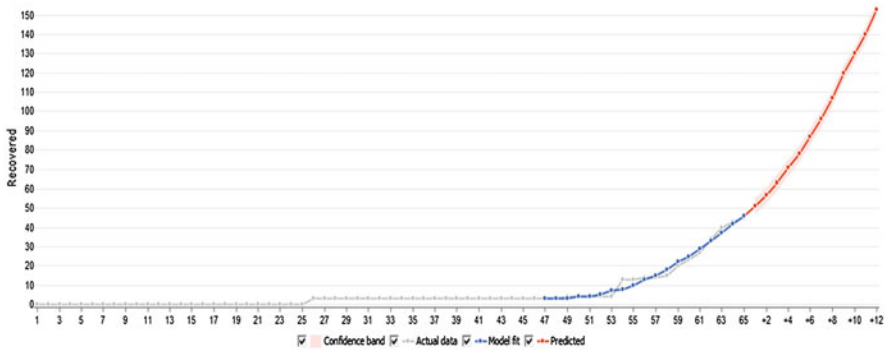


Fig. 5.9 Recovered case prediction graph plot

With the above mathematical function (5.8) and system generated criterion value of 0.17355, the system is predicting the recovered cases. Figure 5.9 shows the predicted values for recovered cases.

Tables 5.3 and 5.4 shows the predicted value and post-processed results of confirmed, death and recovered cases based on combinatorial (quick) algorithm.

5.4.2 Stepwise Forward Selection Approach

Forward selection is a kind of stepwise regression which starts with an unfilled model and includes variables individually. In each forward advance one can include the one variable that gives the absolute best improvement to your model (Glen 2019). Here for the experimental part with stepwise forward selection method, the parameters used are reorder observation as Pseudo-random, validation strategy as *k*-fold validation, twofold, validation criteria as RMSE.balance, variable ranking as

Table 5.3 Forecast based on combinatorial(quick) approach

Target name	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12
Confirmed	887	1056	1282	1516	1689	1790	1874	2275	1996	1879	2163	2606
Deaths	22	26	31	36	42	48	53	60	66	73	80	90
Recovered	51	57	63	71	78	87	96	107	120	130	140	153

Table 5.4 Post-processed results by combinatorial (quick) algorithm

Post-processed results	Model fit (confirmed)	Model fit (death)	Model fit (recovered)
MAE	5.54	0.56	1.57
RMSE	6.89	0.90	2.05
Standard deviation of residuals (SD)	6.85	0.89	2.05
Correlation	0.99	0.98	0.98

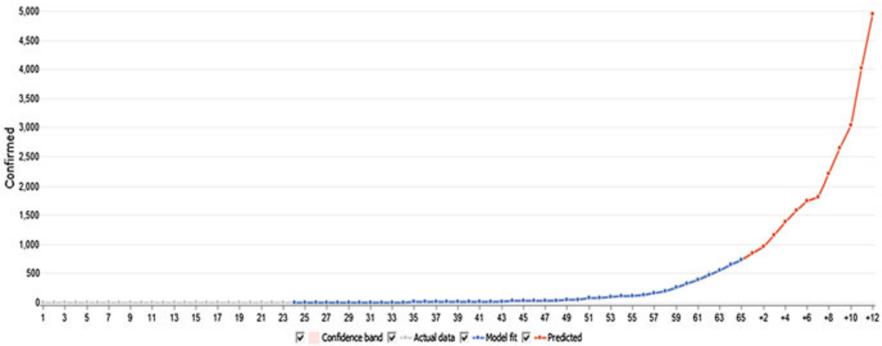


Fig. 5.10 Confirmed case graph plot

correlation, drop variable as rank 100, no additional variable are used with limit model complexity as 200, return best model as 100 with time series mode.

$$Y_1[t] = -1497.69 + \text{``Confirmed}[t-8], \text{cubert''} * 413.182 \tag{5.9}$$

With the above mathematical function (5.9) and system generated criterion value of 0.00153, the system is predicting the confirmed cases. Figure 5.10 shows the predicted values for confirmed cases.

$$\begin{aligned} Y_1[t] = {} & 1.84925 + \text{cycle} * 1.17415 + \text{``Deaths}[t-5], \text{cubert''} \\ & * (-2.82812) + \text{``Deaths}[t-9], \text{cubert''} * (-2.50114) \end{aligned} \tag{5.10}$$

With the above mathematical function (5.10) and system generated criterion value of 0.11036, the system is predicting the death cases. Figure 5.11 shows the predicted values for death cases.

$$Y_1[t] = -98.82 + \text{cycle} * 1.44 \tag{5.11}$$

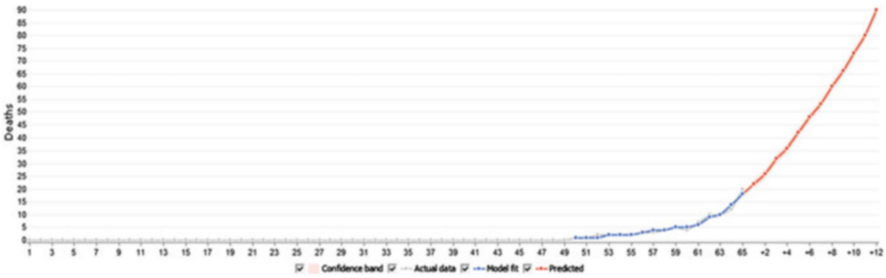


Fig. 5.11 Death case graph plot

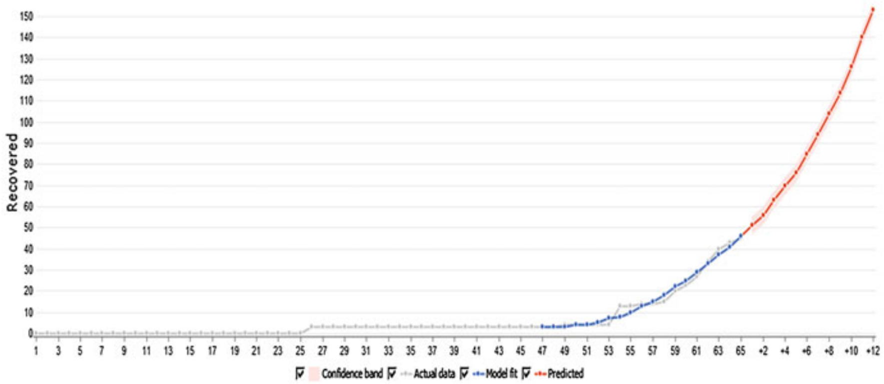


Fig. 5.12 Recovered case prediction graph plot

With the above mathematical function (5.11) and system generated criterion value of 0.17355, the system is predicting the recovered cases. Figure 5.12 shows the predicted values for recovered cases.

Tables 5.5 and 5.6 shows the predicted value and post-processed results of confirmed, death, and recovered cases based on stepwise forward selection algorithm.

5.4.3 Stepwise Mixed Selection Approach

The mixed stepwise variable determination system will ponder both including and evacuating one variable at each progression and make the best stride. In mixed calculation we could without much of a stretch include one variable, at that point include or expel another and afterward evacuate the primary variable included (CMU Statistics 2015). Here for the experimental part with stepwise mixed selection method, the parameters used are reorder observation as Pseudo-random, validation strategy as *k*-fold validation, twofold, validation criteria as RMSE.balance, variable

Table 5.5 Forecast based on stepwise forward selection approach

Target name	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12
Confirmed	856	972	1164	1392	1584	1750	1818	2212	2648	3040	4018	4952
Deaths	22	26	32	36	42	48	53	60	66	73	80	90
Recovered	51	56	63	70	76	85	94	104	114	126	140	153

Table 5.6 Post-processed results by stepwise forward selection algorithm

Post-processed results	Model fit (confirmed)	Model fit (death)	Model fit (recovered)
MAE	6.23	0.56	1.06
RMSE	8.26	0.90	1.47
Standard deviation of residuals (SD)	8.22	0.89	1.46
Correlation	0.99	0.98	0.99

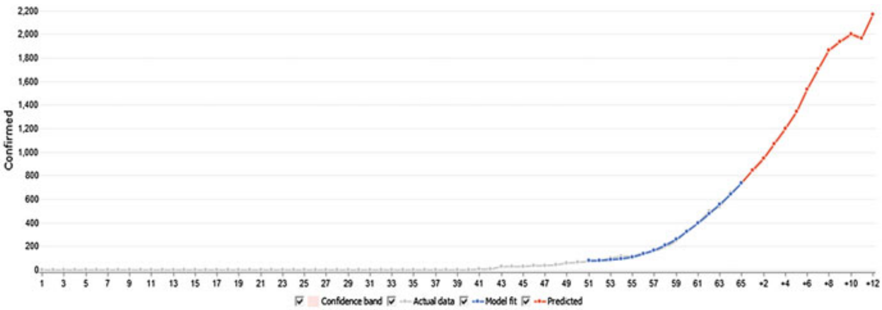


Fig. 5.13 Confirmed case prediction graph plot

ranking as correlation, drop variable as rank 100, no additional variable are used with limit model complexity as 200, return best model as 100 with time series mode.

$$Y_1[t] = 304.496 + N_3 * N_2 * 0.000803145 \tag{5.12}$$

$$N_2[t] = 301.867 + N_4 * N_3 * 0.000810118 \tag{5.13}$$

$$N_3[t] = 298.562 + N_5 * N_4 * 0.000818998 \tag{5.14}$$

$$N_4[t] = 296.225 + N_6 * N_5 * 0.000825283 \tag{5.15}$$

$$N_5[t] = 71.2228 + \text{time} * N_6 * 0.0161384 \tag{5.16}$$

$$N_6[t] = -1591.51 + \text{time} * \text{cycle} * 0.00773787 \tag{5.17}$$

With the above mathematical functions (5.12–5.17) and system generated criterion value of 0.0921, the system is predicting the confirmed cases. Figure 5.13 shows the predicted values for confirmed cases.

$$\begin{aligned} Y_1[t] = {} & 1.84925 + \text{cycle} * 1.17415 + \text{``Deaths}[t-5], \text{cubert''} \\ & * (-2.82812) + \text{``Deaths}[t-9], \text{cubert''} * (-2.50114) \end{aligned} \tag{5.18}$$

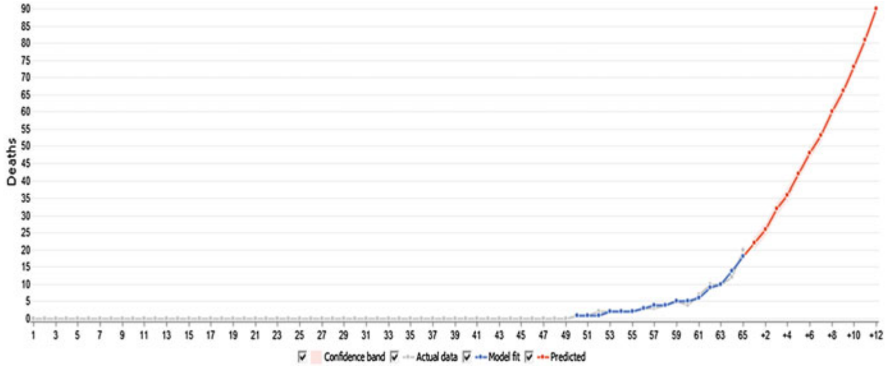


Fig. 5.14 Death case prediction graph plot

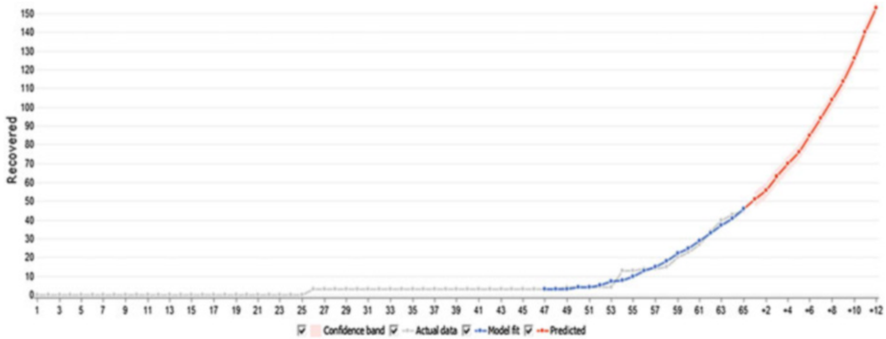


Fig. 5.15 Recovered case prediction graph plot

With the above mathematical function (5.18) and system generated criterion value of 0.11036, the system is predicting the death cases. Figure 5.14 shows the predicted values for death cases.

$$Y_1[t] = -98.82 + \text{cycle} * 1.44 \tag{5.19}$$

With the above mathematical function (5.19) and system generated criterion value of 0.17355, the system is predicting the recovered cases . Figure 5.15 shows the predicted values for recovered cases.

Tables 5.7 and 5.8 shows the predicted value and post-processed results of confirmed, death, and recovered cases based on stepwise mixed selection algorithm.

Table 5.7 Forecast based on stepwise mixed selection approach

Target name	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12
Confirmed	845	947	1071	1392	1199	1343	1706	1864	1939	2002	1968	2172
Deaths	22	26	32	36	42	48	53	60	66	73	81	90
Recovered	51	56	63	70	76	85	94	104	114	126	140	153

Table 5.8 Post-processed results by stepwise mixed selection algorithm

Post-processed results	Model fit (confirmed)	Model fit (death)	Model fit (recovered)
MAE	11.2	0.56	1.63
RMSE	13.06	0.90	2.09
Standard deviation of residuals (SD)	13.05	0.89	2.08
Correlation	0.99	0.98	0.98

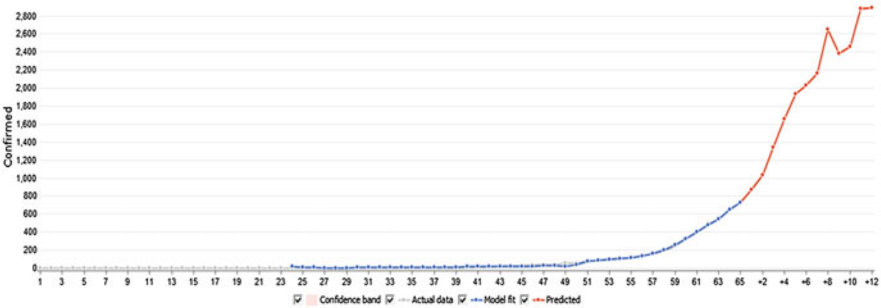


Fig. 5.16 Confirmed case prediction graph plot

5.4.4 GMDH Neural Network Approach

GMDH neural network comprehends time arrangement anticipating and information mining undertakings by building artificial neural networks and applying them to the information. Neural network estimating is more adaptable than ordinary linear or polynomial approximations and is along these lines progressively exact. With neural networks one can find and consider nonlinear associations and connections among information and construct an up-and-comer model with high forecast quality (NNS 2020) . Here for the experimental part with stepwise mixed selection method, the parameters used are reorder observation as Pseudo-random, validation strategy as *k*-fold validation, twofold, validation criteria as RMSE.balance, variable ranking as correlation, drop variable as rank 100, neuron function as $a + xi$ (linear), maximum number of layers as 33 with initial layer width as 1 with time series mode.

$$Y_1[t] = -1497.69 + \text{“Confirmed}[t-8], \text{cubert”} * 413.182 \tag{5.20}$$

With the above mathematical function (5.20) and system generated criterion value of 0.0015284, the system is predicting the confirmed cases. Figure 5.16 shows the predicted values for confirmed cases.

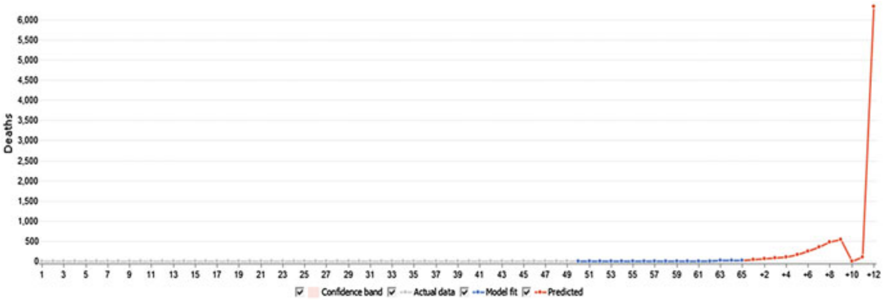


Fig. 5.17 Death case prediction graph plot

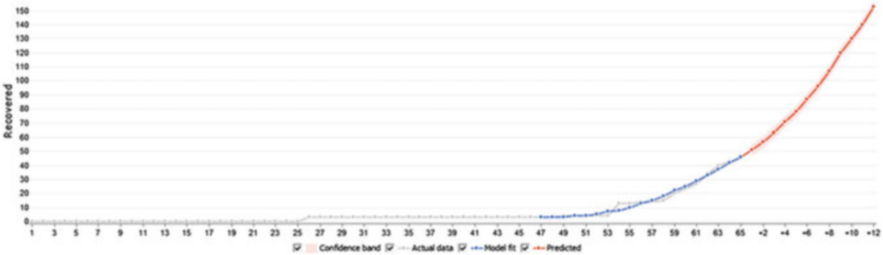


Fig. 5.18 Recovered case prediction graph plot

$$Y_1[t] = 0.426828 + \text{``Deaths}[t-6].\text{cubert''} * N_3 * 0.142041 + N_3 * 0.740675 \tag{5.21}$$

$$N_3[t] = -0.219251 + \text{``Deaths}[t-5].\text{cubert''} * N_3 * 0.491739 + N_3 * 0.957112 \tag{5.22}$$

$$N_4[t] = 0.438937 + \text{``Deaths}[t-9].\text{cubert''} * N_5 * 0.126892 + N_5 * 0.797122 \tag{5.23}$$

$$N_5[t] = 0.671779 + \text{``Deaths}[t-1].\text{cubert''} * \text{cycle} * 0.437579 \tag{5.24}$$

With the above mathematical functions (5.21–5.24) and system generated criterion value of 0.031344, the system is predicting the death cases. Figure 5.17 shows the predicted values for death cases.

$$Y_1[t] = -98.82 + \text{cycle} * 1.44 \tag{5.25}$$

With the above mathematical function (5.25) and system generated criterion value of 0.17355, the system is predicting the recovered cases. Figure 5.18 shows the predicted values for recovered cases.

Tables 5.9 and 5.10 shows the predicted value and post-processed results of confirmed, death, and recovered cases based on GMDH-NN algorithm.

5.5 Comparison Between the Algorithms Based on MAE, RMSE, SD, Correlation

Figure 5.19 shows the comparison of various used algorithms on parameters like Correlation, SD, MAE, RMSE. Based on the comparison it is clear that the stepwise mixed algorithm gives good prediction result for confirmed cases.

Figure 5.20 shows the comparison of various used algorithms on parameters like Correlation, SD, MAE, RMSE. Based on the comparison it is clear that the GMDH-NN algorithm gives good prediction result for death cases.

Figure 5.21 shows the comparison of various used algorithms on parameters like Correlation, SD, MAE, RMSE. Based on the comparison it is clear that the GMDH-NN algorithm gives good prediction result for death cases.

5.6 Conclusion

As this disease is declared as an epidemic, the present study will help researchers to understand the impact of this outbreak. We have used combinatorial (quick), stepwise forward selection, stepwise mixed selection and GMDH neural network to predict the spread of disease in India. Mathematical function mentioned in the each approach provides insight about the provided prediction. From the parametric comparisons it is clear that the GMDH-NN algorithm provides good accuracy in our case. Post-processed results obtained give the accuracy of the fitted model. COVID-19 provides a broad spectrum of future work in various disciplines.

Table 5.9 Forecast based on GMDH-NN approach

Target name	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12
Confirmed	869	1038	1337	1655	1933	2029	2161	2653	2380	2460	2877	2889
Deaths	22	27	32	36	43	48	53	60	66	73	81	90
Recovered	51	57	63	71	78	87	96	107	120	130	140	153

Table 5.10 Post-processed results by GMDH-NN approach

Post-processed results	Model fit	Model fit	Model fit
MAE	8.64	0.12	1.68
RMSE	10.56	0.35	2.20
Standard deviation of residuals (SD)	10.55	0.35	2.19
Correlation	0.99	0.99	0.98

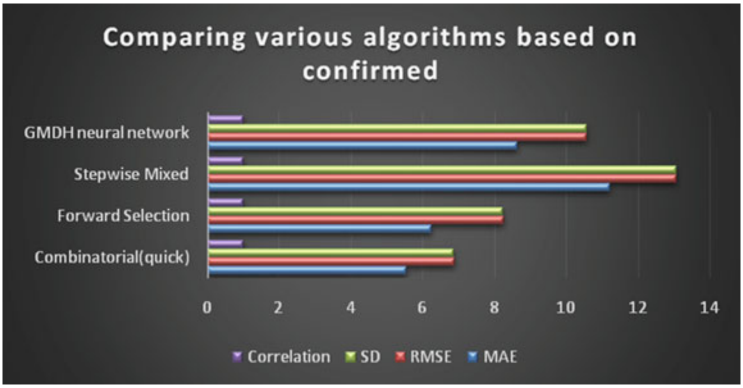


Fig. 5.19 Comparing algorithms for confirmed cases based on various parameters

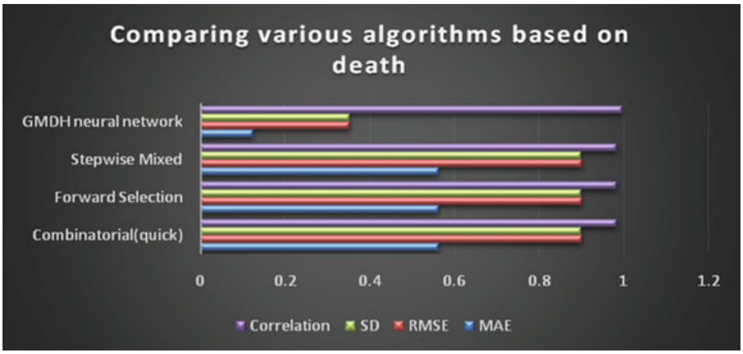


Fig. 5.20 Comparing algorithms for death cases based on various parameters

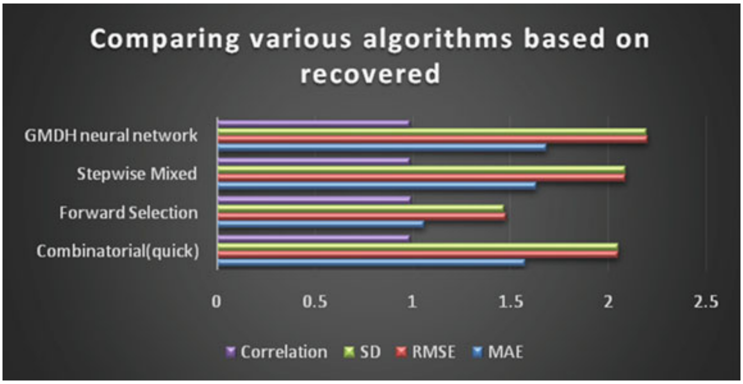


Fig. 5.21 Comparing algorithms for recovered cases based on various parameters

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Data-Driven Symptom Analysis and Location Prediction Model for Clinical Health Data Processing and Knowledgebase Development for COVID-19

6

Subhasish Mohapatra, Suneeta Satpathy, and Debabrata Paul

Abstract

The healthcare community in a global forum has been fighting to break the unprecedented growth of COVID-19 outbreak. So, the researchers across the world are enabling AI-oriented technologies to develop computerized models that can imitate human intelligence and better understand and analyze galactic volumes of data to identify patterns of interest and its perceptiveness. The said fields have already proven to be invaluable in predicting, classifying, and forecasting any types of diseases as well as the risks associated with it in many spheres. Both AI and Machine learning potentially has reformed healthcare domain in terms of early diagnosis and treatment by developing an approach to make health care sector faster and smarter. The present chapter has focused on symptom analysis and evaluation for COVID 19 patients by adopting Random Forest machine learning algorithm and at the same time made use of cloud event for putting an insight of region tracking into different color zones when patient symptom is captured through graphical user interface. Furthermore, the study has proposed a novel data driven decision level forecasting modeling approach for data integration, processing, and knowledgebase development related to health network for dynamic analysis of COVID 19. Based on data and knowledge evaluation and by extracting relevant features from such evidence based symptom analysis, a thorough review of various COVID 19 literatures and recent applications of AI and machine learning for dwindling and suppressing the strikes of the outbreak has been done with a belief that the integration of machine

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learning application with cloud application programming interface for symptom perusal and tracking would provide a justification of the establishment of association for a better forecasting and impending faster decision broadcasting for next generation AI-driven health care sector to defeat this challenging virus battle.

Keywords

Machine learning · Random forest · COVID 19

6.1 Introduction

World Health Organization has acknowledged COVID-19 as a novel virus with its source being originated from Wuhan city, China, 2019 and has taken many lives throughout the globe. Though the novel virus origin is traced back since the year 1965 but it is not being identified formerly in human body. COVID-19 virus is seen causing health impacts on people starting from regular cold to Middle East respiratory syndrome (MERS-CoV) (Hossain and Househ 2016) and severe acute respiratory syndrome (SARS-CoV) (Qiu et al. 2018) with general symptoms being detected are fever, cough, shortness of breath, and breathing problems leading to pneumonia and other respiratory track problems. As there is not yet any precise or well defined cure for this new signature of COVID-19, the healthcare system globally is thrashing about for the integration of latest technologies and decision-making strategies enabling prediction, detection and diagnosis to knob the uncontrolled growth of corona virus. As novel COVID-19 is a new signature, it is expected to rise exponentially to make more impact on human life in turn to global healthcare industries and public health sector, hence analyzing, predicting the disease symptom parameters and its outbreaks is a demanding assignment. In this perspective, artificial intelligence (AI) plays an important role at an earlier stage of symptom analysis and disease prediction. Such application of AI can definitely extend a helping hand to the healthcare industries as because early patient symptoms' history diagnosis by AI can try beforehand to save lives of people. So the present research work makes an attempt to capture the living habits of people through graphical user interface (GUI) which judiciously monitor symptoms being entered to detect COVID-19 case by case. The symptom data set as a knowledgebase is collected from various research works through web as well as from WHO and mygov.in sites. Further, the research adopts Random Forest technique for making a symptom analysis of COVID-19 and at the same time implements cloud API based location tracing so that it can assist in location tracking of COVID-19 cases. Moreover, this present research work not only focuses upon COVID-19 prediction but also makes an attempt to track spatial location of the patients with positive symptoms leading to increased people satisfaction. As we all agree with the healthcare punch line "prevention is better than cure," so the present study believes in preventing the spread of the epidemic outbreak by early tracking of patient.

The study is based on research articles and papers reviews published recently with an intention to gain a substantial knowledge on the pandemic and the current developments being done in this field. The primary motive is to carry the research forward so as to support the healthcare industries, public health as well as research communities in providing a solution, which can act as an augmentation to the existing healthcare solutions.

The chapter is systematized as follows. Section 6.2 is endowed with an up to date literature survey to highlight the COVID-19 pandemic and the contributions provided by the researchers to deal with the epidemic. Section 6.3 describes the rudiments of Random Forest machine learning algorithm and its possible application for predicting and detecting the COVID-19 symptoms. A Case study COVID-19 symptom analysis and its prediction using Random Forest algorithm as well as cloud-based API application for differentiating the spatial locations of eastern region district of India into different colored zones is visualized and illustrated in Sect. 6.4. Section 6.5 further highlights the improvement of detection algorithm to handle chronic disease patients for COVID-19 symptom prediction and early medical attention. Alignment of output of this research work to healthcare is done in Sect. 6.6. Finally, Sect. 6.7 concludes the chapter followed by future scope of the work in Sect. 6.8. However, in a rapidly increasing and spreading epidemic field like COVID-19 we expect that our work will provide a useful informational application of machine learning toward COVID-19 symptom analysis as well as location prediction and can be an augmented assistance to public healthcare and research community.

6.2 Related Work

The technological applications and computer science integration with healthcare industries contribute substantially in different disease identification, prediction as well as its diagnosis. The computer science research is in continuous progress to reveal the information about the current epidemic outbreak of COVID-19 by developing models, strategies for its detection, monitoring, impact prediction with the applications of machine learning, deep learning, AI, IoT-enabled healthcare solutions, etc.

Healthcare experts including doctors, radiologists are able to make a manual diagnosis of chest CT images to identify the COVID 19 cases. The research work in Bai et al. (2020) uses the chest images to differentiate COVID-19 from other viral pneumonia and achieved substantial accuracy. But the work done manually takes more time and plays a major factor when the requirement is to analyze lot of chest images. In order to deal with time as well as correctness factor which can be a life threatening issue a range of AI methods are adopted to automate radio diagnosis process. Many current researches carried out by implementing AI techniques to identify COVID-19 from X-ray and CT images of chest showed potential accuracy. Also the research study in Li et al. (2020a, b) developed AI based learning model in order to diagnose COVID-19 disease from chest images. Various machine learning and deep learning models are also developed to unearth new corona virus from chest X-ray images (Barstugan et al. 2020; Xu et al. 2020; Zheng et al. 2020; Wang et al. 2020; Khadidos et al. 2020). Similarly deep learning policies and approaches are used (Zheng et al. 2020) on Computed Tomography pictures at the initial phase and became the fast ever process to detect COVID-19 infect ants enabling in time quarantine and medical treatment. The categorization of COVID 19 disease genes is done using machine learning techniques in research works Randhawa et al. (2020) and Metsky et al. (2020). The mortality rates as well as survival rate of COVID 19 patients are also predicted in Yan et al. (2020) and Satpathy et al. (2021). The innovation of prospective drug to fight with novel COVID-19 is also narrated in the research study Ge et al. (2020). Various classifiers of neural network as well as deep learning analysis mechanisms are developed to identify, detect, and monitor the COVID-19 symptoms over the time (Gozes et al. 2020). An AI based prototype is also developed taking into consideration social network data as well as demographic data in Ye et al. (2020) to make an assessment of risks of COVID 19 infections for particular geographical region. The genetic attributes for COVID-19 are taken into consideration using machine learning alignment-free and decision tree approaches for the categorization of the said disease (Randhawa et al. 2020). Social media based Situational awareness information associated with COVID-19 are classified using various classifiers like support vector machine, naive Bayes and Random Forest (Li et al. 2020a, b). The COVID-19 infection risk prediction through machine learning algorithm is also done with the data being collected from an online tele-survey to obtain the travelling histories of the people (Rao and Vazquez 2020) with a focus to minimize the dissemination of the infections. The concluding remarks made from the literature survey that ample amount of investigative research work has been done to have a comprehensible representation of the present wide spread pandemic. Also vigorous research is in progress with artificial intelligence, machine learning, IoT, big data and deep learning techniques to get hold of speedy detection, prediction and diagnosis with great accuracy for COVID-19 patients so that a collaboration can be made with healthcare industries for better management and processing of this pandemic outbreak. There are also various competent machine learning based prediction models available that can be used and tested for developing hands-on strategies to cater to the instant needs of public health as well as clinical health care industries to fight with current COVID-19 pandemic as well as similar kind of outbreak in future.

6.3 Rudiments of Random Forest Machine Learning Algorithm

Machine learning is a subfield of AI which is considered to be a successful application in many facets of healthcare industry from medical imaging to symptom analysis. The Machine learning applications can learn, analyze and predict result outcomes faster than human experts as it can effectively overcome human limitations by analyzing a lot of factors efficiently in less time. Further, it gives precise result that would be more helpful in concluding with better decision-making strategies in healthcare research. Random Forest is one of the machine learning technique that falls under supervised classification technique as it creates a forest by accumulating features from dataset randomly (Janitza et al. 2018). It conceptually builds a direct relationship between numbers of trees in formed forest. The result accuracy in Random Forest classification technique is dependent on the number of trees. Features of the data set under study are evaluated which results in the consequences and formation of decision trees. Such decision tree representation takes input data randomly from training dataset and predicted outcome is reflected in the leaf node (Wang and Xia 2016). Random Forest root node selection and splitting of feature node is computed randomly composing of many decision trees which in turn takes the maximum outcome of the response from each tree in the forest (Zimmerman et al. 2018).

Algorithm

1. 'M' features are randomly selected from total 'N' features where M<<N.
2. From the subset of 'M' features the node 'G' is enumerate doing best split technique.
3. Splitting technique is applied for each daughter node by using proper split method.
4. Steps 1 to 3 is redone until '1' number of node has not been identified.
5. Creation of forest is accomplished by replicating step-1 to 4 for 'n' number of epochs to fabricate 'n' number of trees.

In the final stage of the algorithm Random Forest classifier is concentrated upon prediction that describes the following in general

1. Test features would be accumulated and implemented in terms of a rule for each randomly created decision tree. Outcome would be predicted as well as restored known as target value (Feurer et al. 2019).
2. Response if computed is termed as vote for each predicted target.
3. At the end, high rise response would be considered as the final prediction from the Random Forest algorithm (Wu et al. 2017).

Random Forest based disease analysis is a versatile technique as it uses ensemble learning method. Ensemble learning technique is concentrated upon multiple learning algorithms in the present context of the Random Forest which is widely adopted by many researchers and data science professionals by providing optimum predictive performances over data set (WHO and mygov.in/covid-19/) for eastern region in India. Random Forest application normally uses a technique known as bootstrap aggregating or bagging that in turn results into better performance with reduced variance of model with no rise in bias value (Utkin et al. 2019). In comparison to a single tree Random Forest is a combination of multiple decision trees that choose features randomly to construct multiple decision trees and take the average of the result being obtained (Hu and Steingrimsson 2018). The algorithm decreases the error variance instead of the bias that can be fruitful and would witness its power in terms of accuracy in an unpredicted datasets like novel COVID-19 dataset (Schmid et al. 2020).

6.4 Case Study for Symptom Analysis and Its Prediction with Random Forest Using COVID-19 WHO Data Set

The WHO takes the responsibility of controlling, managing and harmonizing the international health by keeping a continuous eye on the communicable diseases through supervision, inspection attentiveness and timely rejoinder. Since January 2020 WHO has started uncovering its Dashboard for COVID-19 that highlights and mentions the lists of COVID-19 cases, total death counts by country both in term of numeric figure and visual map along with its data resources (World Health Organization n.d.-a. Novel corona virus (COVID-19) situation (public dashboard); World Health Organization n.d.-b. WHO Health Emergency Dashboard. https://extranet.who.int/publicemergency). At the other hand JHU CSSE dashboards were also maintained in the same way. But the WHO and JHU CSSE dashboards were differing in terms of total COVID 19 counts prior to February 2020 (Johns Hopkins n.d. CSSE Corona virus COVID-19 Global Cases (dashboard) https://gisanddata.maps.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6.), the former was showing laboratory-confirmed cases and the later was showing diagnosed cases regarding symptom array and chest imaging. However, from late February onwards both WHO and JHU CSSE dashboards are synchronized to display total no of COVID-19 cases. In our case study analysis, the WHO as well as JHU CSSE specified COVID-19 dataset is exercised along with disease specific features, attributes from the daily updated guidelines and information highlights of the disease.

6.4.1 Step Wise Experimental Result Analysis and Discussions

Step 1: Data Set Preparation

The dataset being downloaded from (WHO and mygov.in/covid-19/ for eastern region in India) and is recreated and saved with extension as .csv file for analysis.

All the required libraries are imported with all essential modules being installed.

In order to study the disparities in the relative significance of the variables, a simple bar plot of the feature importance is drawn for visualizing the variables. The variable parameters that are considered to have a precise overview for further analysis is illustrated in Fig. 6.1. So, it further propagates the experimental set up in this research study. The research study also referred symptom inputs of overall parameters of Covid19 cases from WHO, JHU as well as from mygov.in/covid19. More over the precise result is taken from daily news to track the mortality rate and symptoms behind demise of the patient (Brown and Nicholls 2015). In certain cases, symptoms are also referred from twitter, social networking website to collect the required information from the patient's relatives to achieve better resultant output (Bermbach et al. 2017).

Step 2: Following step 1, the COVID-19 dataset is further segregated into training set and validation set (85%) and (15%) samples. It is then being fitted into the

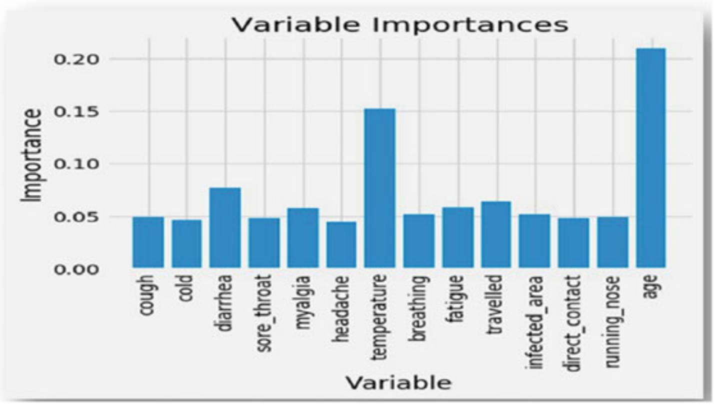

Fig. 6.1 Symptom plot graph of COVID-19

RandomForestClassifier, by using the RandomForestClassifier.fit with the parameter as X_train and Y_train.
The RF model contains 300 decision trees, as the n_estimators is taken as 300. The input of the RF model includes 13 quantitative features calculated from Body Temperature, and the output is either affected or not affected by COVID-19. To explore the relations of 13 quantitative features to identify COVID-19 positive or negative, importance of each quantitative feature is also calculated based on the RF model. The importance of each quantitative feature (F_i, $i = 1, \ldots, 13$) is related to the reduced Gini index in the RF model using F_i, which reflects the capacity of F_i in discriminating the positivity or negativity case. Specifically, the reduced Gini index (G_{RD}) of F_i is calculated by Eq. (6.1):

$$G_{\mathrm{RD}}(F_i) = \left(1/|\mathrm{node}^i|\right) \sum G\left(x^i\right) - G\left({x^i}_{\mathrm{left}}\right) - G\left({x^i}_{\mathrm{right}}\right) \tag{6.1}$$

$$x_i \in \mathrm{node}^i$$

Where node_i is the nodes in the RF models that use quantitative feature F_i to split samples x^i in node^i into ${x^i}_{\mathrm{left}}$ and ${x^i}_{\mathrm{right}}$. Based on $G_{\mathrm{RD}}(F_i)$, the importance of F_i can be defined as Eq. (6.2):

$$(F_i) = \left({}_{\mathrm{RD}}(F_i) / \sum_{i=1}^{13} G_{\mathrm{RD}}(F_i)\right) \tag{6.2}$$

According to the resulting importance of quantitative features, top quantitative features of the great importance are selected and used to build the RF model. To get the proper hyper-parameter, agrid search strategy is adopted. Specifically, in the experiment, besides the RF model using 13 quantitative features (i.e., K13), the model is built and thereafter it is being tested with the validation samples

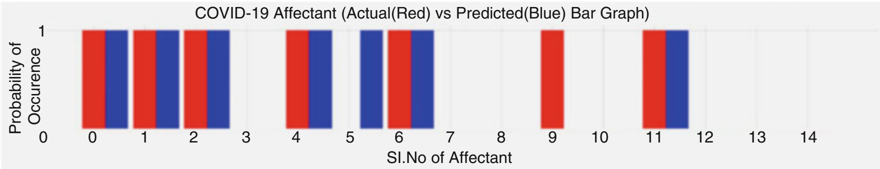

Fig. 6.2 Analysis of accuracy result in Covid-19 case

followed by performance evaluation and comparison using validation samples. Details of the evaluation results of these RF model and the corresponding bar chart is in Fig. 6.2. The model score being predicted comes approximately 86.66%, which is a great value at the initial phase. The score can be further enhanced enormously with the dataset being more refined in due course of time. Here in this section authors include analysis result of COVID-19 infecting cases. In Fig. 6.2, one signifies number of infected persons and zero indicates normal person. Red bar indicates actual infected cases and blue bar indicates predicted cases from Random Forest analysis.

It could be observed that the RF model gives good performance while predicting the validation samples.

6.4.2 Calculation of Average Baseline Error

Step 3: As a normal concept the chances of getting the infection is more in the people who are getting in direct contact of the COVID-19 patients. So, the parameter **direct contact** is chosen having higher impact on getting impinged by COVID-19 disease.

Step 4: It could be observed that the RF model gives good performance while predicting the testing samples. Specifically, the evaluation result by the RF model, the baseline error is calculated as 0.6, the mean absolute error is calculated and the value is dropped to 0.13 that justifies the model is less error prone.

The bar graph shows the 13 quantitative features of the great importance to the severity i.e., given in Fig. 6.1. The age is at the top rank. An interesting finding is that quantitative features calculated from the age are relatively more important than those of headache, from the bar graph of the variable of symptoms importance which are mentioned from 0 to 13.

Step 5: Finally, the accuracy of the model is being tested and is found to have 93.33% detection accuracy that derives a conclusion that if a patient is reckoned to be COVID-19 positive by the classifier, then in real it can be concluded the patient is suffering from COVID-19. The accuracy result can further be exercised for enhancements with more sample dataset from WHO and other approved sites for research.

Step 6: Again a new threshold level has been set for the case if any person is having any chronic disease. If the user is having any chronic disease for that the threshold value for the detection algorithm is directly dropped down by 0.45. So, if the user is found above 0.45 with a chronic disease then it would be reflected that the user needs to have an immediate medical attention.

As per the current medical research and public healthcare instructions reflected in various medical awareness news and websites rationalize that the people having chronic diseases like Diabetes, Blood Pressure and Asthma are more prone to be affected by COVID-19, so keeping healthcare advisory guidelines in mind the threshold value is dropped to an extent. Such people having chronic diseases are more prone to get attacked by COVID-19 and seek medical attention at an early stage. If the user is not having any one of the mentioned chronic diseases then the model would be evaluated by the default threshold and result would be predicted as per the analysis. So the above-mentioned detailed analysis illustrates only the victims who are infected by COVID-19 and come across to the server, go for a test with his/her present health condition, and if found positive by our stated prediction decision algorithm, then his/her location is getting fetched and added to the database as well as location is shown in the tracing map.

In addition to the mentioned analysis, to get more value additions to this research study a specific spatial location i.e., eastern part of India (West Bengal) is chosen and classified into three zones Red, Orange, and Green based on the brutality of COVID-19 according to Ministry of Health and Family Welfare, Government of India.

The containment zone in the districts of the state is delineated based on:

- COVID case mapping and contacts tracing
- Spreading of COVID cases and its respective contacts in the geographical region
- Areas affected with COVID-19 cases
- Administrative rules

Now on basis of classification of the zones into three categories, this feature is being implemented in the map to serve the healthcare industries, public health sector in a better way. In our research work, the case study as eastern part of India and its spatial jurisdiction are being classified into three different zones based on the instructions, the latest current report as well as daily news update over internet. Further procedural details are explained as follows.

6.4.3 Classifying Into Zones

Step 1: The most important thing before classifying into zones is to get the geographical data, i.e., the latitudes and longitudes of the country, and its states and its districts. GADM (Singh et al. 2020a, b) uses a high spatial resolution with extensive set of attributes able to map the administrative areas of all countries with all levels of subdivision. So, in the present research work we are using KMZ: level2 data (Robbins et al. 2007) to get the geographical data of India. Now KML file is obtained by extracting the KMZ file from which latitude and longitude of the entire India, followed by its States as well as for all its districts are retrieved (Singh et al. 2020a, b).

Step 2: Following Step 1 the necessary data according to the requirement, in this case study West Bengal data followed by its districts and saving all the latitude and longitude individually into Districts wise in a text file is taken out which would be used for coloring the map.

Step 3: Next to test the working effectiveness of the data the entire West Bengal into its different districts is mapped by enabling the drawing on maps with maps (Tuli et al. 2020). It progressively passes the data into gmaps drawing layer by creating layers and implementing the features region wise. Polygon coordinate mapping function and the specified color (for current testing red is chosen) for coloring in spatial domain is selected for COVID-19 spread.

Step 4: Next the districts are colored into different colored zones for which a folder is created which contains all the district wise COVID-19 cases according to the latest report as on 12-05-2020. The idea is to color the map by setting some threshold value with a count of affected COVID-19 cases. According to latest information set by government, there is no formal notice or parameter that observes the minimum no of affected COVID-19 cases as a criterion to be set for declaring the region as a Red or Orange or Green zone. So, the present research analyses based on the data currently available which can be further modified in future with more information on hand.

6.4.3.1 Setting Threshold Value

So, according to the Global WHO analysis Report the parameters being set are:

If the no of cases is 0–5 it can be declared as Green Zone.
If the no of cases is 5–20 it can be declared as Orange Zone.
If the no of cases is above 20, it can be declared as Red Zone.

Important—The above-mentioned numerical range of value is only used for experimental coloring the spatial region of a map into different zones by setting a threshold value. This threshold is set for research testing purpose and not provided by Government as the threshold value if set only for testing the model it may happen that some of the districts might not fall under the category of zones provided by Government.

There are few research questions as follows that has been set during the experimental case analysis of the said prediction algorithm along with differentiating the spatial regions of the map in colors.

Q1. How to modify the data of the no of infectants if the user tested positive by the server? If so, how to identify in which district is the user from?

Previously the information is already stored for the no of cases, now if any of the peoples tested positive by the testing algorithm then the no of cases is expected to be incremented by one. It is possible with the help of Google maps api using the Geolocating and Geocoding being enabled, which can easily identify from which

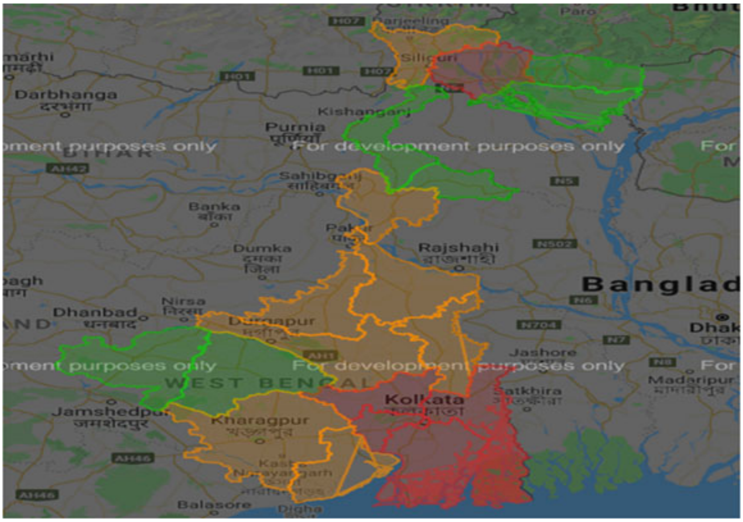

Fig. 6.3 Different zones of eastern region (India)

district is the user from, but the limitation for the work is a billing account is needed and if the traffic exceeds they will charge for it.

Q2. So, is it possible to geocode without having a Google maps api?

Yes, it is possible. After searching in various sites in web there is a python module reverse_geocoder. It can simply be installed using pip command. Reverse geocoder gets a latitude/longitude coordinate and returns the nearest town/city and hence helps to get from which district is the user from for free of cost.

Q3. So, how to do that?

The user latitude and longitude is passed to the Reverse geocoder mode and from its result the name of the district is extracted. After extraction of the district name, the name is searched in the folder in which the data of no of infected person are stored in the list of district name wise manner. On getting the name of the district the content of the file is read, which is a string and then converted into integer and incremented by 1 and finally the updated incremented value is written into the text file that illustrates fetching of user's latitude and longitude and reverse geocode it to get the actual district (Kalantar et al. 2020).

Important—By using Google Maps api it will be more faster and accurate to geocode, but as it is in the development phase so not used here. This is kept as our future enhancement work for fetching the location info more accurately and efficiently in terms of time.

The geocoding and zone analysis is only done into the map for eastern part of India and shown in Fig. 6.3.

6.4.4 Color Attribute of Map with Zones (Green, Orange, and Red)

Step 5: After the map is created with zones, it is integrated with the previous part of our research work to point the marker on the map that would reflect the people who are being tested infected by the detection algorithm. The aggregated component of research would give a more clear and detailed view to identify area as green, orange or red zones along with the people who are detected nearby. Map of eastern region of India with Zones (Green, Orange, and Red) and Marker Pointing infected person are done by adding the layer of the markers using the add_layer method of gmaps shown in Fig. 6.4. The COVID-19 cases are accumulated from mygov.in/covid19 website for experimental analysis (Rahman et al. 2020).

Step 6: The next integration is done into the server and flask server is used for testing in the present study. When user clicks on the view map button, the basic html file is loaded and our specified maps html file is being embedded into this html file. So, when user clicks it the entire embedded html file would be created first, i.e., the python file for creating the map will run to create the map with the present updated data which would be embedded into the basic html file which the user would be viewing (Annamalai et al. 2019; Gong et al. 2020).

Each time the user wants to check the data, the map would be created in the real time and would be shown to the user (Singh et al. 2020a, b; Gansner et al. 2010). The design of the interface is not a primary focus of the present research rather more emphasis is given to location prediction as well as symptom analysis (Liu et al. 2020). Design can be implemented in a better way in future. Figure 6.5 shows a sample page which shows the zones as well as the persons who are tested positive by

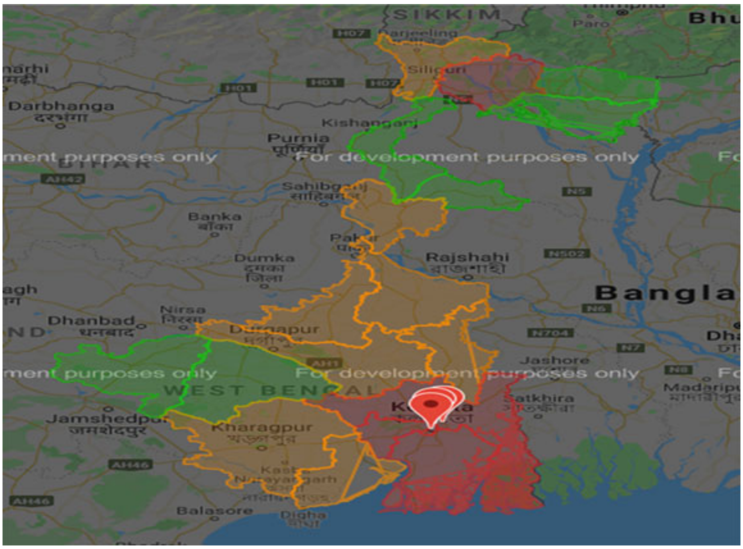

Fig. 6.4 Demarkation of zone where people are tested for COVID-19

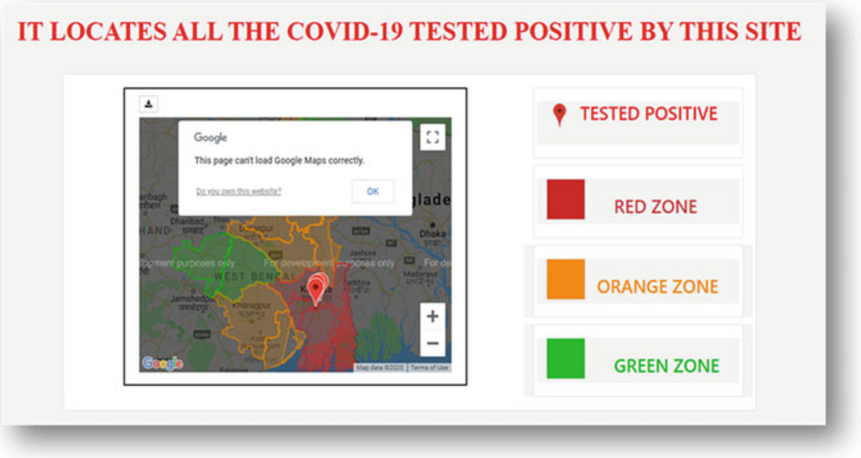

Fig. 6.5 Region map demarcation Page after COVID-19 detection in each subzone

this site. So, in this way the entire map will work in the real time with the present updated data (Allam and Jones 2020).

6.5 Augmented Enhancements to the Detection and Prediction Analysis for COVID 19

In the recent scenario, we have seen that the persons having any chronic disease are getting affected at a faster rate and are prone to death due to multi organ failure. Late prediction and detection can be a life threatening issue as due to less no of testing, people having chronic disease won't be able to understand whether they are infected by COVID-19 or not. At the end when the symptoms are identified, in spite of having medical support doctors may not be able to help. So, early detection is the need of the hour and a challenging task to avoid such type of deaths.

Keeping all these sensitive instances into consideration, the symptom analysis and detection is slightly modified to handle the persons with chronic diseases. Such modification to the detection algorithm can lead to early stage prediction as well as detection of the epidemic and can seek the medical attention with probability of high recovery rate.

6.5.1 Appending a New Drop-Down Menu in the Detection Page

A new drop-down menu is being added with few lists of the chronic diseases. In our present work some of the diseases which are more prone to get attacked by COVID-19 as per the healthcare advices and government guidelines are considered. The lists of chronic diseases are diabetes, blood pressure, and asthma. Such types of patients

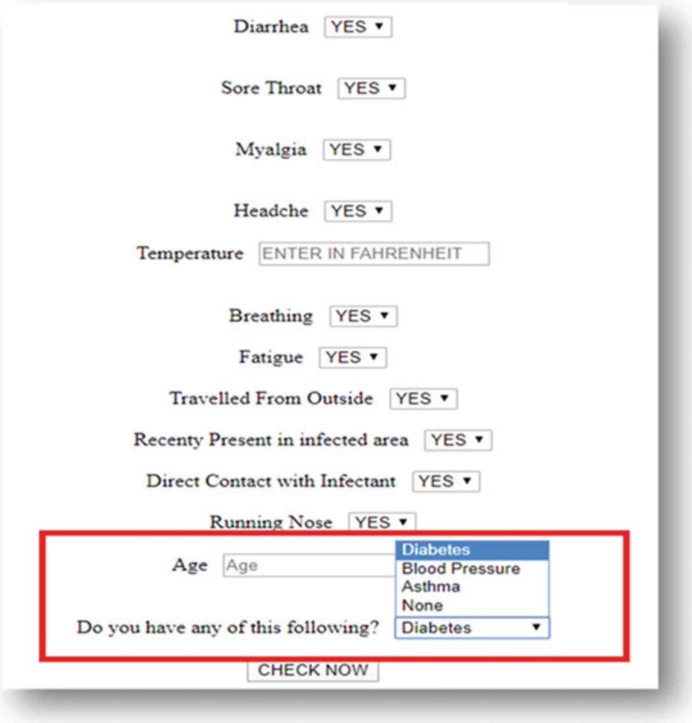

Fig. 6.6 GUI interface to collect symptom from user

seek medical attention at an early stage. The list Fig. 6.6 illustrates it and is also enriched with "none" option for those not having any chronic diseases.

Q. The research question is set as what happens when a user chooses any of the given chronic disease?

When a user chooses any of the given chronic disease from the list, the algorithm runs with a dropped threshold value by 0.45. On the other hand, if the user is found above 0.45 threshold values and at the same time having a chronic disease then it would be shown that the user needs to have a medical attention. Again, if the user is not having any one of the given chronic diseases then the algorithm would be evaluated by default threshold value and result would be given as per the analysis.

The flowchart below in Fig. 6.7 describes the working principle of the model as well as the server if a demand for detection is raised for a person with chronic disease.

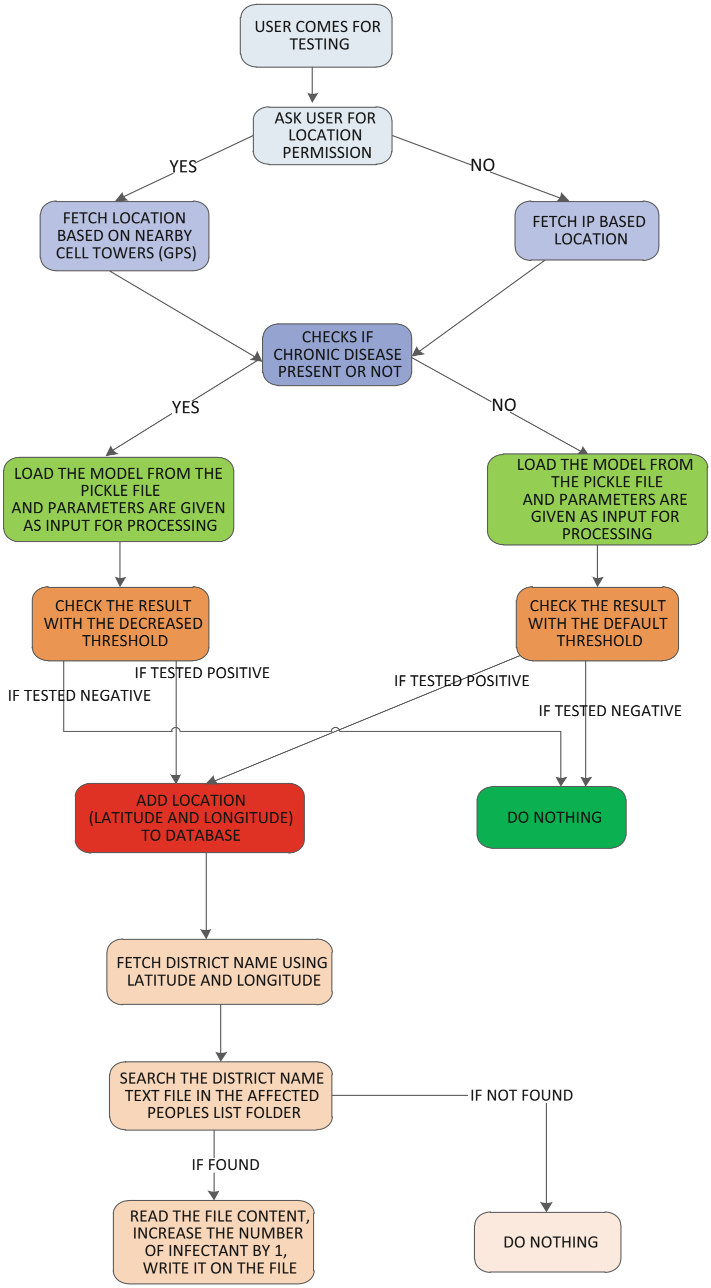

Fig. 6.7 Flow chart of COVID-19 predictor and tracker

6.6 Aligning Output of This Research as a Supplement to Heighten Up Healthcare and Public Health

This research study outcome is a well-founded framework with the use of Random Forest technique that can predict symptom analysis results (symptoms have been adopted according to WHO guidelines) precisely at the same time classifying a person (He/She is a COVID-19 positive or not) from his symptom inputs through kiosk. Since the rapid spread of COVID 19 pandemic has become a headache for every administrative officer, trying deliberately to check on its spread, the suggested research application can assist these frontline fighters by doing a minute watch over the spread of COVID-19 region wise through cloud based application and thereby generating a region wise report. However, when a person makes a login into this application, the cloud API has been used to take geographic information of user as per his/her prior consent to assist public health officials to combat the movement of the epidemic along with outlining a helping hand to the clinical healthcare industries to forecast the spatial location where epidemic has been spread at a higher rate. So, Cloud API (Application programming interface) includes front line tracking of corona virus pandemic and would be committed to provide assistance to research, health care professional as well as government. Also, COVID-19 geographical tracker API exploration is useful to track progression of pandemic and can enhance the information regarding active disease cases, confirmed cases and recovery results of patient region wise. Authors hope to obtain more dynamic responses if analysis will be done in an open case platform.

6.7 Conclusions

This research study has adopted Random Forest machine learning algorithm to analyze sufficient number of cases to perform proper diagnosis of COVID-19 disease symptoms and automates COVID-19 disease prediction by analyzing symptom collection dataset as per WHO (World health organization) guideline as well as certain prominent cases of COVID-19 from internet as a daily update case. The expected take away from this research work can be the formulation of better accuracy by taking responses from patient through a GUI interface (in Fig. 6.6). Since Machine Learning has not only proved it to be potentially improving the healthcare domain in terms of early diagnosis and treatment but also makes health care sector faster and smarter in variety of ways. The present work also demonstrates the application of machine learning for symptom evaluation for impending faster decision dissemination which is the biggest provocation in service industries like healthcare.

6.8 Future Work

Machine learning and cloud based mobility tracker can produce content specific result to health care professional and government. So as a future extension of this research can be studying the COVID-19 API request and response mechanism over the cloud more technically as well as develop more robust API that can be integrated with IoT-specific device to control the spread increasing at an exponential rate. Moreover Progressive cumulative research has to be done in this regard that can track information from the patient in the first step and investigation need to be done in the back end through machine learning mode as a second step followed by generation of a concise report providing a visualization overview of pandemic spread. In addition to the above research in this regard still need to explore actionable information in terms of citizen adaptability.

Conflicts of Interest The authors state no conflicts of interest in the publication of this chapter.

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A Decision Support System Using Rule-Based Expert System for COVID-19 Prediction and Diagnosis

7

Ishan Ayus and Niranjan Panigrahi

Abstract

Recently, the pandemic COrona VIrus Disease (COVID-19) has shown exponential growth in almost all part of the world. It has resulted more than 2 crores infection cases and nearly 7 lakhs death cases worldwide till date and the count is still increasing. Due to lock down, scarcity of medical experts and other constraints, this emerging health crisis requires a systematic and reliable Decision Support System (DSS) at the user level which will help in quick prediction and diagnosis by common healthcare workers without consulting medical expert. Expert system, a field of Artificial Intelligence (AI), has been playing a vital role in developing such systems. In this chapter, a brief outline is presented on fundamentals and generic design issues of expert system. The different AI approaches are surveyed in healthcare field for different diseases. An expert system, ESCOVID, is proposed with a set of 43 rules. The implementation of ESCOVID is done in ES-builder and validated by testing all possible inference paths.

Keywords

Artificial Intelligence · COVID-19 · DSS · Expert system · ESS · ES-builder

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7.1 Introduction

Recently, the pandemic COrona VIrus Disease (COVID-19) has shown unpredicted growth rate and resulted more than 2 crores infection cases and nearly 7 lakhs death cases worldwide till date and the count is still increasing (WHO n.d.). The disease originated at Wuhan state of China in the end of December 2019. It belongs to the virus family with Middle East Respiratory Syndrome (MERS) and Severe Acute Respiratory Syndrome (SARS). The COVID-19 infected people face mild to severe respiratory problems. Initial cases show that people above the age 60 and having other medical complicacies like cardiovascular diseases, hypertension, cancer, diabetes, kidney problems, and chronic respiratory diseases are more susceptible to this virus. Since last 2 months, the disease has shown exponential growth in the USA, Canada, and many European countries. It has also shown a continuous increase in many other countries.

The flu-like common symptoms of COVID-19 makes it more challenging for early detection by the general health professionals. Presently, the most reliable diagnostic test for COVID19 is RT-PCR but it is almost taking a week to give the result. In contrary, the recent rapid testing kits are gaining popularity, but they are subjected to error which may lead to inappropriate treatment of the patients. Secondly, in a highly populated country like India, going for clinical tests at early stage for all suspected patients is infeasible. Due to lock down and scarcity of medical experts as maximum of them are engaged in COVID hospitals, common people are not getting proper guidelines about the disease diagnosis. Also, people in rural area are not able to find expert health professionals who can detect this disease and guide them for suitable treatment.

Hence, this emerging health crisis requires a systematic, reliable and intelligent decision support system at the user-level which will assist common healthcare worker to diagnose the disease without consulting medical expert. In this context, Artificial Intelligence (AI) technology can play a vital role in developing such systems which can act as a supplement for human expert and assist the common healthcare personnel to do the task of diagnosis without expertise knowledge about this disease (Moore and Loper 2011).

In last several decades, AI has witnessed many such useful applications in healthcare field (Chang 2020). One such field of application of AI is expert system (Smith 1986). An expert system is a kind of DSS, which has a knowledgebase (KB), inference engine (IE), and user interface (UI). The KB contains set of factual rules and relevant data about an intended problem and using the IE, it can suggest relevant solution. In early 1980s, some well-known expert systems developed in the field of medical diagnosis are: MYCIN, PXDES, and CADeT (Wai et al. 2005). So, continuing this trend, expert system can also be thought of as a feasible approach for COVID-19 prediction and trusted diagnosis.

The chapter contributes the following major points:

1. An outline of AI-based approaches in medical field is highlighted
2. Fundamentals of expert system and its generic design issues are discussed

3. An expert system based on rules, ESCOVID, is proposed for COVID-19 by formulating 43 rules with reference to different medical sources
4. The implementation and testing of ESCOVID is carried out using an online ESS, ES-builder.

The remaining of the chapter is structured as: A gist about expert system and its design issues is presented in Sect. 7.2. Section 7.3 summarizes the application of expert system in medical field. The proposed system, ESCOVID, is discussed in Sect. 7.4 and its implementation in ES-builder in Sect. 7.5. Section 7.6 finally concludes the chapter.

7.2 Background

This section highlights different AI-based methods used to predict and diagnose diseases. The literature survey in this context can be broadly classified into two categories as shown in Fig. 7.1. The works done in this field are discussed below.

7.2.1 Machine Learning-Based Data-Oriented Approach

Machine learning (ML) is a field of AI with the ability of learning and analyzing abundant data using different models and experiences. The types of learning used in ML are supervised, unsupervised, and reinforcement learning (Jordan and Mitchell 2015). In this method, the statistical inference is performed by fitting a model or prediction, for the process of decision-making. This starts with the acquiring of a large amount of data in the domain of the problem. As the accuracy of the model is influenced by large amount of data i.e., larger the amount of data collected, more the accuracy of the analysis conducted. The machine learns these data and it explores events based on a bunch of data around the domain using different machine learning models. Some implantations of data-oriented approaches in the field of clinical diagnosis and prediction of the diseases are as follows.

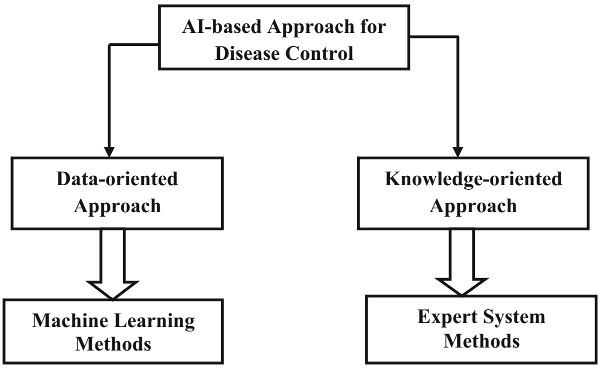


Fig. 7.1 Classification of AI based approaches for disease control

A machine learning-based system that utilizes artificial neural network for the diagnosis of various heart diseases (Safdar et al. 2017). A DSS for the diagnosis of acute nephritis disease and heart disease is evaluated using artificial neural network (ANN) (Al-Shayea 2011). An intelligent system to diagnose hepatitis B using generalized regression neural network is presented and evaluated its severity (Panchal and Shah 2011). For Type-1 diabetes mellitus (T1DM) patient, a DSS is designed using feed forward neural network (FNN), and other regression methods for the prediction of the risk of develop retinopathy (Skevofilakas et al. 2010).

7.2.2 Expert System-Based Knowledge-Oriented Approach

The expert system emulates and replaces the decision-making ability of human experts in a domain (Smith 1986). The fact, data, and experience combine to form knowledge. Knowledge engineers interview domain experts and store the knowledge in the KB using required knowledge representation scheme. When the user accesses the system, it put some queries about the problem, and based on the entry made by the user the system will infer output for observed data using inference system. It will act based on certain rules to provide the conclusive solution for the problem.

Some implantations of knowledge-oriented approaches in the field of clinical diagnosis and prediction of the diseases are as follows. Knowledge-oriented system to detect Alzheimer's with the help of multidisciplinary facts, inference and reasoning over the stored Knowledgebase is presented (Sanchez et al. 2011). A diagnosis system of hepatitis B is developed with the help of a user-friendly application software program. The Java application (J2SE) uses MySQL as back-end relational database to design this decision support system (Mailafiya and Isiaka 2013).

A decision tree-based system is developed to diagnose tuberculosis patients with positive tuberculin skin tests that can assist health workers for the proper treatment of patients (Gerald et al. 2002). The analysis was conducted on 20 chronic hepatitis B patients from Turkey and North Cyrus was helpful for designing of CHBDX (chronic hepatitis B diagnosing expert system) using VP expert system programming (Mirzaei 2019).

The adaptive learning-based expert system is designed using SWI-PROLOG editor. The system can collect, inferring and storing of dynamic knowledge (Yared Agizew 2019). An expert system based on rules, is developed to diagnose some common health problems like malaria, typhoid fever, cholera, tuberculosis, and breast cancer (Hambali and Adewole 2015).

The objective of this chapter is to use expert system-based approach for COVID-19 prediction and diagnosis. Before going into its implementation, the following section outlines the fundamentals and design challenges in the usage of expert system.

7.3 Overview of Expert System

In this section, a brief about fundamentals of expert system, its architecture and its generic design issues are presented.

7.3.1 Fundamentals

An expert system can be theoretically defined as a DSS which can mimic human's thinking process to solve domain-specific problems (Turban and Frenzel 1992). It is basically an intelligent decision support system which is built upon the concept of knowledge engineering. It has started its evolution from late 1960s to 1970s and has shown many diversified areas of applications like medical diagnosis, chemical compound analysis, and computer system configuration, etc. Some representative examples of expert system include (Smith 1986):

1. MYCIN: It is developed at Stanford University, California, USA in 1970 for diagnosis and treatment of bacterial infection in blood.
2. XCON: It is designed for computer system configuration at Carnegi-Mellon University, USA by John McDermott.
3. DENDRAL: It is designed for structural prediction of chemical compound given mass-spectrogram data.
4. PROSPECTOR: It is designed by Richard O. Duda in 1979 as a DSS for mineral exploration.

The basic difference between a conventional computing system and an expert system can be written as:

Conventional computing system = *Data* + *Algorithm whereas Expert system* = *Knowledge* + *Inference*

The interaction between different components of an expert system is shown in Fig. 7.2 in the context of our problem domain, COVID-19. The following section briefly presents its architectural details and its design challenges.

7.3.2 Expert System Architecture

The design of expert system mostly requires three major components:

1. Knowledgebase (KB): It contains set of factual rules and relevant data about an intended problem domain which are stored using some standard knowledge representation techniques. Some of the traditional and commonly used knowledge representation techniques are: IF-THEN rules, semantic network, predicate logic, object-attribute-value tuples, script, and frames (Nilsson 2014). Some modern knowledge representation methods are based on ontology and semantic web (Lagos-Ortiz et al. 2020; Shilov et al. 2020).

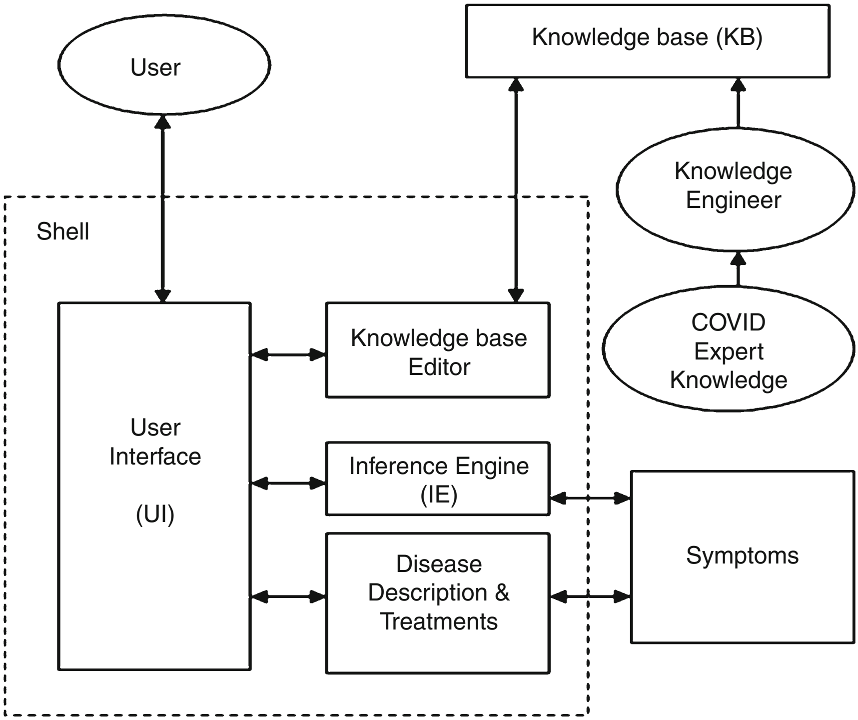


Fig. 7.2 Block diagram of expert system for COVID19

The knowledge stored in KB may be factual, heuristic, or both. The factual knowledge is basically obtained from facts about the problem and the heuristic knowledge is normally acquired by experience, evaluation and guess by the knowledge engineer while consulting with the domain expert. For example, in COVID19 problem domain, the common symptoms like high fever, cough, loss of taste and smell, and body pain can be considered as factual knowledge whereas a patient's travel history or contact with other affected person will be treated as heuristic knowledge.

2. Inference Engine (IE): The IE can be considered as the brain of expert system whose job is to derive conclusions from KB using some inference mechanism when queried by the user. The inference is mainly derived in two ways (Smith 1986). The first method is known as forward chaining in which the process starts from facts or rules and terminates with the conclusion in a top-down approach whereas, in the second method which is known as back ward chaining, the process starts with the goal, moves in bottom-up approach to prove the known facts.

   The IE may be deterministic or probabilistic, based on the type of knowledge (Turban and Frenzel 1992). If the knowledge is represented with absolute facts

and strong rules, then the inference is deterministic. If the knowledge is represented with uncertainty, then the inference will be probabilistic in nature.
3. User Interface (UI): The user of the expert system interacts with it through user interface. The queries asked by user are forwarded from UI to IE and IE uses KB to give answer to the user. The UI hides the IE and KB from the user and make the user to feel as if he or she is interacting with a human expert.

In earlier expert system, the components are separately developed using programming languages like LISP, PROLOG, and CLIPS (Mercy and Thangaswamy 2013). But, to minimize the time of development and for reusability, Expert System Shell (ESS) was introduced. An ESS basically provides a platform with built-in UI and template of IE but an empty KB. The knowledge engineer's job is to collect only domain-specific rules from the human expert and store in the empty KB. It helps in rapid prototyping of the expert system. For example, EMYCIN is the shell derived from MYCIN expert system by removing its bacterial infection specific rules in the KB and providing its UI and IE for development of other expert system.

While designing a complete expert system, the developer faces different challenges at different phases of development. These are discussed in the following section.

7.3.3 Expert System Design Issues

After selecting a feasible problem domain for expert system design, the development cycle goes through different phases and in phase, there lie some issues which are discussed below.

1. Knowledge Acquisition Phase
This is the first and most important phase of expert system design. In this phase, the knowledge engineer consults human experts and other reliable knowledge sources, e.g., in medical diagnosis; specialist of specific disease, case history of some specific patients and clinical test results, in order to gather informal knowledge about the problem domain. Some major challenges faced by knowledge engineer in this phase are (Turban and Frenzel 1992): (1) getting familiarize with domain vocabulary, (2) adapting models and tools to gather knowledge from human experts, and (3) resolving ambiguity between knowledge acquired from multiple experts.
2. Knowledge Representation Phase
In this phase, the job of knowledge engineer is to create the Knowledgebase (KB) by translating the informal knowledge, acquired in the previous phase, to a more formal and platform (programming languages/shell) specific format using state-of-the-art knowledge representation techniques. Some of the well-known knowledge representation techniques are logic, semantic net, frames, production rules and ontology (Turban and Frenzel 1992). The challenges in this phase are: (1) selecting a suitable representation method for specific type of knowledge, and

(2) selecting platform for implementation, either general-purpose programming languages like LISP, PROLOG, CLIPS or domain independent expert system framework, known as shell.

3. Knowledge Inference Phase

   This phase deals with the design of inference engine (IE) which acts as the brain of expert system. In this phase, control strategy and inference mechanism is designed. The control strategy defines the searching algorithm on the KB to derive conclusion using forward chaining or back chaining inference mechanism. The challenges in this phase are: (1) designing deterministic or probabilistic IE based on type of knowledge acquired, and (2) handling uncertainty in case of inexact knowledge.
4. User Interface Phase

   This phase involves in the design of user interface (UI) for end users who are going to use the expert system. In fact, if the general-purpose languages are used to develop the expert system, then designing UI is an overhead for the developer. To reduce development time and for rapid prototyping, shells are mostly used in modern expert system which provides a built-in UI.

Considering the design issues and benefits of expert system in medical field, the following section presents the proposed expert system, ESCOVID for COVID-19.

7.4 Case Study: COVID-19

This section mostly focuses on the feasibility of selecting expert system as a tool for COVID-19, the formal problem description and the design of proposed expert system which is named as ESCOVID.

7.4.1 Feasibility of Expert System on COVID-19

Most of recent AI applications on disease prediction and diagnosis are mainly dependent on machine learning (ML) techniques, but ML techniques are data-oriented approaches whereas, expert systems are based on domain-specific rules. So, expert system can be treated as a dual of ML which can show better performance if the rules in the KB can be correctly represented by consulting with a domain expert. Since, infectious diseases like COVID are detected and diagnosed mainly on symptomatic behavior of patients; these symptoms can be better expressed using rules than raw clinical data. Hence, an expert system-based approach is adapted to address the problem, which is formally described below.

7.4.2 Problem Description

To design an expert system-based decision support system to predict and diagnose COVID-19, the problem can be formally defined as follows.

Suppose, S represents the symptoms and clinical test data set, $S = \{S_1, S_2, \ldots, S_n\}$ which will act as the input to the system. The proposed expert system will produce the output which will be a confirmation of COVID-19 or not and a set of possible suggestions for diagnosis, $D = \{D_1, D_2, \ldots, D_n\}$.

The set S is required to be converted to a rule set by consulting human medical experts and following the guidelines of different reliable sources, e.g., WHO, ICMR in India. These rules will be then stored in knowledgebase (KB). As a next step, an inference engine (IE) needs to be designed which will search the KB to infer appropriate output from the set D. The IE deduces the conclusion in the form of prediction and diagnostic suggestions using forward or backward chaining mechanism.

7.4.3 Proposed Expert System: ESCOVID

7.4.3.1 Rule Set and Knowledgebase

Some prerequisite for the efficient utilization of this system include-

1. The FLIP camera and infrared thermometer are used for sensing the elevated temperature of COVID patients.
2. Rapid antibody test kit from authorized bodies.
3. Labs perform RT-PCR after collecting swabs or blood samples from the patient.
4. Passport can be used to check for travel history.
5. Aarogya Setu App, a contact tracking, syndromic mapping, and self-assessment tool is used to determine whether you were in contact with any COVID-19 patient.

The generation rules of the proposed ESCOVID are formulated which include ten important attributes that serve as inputs they are:

1. What is the temperature reading of the person?
2. What is the temperature reading of the person after a period of 1 h?
3. What is the temperature reading of the person after a period of 24 continuous hour?
4. Are you having symptoms fever, cough, difficulty breathing, muscle ache, runny nose, sore throat, and headache?
5. What is the result of the Rapid antibody test?
6. Was your Rapid antibody test result negative (−ve)?
7. What is the result after 10 days?
8. What is the result of the RT-PCR test?
9. Do you have any travel history to foreign countries since December 2019?
10. Did you ever get in contact with any COVID-19 patient? (Aarogya Setu App data is only valid for this purpose)

Table 7.1 Rule set for ESCOVID

S. No.	Rule	Notes
1.	**IF** What is the Temperature reading of the person? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019? NO **AND** Did you ever got in contact with any COVID-19 patient? (AarogyaSetu App data is only valid for this purpose) NO **THEN** The conclusion is **May not be COVID-19**.	
2.	**IF** What is the Temperature reading of the person? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019? NO **AND** Did you ever got in contact with any COVID-19 patient? (AarogyaSetu App data is only valid for this purpose) YES **AND** What is the result of Rapid Antibody Test? +VE **THEN** The conclusion is **Probable COVID-19**.	Clinical Assessment Hospital Treatment/Home Isolation
3.	**IF** What is the Temperature reading of the person? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019? NO **AND** Did you ever got in contact with any COVID-19 patient? (AarogyaSetu App data is only valid for this purpose) YES **AND** What is the result of Rapid Antibody Test? −VE **AND** Was your Rapid antibody test result negative (−ve)? Perform RT-PCR test **AND** What is the result of RT-PCR test? +VE **THEN** The conclusion is **Probable COVID-19**.	Clinical Assessment Hospital Treatment/Home Isolation
4.	**IF** What is the Temperature reading of the person? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019? NO **AND** Did you ever got in contact with any COVID-19 patient? (AarogyaSetu App data is only valid for this purpose) YES **AND** What is the result of Rapid Antibody Test? −VE **AND** Was your Rapid antibody test result negative (−ve)? Perform RT-PCR test **AND** What is the result of RT-PCR test? −VE **THEN** The conclusion is **Non COVID-19**.	Common ILI (influenza like illness)
5.	**IF** What is the Temperature reading of the person? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019? NO **AND** Did you ever got in contact with any COVID-19 patient? (AarogyaSetu App data is only valid for this purpose) YES **AND** What is the result of Rapid Antibody Test? −VE **AND** Was your Rapid antibody test result negative (−ve)? Quarantine, test after 10 days **AND** What is the result after 10 days? +VE **THEN** The conclusion is **Probable COVID-19**.	Clinical Assessment Hospital Treatment/Home Isolation

(continued)

Table 7.1 (continued)

S. No.	Rule	Notes
6.	**IF** What is the Temperature reading of the person? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019? NO **AND** Did you ever got in contact with any COVID-19 patient? (AarogyaSetu App data is only valid for this purpose) YES **AND** What is the result of Rapid Antibody Test? −VE **AND** Was your Rapid antibody test result negative (−ve)? Quarantine, test after 10 days **AND** What is the result after 10 days? −VE **THEN** the conclusion is **Non COVID-19**.	Common ILI (influenza like illness)
7.	**IF** What is the Temperature reading of the person? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019? YES **AND** What is the result of Rapid Antibody Test? +VE **THEN** The conclusion is **Probable COVID-19**.	Clinical Assessment Hospital Treatment/Home Isolation
8.	**IF** What is the Temperature reading of the person? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019? YES **AND** What is the result of Rapid Antibody Test? −VE **AND** Was your Rapid antibody test result negative (−ve)? Perform RT-PCR test **AND** What is the result of RT-PCR test +VE **THEN** The conclusion is **Probable COVID-19**.	Clinical Assessment Hospital Treatment/Home Isolation
9.	**IF** What is the Temperature reading of the person? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019? YES **AND** What is the result of Rapid Antibody Test? −VE **AND** Was your Rapid antibody test result negative (−ve)? Perform RT-PCR test **AND** What is the result of RT-PCR test −VE **THEN** The conclusion is **Non COVID-19**.	Common ILI (influenza like illness)
10.	**IF** What is the Temperature reading of the person? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019? YES **AND** What is the result of Rapid Antibody Test? −VE **AND** Was your Rapid antibody test result negative (−ve)? Quarantine test after 10 days **AND** What is the result after 10 days? +VE **THEN** The conclusion is **Probable COVID-19**.	Clinical Assessment Hospital Treatment/Home Isolation
11.	**IF** What is the Temperature reading of the person? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019? YES **AND** What is the result of Rapid Antibody Test? −VE **AND** Was your Rapid antibody test result negative (−ve)?	Common ILI (influenza like illness)

(continued)

Table 7.1 (continued)

S. No.	Rule	Notes
	Quarantine test after 10 days **AND** What is the result after 10 days? −VE **THEN** The conclusion is **Non COVID-19**.	
12.	**IF** What is the Temperature reading of the person? The temperature of the person more than or equal to 37.4 °C. **AND** What is the Temperature reading of the person after a period of 1 h? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019 till date? NO **AND** Did you ever got in contact with any COVID-19 patient? (AarogyaSetu App data is only valid for this purpose) NO **THEN** The conclusion is **May not be COVID-19**.	
13.	**IF** What is the Temperature reading of the person? The temperature of the person more than or equal to 37.4 °C. **AND** What is the Temperature reading of the person after a period of 1 h? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019 till date? NO **AND** Did you ever got in contact with any COVID-19 patient? (AarogyaSetu App data is only valid for this purpose) YES **AND** What is the result of Rapid Antibody Test? +VE **THEN** The conclusion is **Probable COVID-19**.	Clinical Assessment Hospital Treatment/home Isolation
14.	**IF** What is the Temperature reading of the person? The temperature of the person more than or equal to 37.4 °C. **AND** What is the Temperature reading of the person after a period of 1 h? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019 till date? NO **AND** Did you ever got in contact with any COVID-19 patient? (AarogyaSetu App data is only valid for this purpose) YES **AND** What is the result of Rapid Antibody Test? −VE **AND** Was your Rapid antibody test result negative (−ve)? Perform RT-PCR test **AND** What is the result of RT-PCR test +VE **THEN** The conclusion is **Probable COVID-19**.	Clinical Assessment Hospital Treatment/home Isolation
15.	**IF** What is the Temperature reading of the person? The temperature of the person more than or equal to 37.4 °C. **AND** What is the Temperature reading of the person after a period of 1 h? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019 till date? NO **AND** Did you ever got in contact with any COVID-19 patient? (AarogyaSetu App data is only valid for this purpose) YES **AND** What is the result of Rapid Antibody Test? −VE **AND** Was your Rapid antibody test result negative (−ve)? perform	Common ILI (influenza like illness)

(continued)

Table 7.1 (continued)

S. No.	Rule	Notes
	RT-PCR test **AND** What is the result of RT-PCR test −VE **THEN** The conclusion is **Non COVID-19**.	
16.	**IF** What is the Temperature reading of the person? The temperature of the person more than or equal to 37.4 °C. **AND** What is the Temperature reading of the person after a period of 1 h? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019 till date? NO **AND** Did you ever got in contact with any COVID-19 patient? (AarogyaSetu App data is only valid for this purpose) YES **AND** What is the result of Rapid Antibody Test? −VE **AND** Was your Rapid antibody test result negative (−ve)? Quarantine test after 10 days **AND** What is the result after 10 days? +VE **THEN** The conclusion is **Probable COVID-19**.	Clinical Assessment Hospital Treatment/home Isolation
17.	**IF** What is the Temperature reading of the person? The temperature of the person more than or equal to 37.4 °C. **AND** What is the Temperature reading of the person after a period of 1 h? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019 till date? NO **AND** Did you ever got in contact with any COVID-19 patient? (AarogyaSetu App data is only valid for this purpose) YES **AND** What is the result of Rapid Antibody Test? −VE **AND** Was your Rapid antibody test result negative (−ve)? Quarantine test after 10 days **AND** What is the result after 10 days? −VE **THEN** The conclusion is **Non COVID-19**.	Common ILI (influenza like illness)
18.	**IF** What is the Temperature reading of the person? The temperature of the person more than or equal to 37.4 °C. **AND** What is the Temperature reading of the person after a period of 1 h? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019 till date? YES **AND** What is the result of Rapid Antibody Test? +VE **THEN** The conclusion is **Probable COVID-19**.	Clinical Assessment Hospital Treatment/home Isolation
19.	**IF** What is the Temperature reading of the person? The temperature of the person more than or equal to 37.4 °C. **AND** What is the Temperature reading of the person after a period of 1 h? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019 till date? YES **AND** What is the result of Rapid Antibody Test? −VE **AND** was your Rapid antibody test result negative (-ve)? Perform RT-PCR test **AND** What is the result of RT-PCR test? +VE **THEN** The conclusion is **Probable COVID-19**.	Clinical Assessment Hospital Treatment/home Isolation

(continued)

Table 7.1 (continued)

S. No.	Rule	Notes
20.	**IF** What is the Temperature reading of the person? The temperature of the person more than or equal to 37.4 °C. **AND** What is the Temperature reading of the person after a period of 1 h? The temperature of the person less than 37.4 °C. **AND** Do you have any Travel history to foreign countries since December 2019 till date? YES **AND** What is the result of Rapid Antibody Test? −VE **AND** Was your Rapid antibody test result negative (−ve)? Perform RT-PCR test **AND** What is the result of RT-PCR test? −VE **THEN** The conclusion is **Non COVID-19**.	Common ILI (influenza like illness)

ESCOVID is designed using ES-builder, a web-based shell with an online platform where attributes are the different queries; values are different attribute values, which are evaluated successively to determine a conclusion for the given problem. The decision tree structure facilitates proper inference and evaluation of queries level by level.

7.4.3.2 Inference Mechanism

A decision tree is designed using the proposed rules set as shown in Table 7.1. This decision tree acts as the backbone for the IE. The IE does a matching of input given by user with rules which are embedded in the KB to derive a conclusion. This process is given in Fig. 7.3. This process of searching for suitable conclusion is carried out by performing traversal from top to bottom on the proposed decision tree. The KB is created for ESCOVID using rule-based knowledge representation scheme using the format IF-THEN.

7.5 Implementation and Testing

ESCOVID is implemented on ES-Builder (n.d.). Being an ESS, it provides a decision tree template for IE creation and web-based run-time user interfaces (UIs) while running the system. Figure 7.4a–j indicate different stages of UI and one possible testing instance of the system in ES-builder. The system asks the user different queries which are based on different symptomatic behavior of a COVID-19 patient. After getting valid responses from the user, the system searches the KB

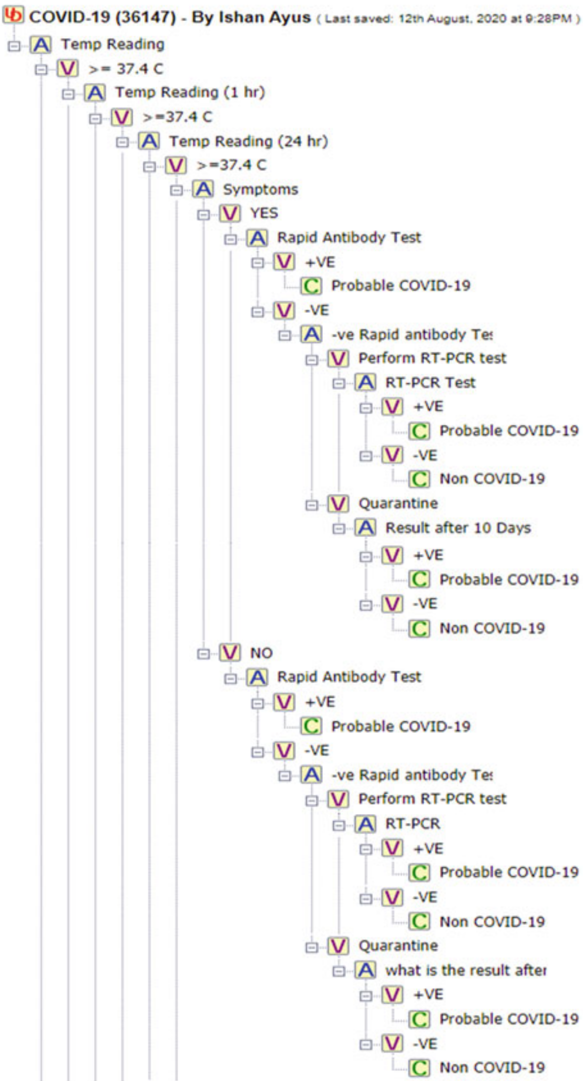


Fig. 7.3 Inference process in ESCOVID

for a suitable inference using the proposed decision tree-based inference mechanism. ESCOVID can be found at: https://www.mcgoo.com.au/esbuilder/viewer/viewES.php?es=64112cf7d6d5c6b09b25103207a68840

a

b

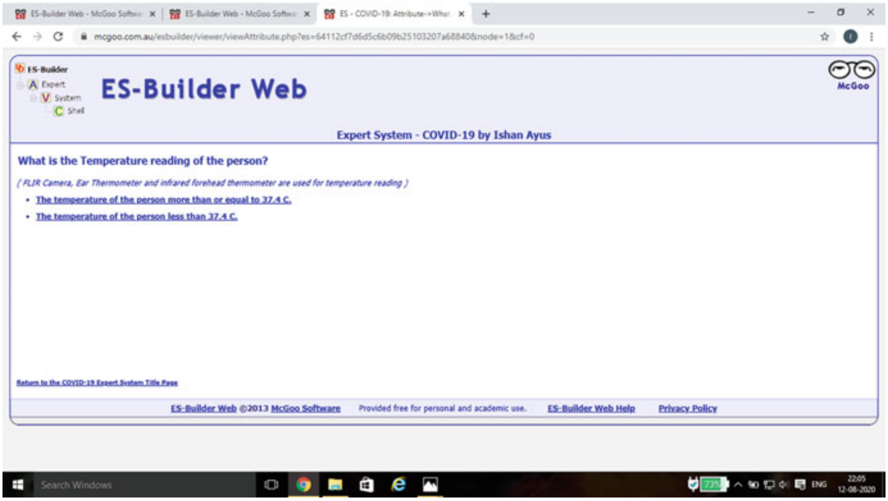
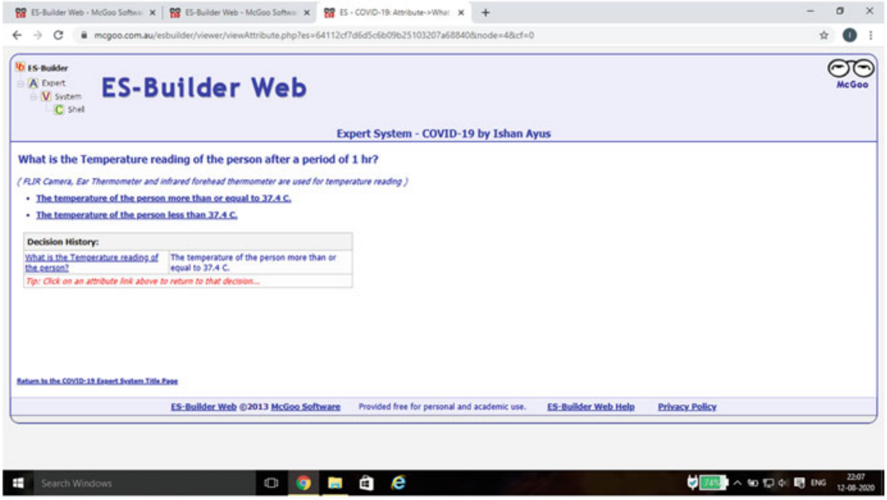


Fig. 7.4 (**a**) Stage-1 of querying on ESCOVID. (**b**) Stage-2 of querying on ESCOVID. (**c**) Stage-3 of querying on ESCOVID. (**d**) Stage-4 of querying on ESCOVID. (**e**) Stage-5 of querying on ESCOVID. (**f**) Stage-6 of querying on ESCOVID. (**g**) Stage-7 of querying on ESCOVID. (**h**) Stage-8 of querying on ESCOVID. (**i**) Stage-9 of querying on ESCOVID. (**j**) Stage-10 of querying on ESCOVID

c



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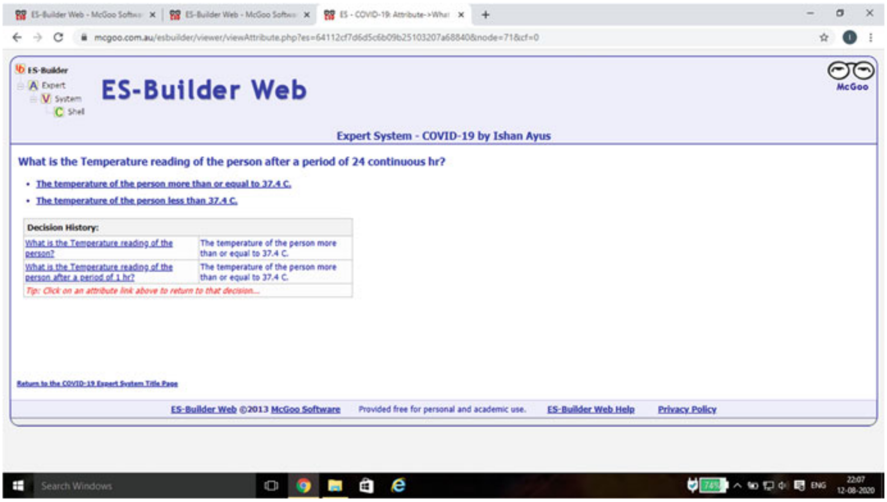
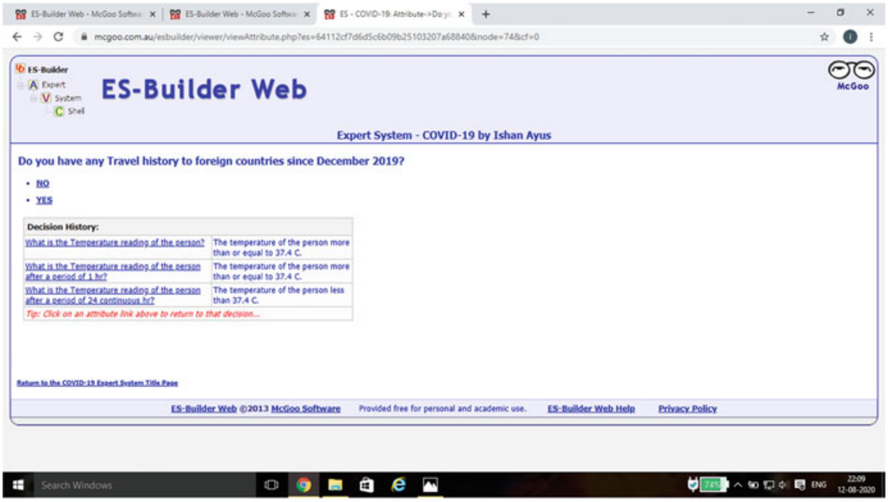


Fig. 7.4 (continued)

e



f

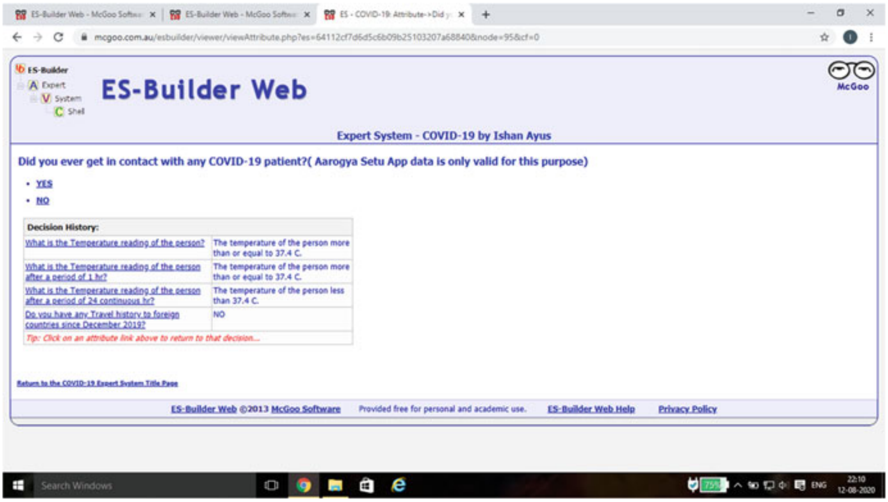


Fig. 7.4 (continued)

g

h

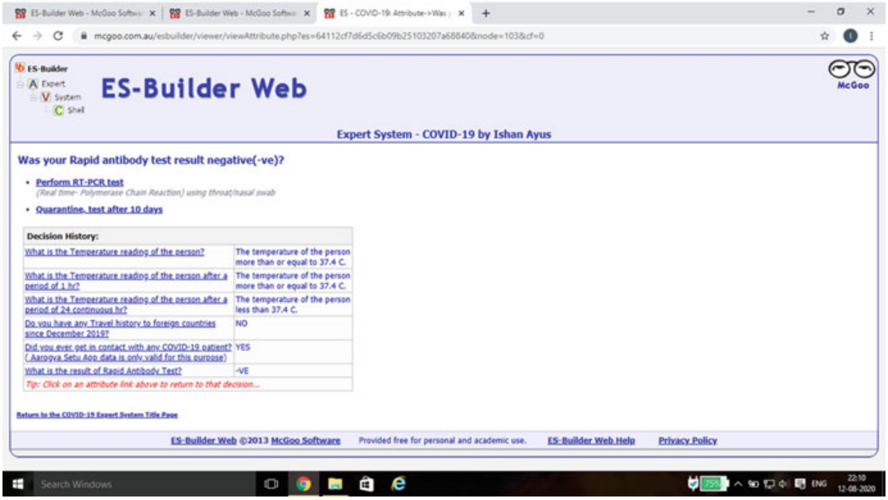


Fig. 7.4 (continued)

i

j

Fig. 7.4 (continued)

7.6 Conclusion

COVID-19, an unknown disease which is already declared as a pandemic, requires an intelligent system to be designed to predict and diagnose this disease in well before time to save thousands of lives. In this context, this chapter highlights AI-based approaches in disease prediction and diagnosis, and special focus is given on fundamentals and design issues in expert system-based DSS in medical field and its feasibility for COVID-19. An expert system, ESCOVID, is proposed and implemented using ES-builder, a web-based ESS and tested extensively. Due to lockdown to control this pandemic, people are unable to find human medical experts who can diagnose them in time. This developed system will help people for self-diagnosis with the assistance of local healthcare workers.

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A Predictive Mechanism to Intimate the Danger of Infection via nCOVID-19 Through Unsupervised Learning

8

Ajay B. Gadicha, Vijay B. Gadicha, and Sneha Bohra

Abstract

Presently, the entire world is suffering from an unexpected pandemic nCOVID-19. The healthcare systems across the globe are yet not successful to counter this disease caused by coronavirus. Here an attempt is made to intimate a healthy normal person about the dangers of infection of nCOVID-19. To accomplish the goal of intimate the danger of infection via nCOVID-19, this chapter illustarte the concept of unsupervised learning using clustering method. This method will accumulate all the points which show analogous observations toward the symptoms of nCOVID-19 and separate the rest of the points which are not carrying the symptoms of nCOVID-19. By virtue of this mechanism at least a predictive system can be realized which will further help in diagnosing nCOVID-19 and treating the same for healthcare systems across the globe.

Keywords

nCOVID-19 · Unsupervised learning · Clustering · *k*-means · DBSCAN · HAC

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8.1 Introduction

The People's Republic of China first reported to the World Health Organization (WHO) about the encountered case of viral pneumonia popularly known as novel Coronavirus (COVID-19) on 31st December 2019. This dreadful virus then started to spread expeditiously across the world. Later, this outbreak was declared as a pandemic by the WHO (Elavarasan and Pugazhendhi 2020). The world has witnessed epidemics earlier as well but what differentiates COVID-19 from others is its ability to spread rapidly via human contact and its capability of leaving behind asymptotic virus carriers. Studies have reported that COVID-19 can be life threatening for patients with weak immune system. This deadly virus can prove dangerous for elderly people and also for people with diseases like diabetes, cancer, heart diseases, HIV/AIDS, asthma, or any neurological issues.

Countries across the globe are striving hard to find a vaccine for this deadly virus. With the unavailability of any therapeutic drug, there is need for cutting-edge solutions to analyze the worldwide shared data (Diginomica 2020). Governing authorities of countries across the globe identified ways of avoiding the spread of this dreadful virus by implementing countrywide lockdown and appealing its residents to maintain personal hygiene, promoting the use of face masks and hand sanitizers, and following social distancing. Various countries have also launched smartphone applications to track coronavirus contact. These apps track the person's movement, including the details of those whom they come in contact with. The information gathered using such apps gives governing authorities vital information in order to limit the transmission of virus (Bogoch et al. 2020; Kumar et al. 2018).

These apps launched by various governing authorities were capable of tracking user's travel history, location, and providing information about nearby users who had a similar application installed. The rapid increase in the number of patients getting infected by this terrifying disease, the lack of effective drugs to treat it, and the need for predictive mechanisms can foresee and warn the users. Therefore, there is a need for a technical approach that will learn users' behavior, keep track of their medical conditions, and then give the possibility of the user being infected by the disease (Verma et al. 2019).

The system proposed in this chapter is a machine learning-based mechanism for predicting the possibility of infection. The proposed method will use unsupervised learning-based clustering algorithm to form clusters. This method will form clusters of users having similar symptoms; for example, cluster 1 will have information about users having symptoms like fever, cluster 2 will have information about users having symptoms like cough, cluster 3 will have information about users having symptoms like only fever and cough, cluster 4 will have information about users having symptoms like fever, cough, and throat pain, and finally cluster 5 will have details of uses having symptoms like fever, cough, throat pain, and muscle pain. After dividing the dataset into clusters, the system will provide the possibility of the user being infected by COVID-19 (Jhunjhunwala 2020).

8.2 Literature Survey

Studies have reported many AI-ML-based systems for predicting the disease or for analyzing the available dataset. We explore some of those existing applications in this section.

A Canadian AI-based start-up called "BlueDot" used AI-ML algorithms to perform thorough analysis of foreign language reports or news scripts or official announcements in order to provide its clients warnings well in advance before the outbreak of any disease. They used Natural Language Processing (NLP) and Machine Learning-based techniques to formulate disease surveillance algorithm. This devised algorithm keeps track of airline data and news about animal disease outbreaks. The system generates automated conclusions, but they are still scrutinized by humans to check their validity against scientific viewpoints. Reports state that BlueDot was among the first in the entire world to have identified the emerging risk from COVID-19 (https://bluedot.global/) (Elavarasan and Pugazhendhi 2020).

In another study, they have analyzed the publicly available data for 30 days (11 January 2020 to 10 February 2020) to foresee the outbreak of deadly unknown virus in its epicenter in China. The authors used Susceptible-Infected-Recovered-Dead (SIRD) model to analyze the input. The forecast issued by these authors was very near to actual figures. The authors commented that Hubei would have 45,000 infected people and 2700 deaths by 29 February 2020 and according to facts and figures nearly 67,000 were found infected and reported death toll were about 2800. These actual figures were close to the predictions (Anastassopoulou et al. 2020).

The Artificial intelligence based Algorithm (PIBA) predicted the mortality rate in the nCOVID-19 disease by using the community data. This algorithm is responsible for estimating the mortality rate based on the actual number of deaths and estimates the number of patients on a specific day, at the same time, the proposed system collected data from patients' admission to their recovery or death. It assumed the principle that the patient generally does not die on the day of admission to the hospital. It calculated daily mortality rate and finally combined it to estimate the overall mortality rate (Wang et al. 2020).

Shreshth Tuli, Shikhar Tuli, Rakesh Tuli, and Sukhpal Singh Gill proposed an ML-based model to provide prediction of the threat of the pandemic. They used Machine Learning (ML) and Cloud Computing to keep track and forecast the spread of the disease and devise various strategies and policies to avoid the spread of the disease. The system used iterative weighting for fitting Generalized Inverse Weibull distribution. Since the system was deployed on cloud platform, it gave accurate and real-time prediction about the growth of the disease (Tuli et al. 2020).

Apart from all these AI-ML-based algorithms, Asian countries have also launched smartphone applications to track COVID-19. Several apps launched by China used direct geographical locations via cell phone networks or either data compiled by checkpoints of either train stations or airports. Based on travel history and exposure of the people who used this app, people were ranked in different colors like red, green, or yellow and then the app would suggest whether the user must enter the public area or not. Research showed that the systematic use of the app helped

Beijing to lift lockdowns and avoid the spread of the disease. While countries like Hong-Kong, Taiwan, and South Korea used official GPS and Wi-Fi to keep track of the patients, other countries like India used Bluetooth-based tracking app which helped authorities to keep track of users when two devices are within Bluetooth range (https://gadgets.ndtv.com/apps/features/coronavirus-contact-tracing-apps-which-countries-are-doing-what-2237952).

Bassi Abhinav, Arfin Sumaiya, John Oommen, and Jha Vivekanand stated that the Government of India also launched its own Bluetooth-based application called “Aarogya Setu.” It was launched to keep track through contact tracing. Following this, several state governments also launched applications in order to create awareness and monitor self-quarantined individuals in their respective states (Abhinav et al. 2020).

Jhunjhunwala: This self-assessing app allows users to answer a simple questionnaire available in 11 regional languages. The National Information Center (NIC) collects the data, which consist of information related to infected patients and their risk factors. This information is easily available in self-assessing application in 11 regional languages. This app uses GPS; it becomes very easy to geographically track users with a high risk of infection. It also uses Bluetooth to detect the proximity and warns the user about the nearest infected person (Jhunjhunwala 2020).

Machine Learning uses big data models for the application like pattern recognition and its evaluations. However, natural language processing has gained popularity in the recent areas mostly in the domain of text analysis. There are various algorithms which are implemented to accomplish classification of text mining in text analysis (Khanday et al. 2020).

Kumar et al. (2018) gave a descriptive SWOT analysis which detailed about various supervised and unsupervised learning for mining the unstructured data. Some of the applications of text classification happen to be spam detection, fraud detection, sentiment analysis, etc. Opinion mining is majorly being used for elections, advertisement, business, etc.

Verma et al. (2019) has provided an analytical study which has proven that the available number of test kits is not sufficient in densely populated country like India; hence he recommended that some automation process be implemented which can detect the spread of nCOVID-19 in some specific areas.

Artificial Intelligence is quite capable enough to intimate the user about the spread of nCOVID-19. It has its subdomains like Machine learning and deep learning which enable users to identify the hotspots of nCOVID-19, which can also create awareness to users about maintaining social distance and wearing mask in some specific areas that are highly prone to nCOVID-19 (Prakash 2018; Prakash et al. 2020) (Fig. 8.1).

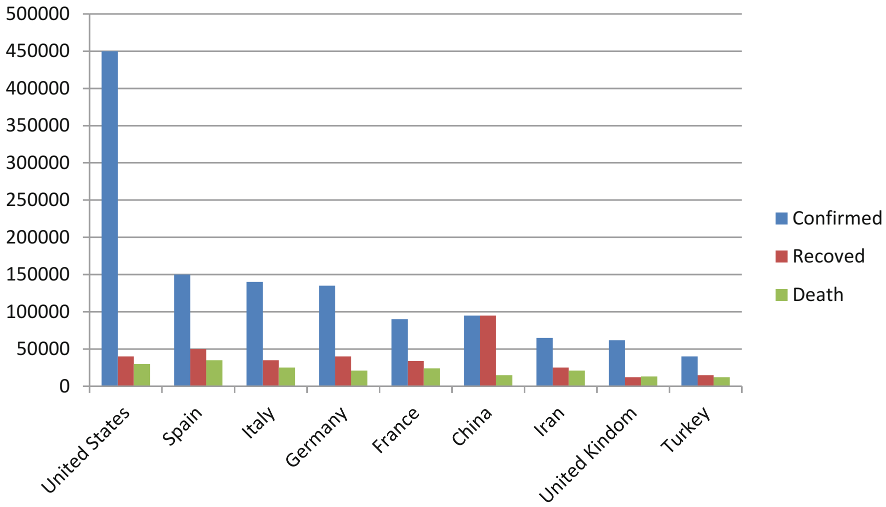

Fig. 8.1 Worldwide coronavirus data as of 10 April 2020 (Prakash et al. 2020)

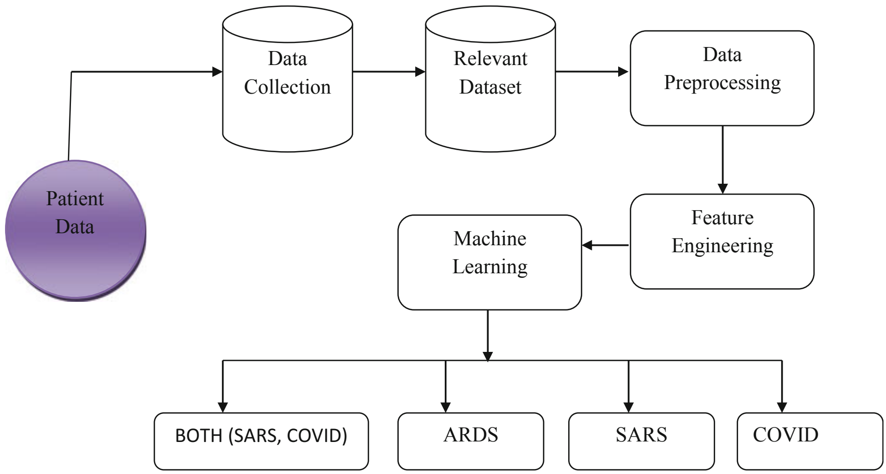

Fig. 8.2 Methodology for detection of COVID-19 (Prakash et al. 2020)

8.3 Methodology

The proposed methodology is depicted in Fig. 8.2; it illustrates the strategy from data collection (step 1) to relevant dataset (step 2). Afterwards the dataset is used for data processing. This mechanism is important in all concern, i.e. collecting and processing of data and finally generates the suitable result, further this data is input

Table 8.1 Symptoms of COVID-19

Mainly frequent	Reasonable	Rigorous
Tiredness, fever, and dry cough	Conjunctivitis, headache, diarrhea, aches, and severe pains	Difficulty in breathing or shortness of breath, pain in the chest

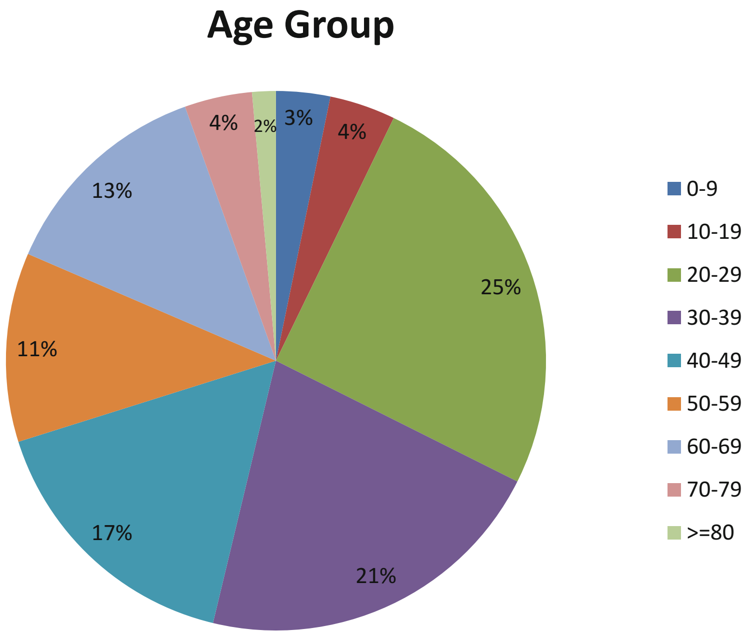

Fig. 8.3 Percentage of COVID-19 cases as per age group

to feature engineering phase, which identify the symptoms of COVID-19 based on that appropriate result generated.

The Figure 8.2 depicted above, i.e., data collection (step 1) to feature engineering (step 4), depicts the execution of the proposed methodology and processes the result based on patient data, i.e., by observing the symptoms of COVID-19 as mentioned in Table 8.1.

Based on Fig. 8.3, the proposed work analyzed the different parameters (stated in Table 8.1), which examine the different age groups and percentage of infections. It is clear from Fig. 8.3 that the 20–29 age group is most affected by COVID-19, followed by those in the 30–39 age group, and so on. The complete study on different age groups is shown in Fig. 8.3.

8.3.1 Data Collection

As the WHO declared the coronavirus pandemic as Health Emergency, researchers and hospitals gave open access to their data regarding this pandemic. The data is collected from https://data.world/shad/covid-19-time-series-data, and studies are performed on various attributes of the data. Time series data with attributes such as city_name, date_wise confirmed cases in diverse countries, date_wise death rate and recovered_rate of time series dataset are analyzed.

8.3.2 Relevant Dataset

The input data set is collected relevant with the time series. Various parameters are identified such as fever, dry cough, and tiredness. The quantities which are expressed in figure are threatening & alarming for the world.

On the basis of time series dataset analyzed, the Correlation Matrix for COVID-19-India Dataset is drawn to observe timely activities like patients confirmed, deaths and cured which are shown in Figs. 8.4 and 8.5 respectively (Figs. 8.6 and 8.7).

China	40.1824	116.4142	14	22	36	41	68	80	91	111	114	139	168	191	212	228	253	274
China	31.202	121.4491	9	16	20	33	40	53	66	96	112	135	169	182	203	219	243	257
India	39.549	116.1306	1	1	2	8	13	18	33	48	65	82	96	104	113	126	135	157
South Afri	26.0789	117.9874	1	5	10	18	35	59	80	84	101	120	144	159	179	194	205	215
Australia	23.8298	108.7881	2	5	23	23	36	46	51	58	78	87	100	111	127	139	150	168
NewZelar	35.1917	108.8701	0	3	5	15	22	35	46	56	63	87	101	116	128	142	165	173
America U	24.974	101.487	1	2	5	11	16	26	44	55	70	83	93	105	117	122	128	133
UAE	19.1959	109.7453	4	5	8	19	22	33	40	43	46	52	62	64	72	80	99	106
Canada	26.8154	106.8748	1	3	3	4	5	7	9	9	12	29	29	38	46	58	64	71
France	39.3054	117.323	4	4	8	10	14	23	24	27	31	32	41	48	60	67	69	79
Guernsey	37.5777	112.2922	1	1	1	6	9	13	27	27	35	39	47	66	74	81	81	96
Jersey	37.8099	101.0583	0	2	2	4	7	14	19	24	26	29	40	51	55	57	62	62
Puerto Ric	22.3	114.2	0	2	2	5	8	8	8	10	10	12	13	15	15	17	21	24
Republic c	41.2956	122.6085	2	3	4	17	21	27	34	39	41	48	64	70	74	81	89	94
The Bahar	43.6661	126.1923	0	1	3	4	4	6	8	9	14	14	17	23	31	42	54	59
The Gamb	49.8175	15.473	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fig. 8.4 Dataset of confirmed COVID-19 cases

US	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
US	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
US	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
China	1457	1596	1696	1789	1921	2029	2144	2144	2346	2346	2495	2563	2615	2641	2682	2727	2761	2803	2835
Iran	0	0	0	0	0	2	2	4	5	8	12	16	19	26	34	43	54	66	77
Korea, So	0	0	0	0	0	0	1	2	2	6	8	10	12	13	13	16	17	28	28
France	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	4
China	2	2	2	4	4	5	5	5	5	6	6	7	7	7	7	7	7	7	7
China	11	13	13	16	19	19	19	19	19	19	19	19	19	20	20	21	22	22	22
China	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
China	2	2	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
China	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
China	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
China	2	2	2	2	3	3	4	4	4	4	5	6	6	6	6	6	6	6	6
Cruise Shi	0	0	0	0	0	0	2	2	2	3	3	3	4	4	6	6	6	6	6

Fig. 8.5 Dataset of deaths due to COVID-19

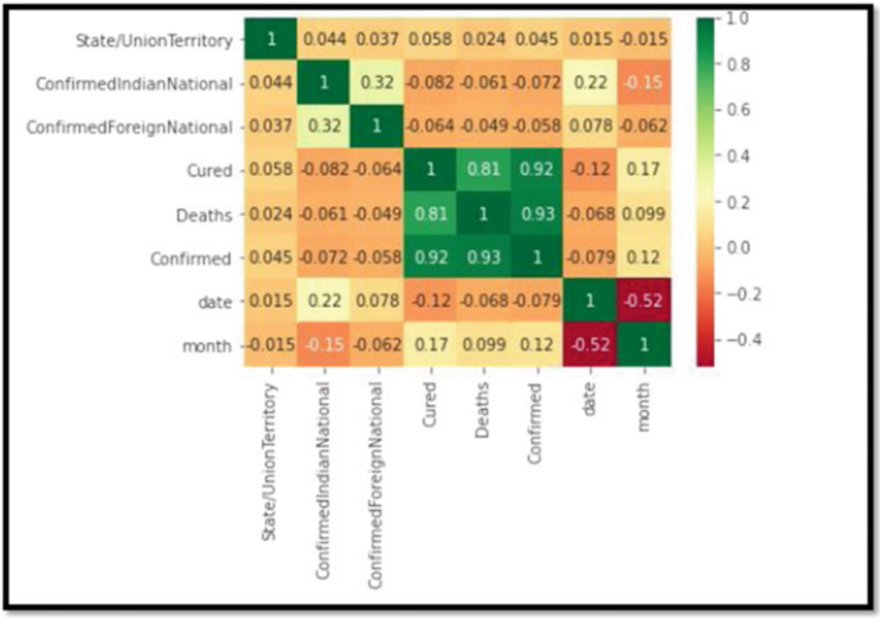

Fig. 8.6 Correlation matrix for COVID-19-India dataset (Prakash et al. 2020)

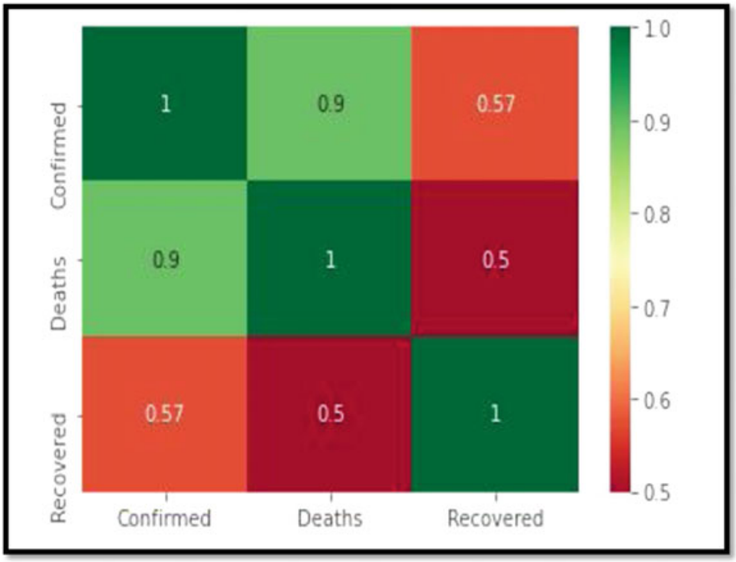

Fig. 8.7 Correlation matrix for COVID-19 dataset (Prakash et al. 2020)

8.3.3 Data Processing

The text is unstructured so it needed to be refined such that machine learning can be done. Various steps are being followed in this step, i.e., clustering and neural network.

8.3.3.1 Algorithm of Clustering

Input:
Dataset = $A_1, A_2, \ldots, A_d$ //$A_i{}^s$ are article
Initialization:
Cluster_Tech [ ]= [$k - means, DBSCAN, HAC$],
Target_Task[ ]= [$T_1, T_2, \ldots, T_N$]

Step 1: Repeat Step 2, 3 ,4 and 5 for every cluster technique in Cluster_Tech
Create_clusters (Cluster_Tech [i], Dataset)
Return (Clusters [i], #Clusters [i])
//#Clusters is Optimum number of clusters

Step 2: Train parallel one class SVMs for all the clusters generated by a
given technique
OCSVM (Clusters [i])
//OCSVM(C_1) || … || OCSVM($C_{\#Clusters}$)

Step 3: //Validation and Testing the models
For #Clusters in Cluster [i]
Test_OCSVM(j) < − (+ve Samples, Outliers)
//j= $C_1, C_2, \ldots, C_{\#Clusters}$

Step 4: // Assignment of target-tasks
Repeat for All defined Tasks (N)
Test_OCSVM(j) < − (T_j)

Step 5: Return (OCSVMs, Target_IDs)

Step 6: Repeat Steps 1 to 5 with reduced features.

Step 7: Stop.

8.4 Result Analysis

Figure 8.8 gives an idea about the results obtained after examining the entire COVID-19 dataset. The relevant group of articles are trained on separate cluster using k-means, DBSCAN, and HAC.

Here results are displayed for various age groups using different algorithms.

In Fig. 8.8 clustering approach of COVID-19 articles, it is observed that the percentage rating of different clustering algorithms like KMeans, DBSCAN, and HAC is remarkable. This is computed due to the fact that the ratio of widespread kind of negative peaks is observed with respect to the overall variety of objectives.

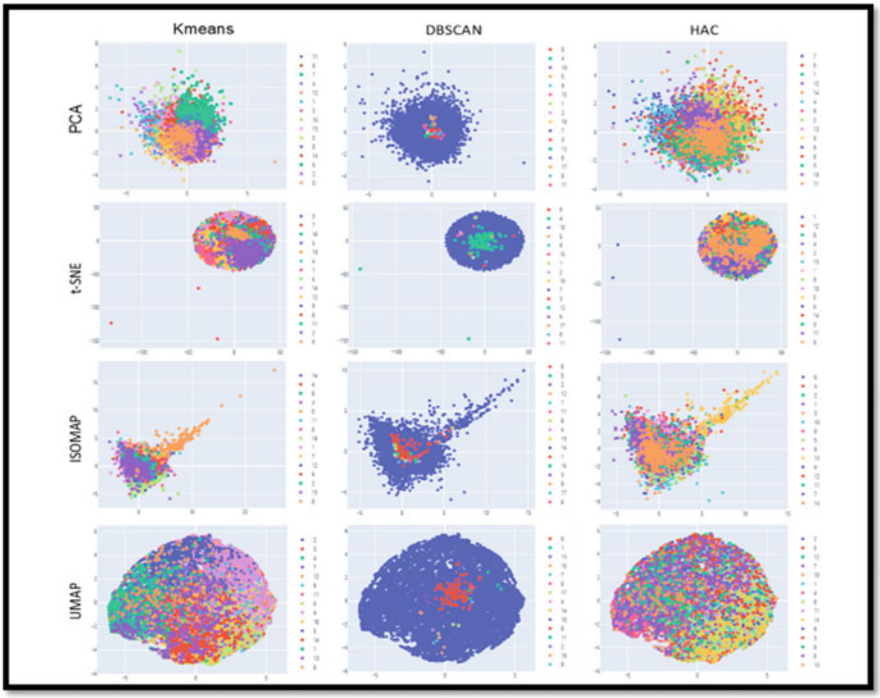

Fig. 8.8 Clustering approach of COVID-19 articles

8.4.1 Overall Behavior of All Unsupervised Learning Model (Figs. 8.9 and 8.10)

Machine learning model	COVID-19 in India		COVID-19 in data	
	Coefficient of determination	Accuracy	Coefficient of determination	Accuracy
K_Means	0.7213	0.1245	0.9241	0.1122
DBSCAN	0.8826	0.3224	0.8799	0.3251
HAC	0.8922	0.1667	0.8842	0.2235

Algorithm	Precision	Recall	F1 score	Accuracy (%)
K_Means	0.91	0.93	0.95	93.21
DBSCAN	0.87	0.82	0.91	94.31
HAC	0.83	0.91	0.81	91.22

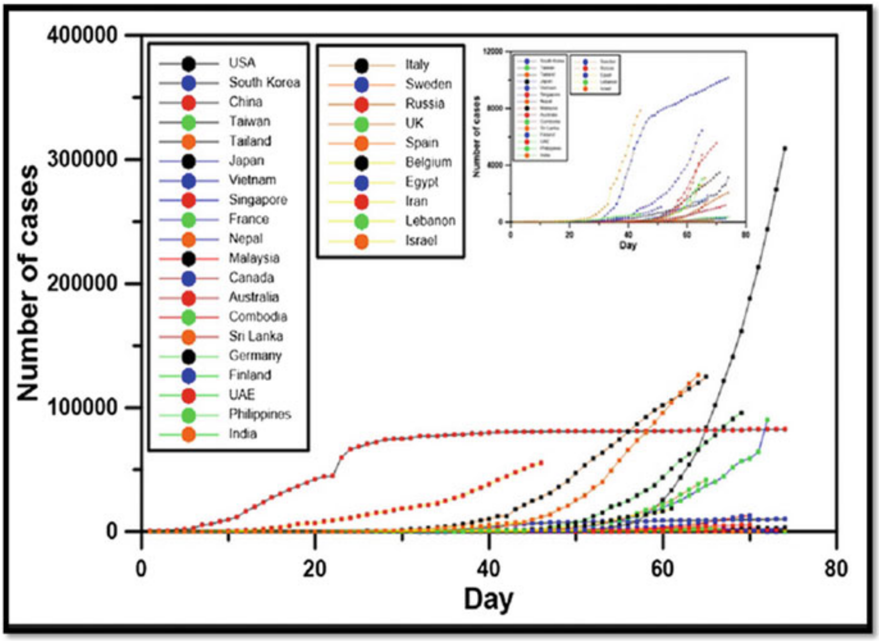

Fig. 8.9 Corpus of COVID-19 day-wise

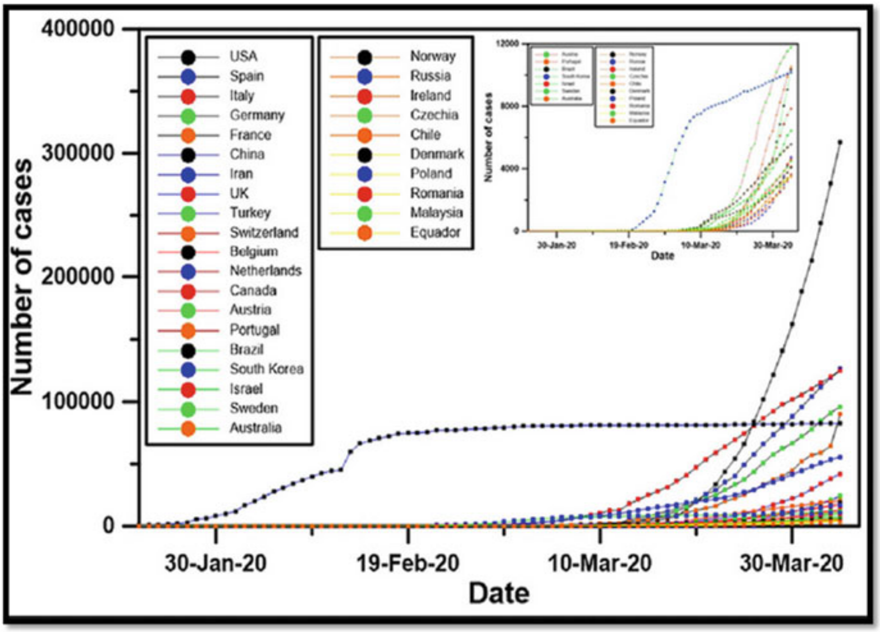

Fig. 8.10 Corpus of COVID-19 date-wise

8.5 Conclusion

The nCOVID-19 pandemic has affected nearly all the verticals of society and industries including education, business, administration, health care, etc. The entire research community is trying to contribute in some way or other to limit the spread of this disease. Here in our proposed system, an attempt is made to predict whether an individual is likely to be infected from nCOVID-19 or not. To accomplish this task, k-means clustering is used to accumulate the data of asymptotic individuals which can get infected from nCOVID-19 diseases by forming the cluster. Individuals who do not exhibit any symptoms are treated as outlier points in the implemented work. It is expected that the present work will provide bright perspectives about predicting the infection of nCOVID-19 in different geographical areas across the globe.

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9 Artificial Intelligence-Enabled Prognosis Technologies for SARS-CoV-2/COVID-19

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Abstract

Background and objectives:

SARS-CoV-2/COVID-19 imparts threat and global challenges for the available prognosis models and generated opportunities to utilize advanced technologies for the healthy life. This virus is highly infectious and transmits extensively through human-to-human contact. This viral diseases which become pandemic in short time period generated requirement of cost effective diagnosis, treatment and easy control methods. The objective of this review is to analyze the current worldwide prognosis scenario (diagnosis and control) along with available technology-based preventive strategies. WHO and native country health policy can affect the preventive measure extensively in SARS-CoV-2 incidences. Artificial intelligence (AI)-based healthcare models have better performance for mass level diagnosis and control. The focus is to evaluate pathogens geographical variation, available healthcare technologies, and best preventive strategies together to understand real impact on mass community health status. In absence of vaccine, delivery of precision, rapid, and cost effective prognosis model is the current requirement of effective control.

Methods:

The research data of epidemiology and clinical variations for this study was obtained from WHO, Scopus, PubMed, ICMR, CDC i.e., multidisciplinary database resources. Role of genomics, proteomics in framing prognosis to treatment contribution was review extensively. The sensor can produce a wide variety of data depending upon the inputs while IoT close the gaps between equipment through fast delivery by logical system. Artificial Intelligence (AI) is useful for analyzing computer programming for specific traits and set algorithms for high performance. Cloud computing can take advance predictive measures through specific algorithm of AI and justified health and ecological parameters through management platform. This review covers all efficient AI-based gadgets and models and discussed in broad sense important databases, optimization used for effective control in regional risk models of diagnosis and control (with sanitization).

Interpretation and conclusion:

Better healthcare facilities based on AI-based technology is the best adaptive strategy in pandemic situation. Using advanced genomics, biosensor, electronics, computational, and management-based technologies are effective under complex pandemic situation. AI enabled healthcare facilities preparation has to go long way in order to functionally control the SARS-CoV-2/COVID-19 worldwide either through pre-diagnosis through mass level surveillance or virus killing via sanitization-based method. Available databases, genomics, computational, electronics and telecommunication shall be helpful for stakeholders in framing better public health policies.

Keywords

COVID-19 · Pandemic · Genomics · Healthcare management · Artificial intelligence · Digital technology · Cloud computing · Sensor

9.1 Introduction

COVID-19 is an infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) generates worldwide pandemic situation due to highly pathogenic and infectious nature impart substantial burden on socio-economic due to health loss, job crisis, lockdown, human migration etc. (Mishra et al. 2020a). Initially, this unprecedented coronavirus outbreaks occurred at fish market in Wuhan, China and called as COVID-19 by the World Health Organization (WHO) (Mishra et al. 2020a). Corona viruses are spherical positive-sense RNA viruses, contain four main structural proteins. These are the spike (S), membrane (M), envelope (E), and nucleocapsid (N) proteins, all of which are encoded within the 3′ end of the viral genome. Homotrimers of the virus encoded S protein make up the distinctive spike structure on the surface of the virus (Fehr and Perlman 2015). Coronavirus has been associated with animal mortalities and human infections across all the continents. In humans, corona viruses cause illness mostly through respiratory or gastrointestinal infections, where symptoms can range from the common cold to more severe lower respiratory infections such as pneumonia (Mishra et al. 2020a). According to the WHO, COVID-19 manifests complex clinical features such as fever, dry cough, fatigue, sputum production, and poses severe public health issues. The number of corona positive cases has been increasing day by day and alarming the whole world for requirement of better healthcare practices.

In this chapter, we have discussed the worldwide COVID-19 situation, pathogenesis, transmission, available technologies and their products, control mechanism with AI-based technologies and unravel effective requirement. We have covered about infectious agents, human diversity, and effective public health policy information's as important role in making control strategies of the disease. In drawing things to specific information, we explain the available technologies such as the Artificial Intelligence (AI), Advanced Genomics, Internet of Things (IoT), Database Analytics, and Cloud computing among others, to contribute effectively in the control of COVID-19 pandemics.

9.1.1 Epidemiology and Phylogeography of Pathogen

Understanding epidemiology of COVID-19 in terms of the disease incidence, prevalence, major determinants and essential risk factors in order to develop diagnosis, treatment, public health policy is must for effective COVID-19 prognosis model. Till today, globally, as of 3:32 pm CEST, 26 August 2020, there have been 23,752,965 confirmed cases of COVID-19, including 815,038 deaths, reported to WHO (n.d.-a). Figures 9.1 and 9.2 represent COVID-19 cases.

The negative effect of COVID-19 pandemic is important to understand for challenges, which should be taken in the account to control any out breaks. Additionally, molecular epidemiology (ME), immuno-epidemiology and genetic epidemiology has substantial role in pathogen severity. Phylogenetic trees were generated

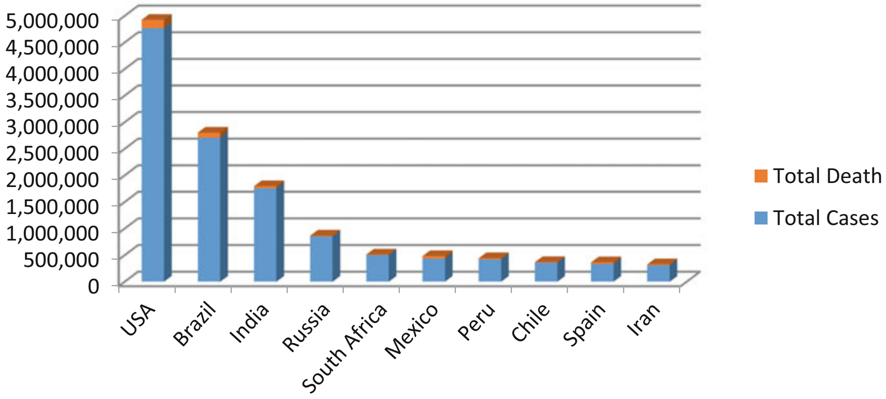

Fig. 9.1 Top ten countries with higher number of COVID-19 cases. (Source World meter; https://www.worldometers.info/coronavirus/)

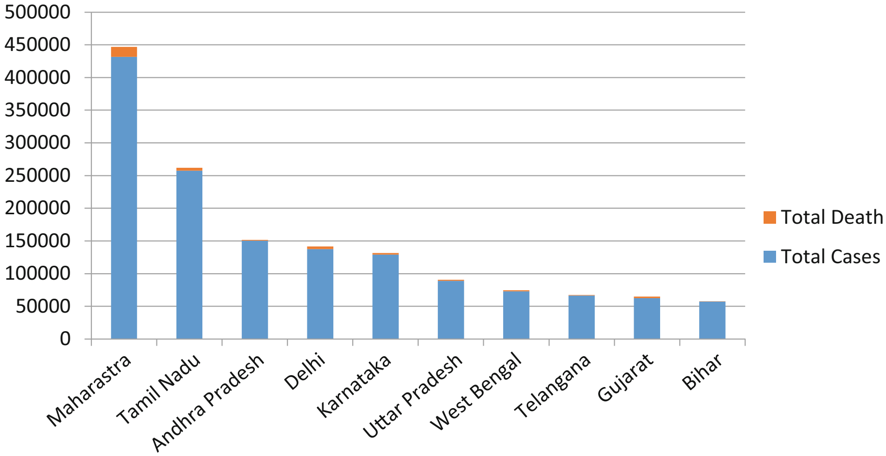

Fig. 9.2 Top ten Indian states with higher number of COVID-19 cases. (Source https://www.covid19india.org/)

using appropriate programs, useful in revealing the evolutionary relationships among isolates (strains) from different species mostly under three categories: distance matrix methods, parsimony methods, and maximum likelihood methods (Das and Huang 2019). From the genetic sequences of virus, we can understand the outbreaks origin, relations, time resolution, location, subtype and pathogenicity. Full-length genomic sequences of SARS-CoV-2 can be retrieved from the NCBI and GISAID databases, established the availability of reference sequence and their deep study for diagnosis and evolutionary-based study through phylogenetic analyses. Tracing transmissions at the local level, country level for public health point of view is important to understand via combination of genetic and epidemiological data analysis (Mavian et al. 2020). Further joint analysis with host species, clinical phenotypes will inferred about complete understanding of disease severity across different region.

9.1.2 Human-to-Human Transmission

Human transmit virus and rapid outbreak of the disease has shifted the focus of the research to human-to human transmission. The virus is primarily transmitted from the spread of respiratory droplets through sneezing and coughing (WHO n.d.-b). These respiratory droplets have the potential to cover a distance of up to 1.8 m (6 ft). Therefore, any person in close contact with an infected person is at risk of being exposed to the respiratory droplets, and by extension, the virus. Although symptomatic people have been identified to be the primary source of SARS-CoV-2 transmission, there is also a possibility of transmission via asymptomatic people. Evidence suggests that the virus can survive for several hours to days in aerosols and on surfaces (van Doremalen et al. 2020). Therefore, direct and indirect contact with infected surfaces has been identified as another potential cause of COVID-19 transmission.

9.1.3 Clinical Phenotype Variations and Pathogenesis

The disease manifests severity based on pathogen variation and host susceptibility together. The complete understanding of host clinical signature, striking genetic variations, and heterogeneities of the pathogens is the clinical presentations of pathogenesis. Angiotensin-converting enzyme (ACE), and its homologue ACE2, having different physiological functions belongs to the ACE family of dipeptidylcarboxy dipeptidase. ACE2 serves as the binding site for COVID-19 and study shows that receptor-binding domain of SARS-CoV-2 has a higher affinity for ACE2, in comparison to SARS-CoV (Chen et al. 2020; Leila and Sorayya 2020). Clinical features of COVID-19 are similar to SARS-CoV signature (Huang et al. 2020). SARS-CoV-2 symptoms vary from asymptomatic to mild, moderate, severe, and critical mentioned in Table 1 of K. Yuki et al. (2020). Transcriptomic profiles of cells, tissues, and fluids from SARS-CoV-2 patients demonstrated higher expression of genes related to oxidative suggesting a critical role for mitochondrial activity, which further suggest its therapeutics role (Gardinassi et al. 2020).

Immunological study shows that T-cell-mediated responses against coronaviruses are initiated by antigen presentation via DCs and macrophages, while patients with severe diseases were reported to have increased plasma concentrations of pro-inflammatory cytokines (interleukin (IL)-6, IL-10, granulocyte-colony stimulating factor (G-CSF), monocyte chemo-attractant protein 1 (MCP1), macrophage inflammatory protein (MIP)1α, tumor necrosis factor (TNF)-α, etc.) (Yuki et al. 2020). Recent progress in database information in Whole Genome Sequencing (WGS) of SARS-CoV-2 ultimately demonstrated set of phenotypic features and explain the possible clinical spectrum of the host. Therefore, clinical and molecular diagnosis together is key priority for conformational diagnosis in COVID-19. Through advanced molecular techniques, the disease diagnosis by using real-time PCR along with distinct phenotype features advocate a confirmatory genotype-phenotype model.

9.2 Current Prognosis Practices

Current epidemiology of COVID-19 highlights worldwide potential regions (in the continent of America, Europe and Asia) as a hotspot of disease incidence and indicated virus transmission region as it is where infected person from different genetic background spreading the highly infected virus during incubation regime. Present diagnosis and control services were highlights the information of public health management under practice, mentioned below.

9.2.1 Diagnosis Services

Understanding the basic concepts of infections and pathogenic mechanism will form the basis for diagnostic approaches. Testing methods ranges from nucleic acid tests, antibody tests and genomic sequencing (Zhai et al. 2020). Infectious disease diagnosis benefits from the exploration of advanced genomics and immunological strip test kits. In spite of the steady high of disease prevalence, the diagnostic based on molecular assays considered better in comparison to immunological methods. In COVID-19, immunological methods are considered as informative while real-time PCR-based analysis is considered as conformational test. Human-to-human transmission described, with incubation times of 2–14 days and early diagnosis, quarantine, are essential to cure patients (Long et al. 2020). Among SARS-CoV-2, S and N were the two main antigenic targets of SARS-CoV-2 antibodies for test kit (Long et al. 2020). For recent infection antibody test performed by measuring IgM (produced within 5–7 days) and IgG (produced within 10–15 days) (Zhou et al. 2020).

The virus that cause COVID-19 diseases, the main factors involved in their infections and the stages in their natural development can be selected as diagnostic molecule. Presently, two major diagnostic approaches immunological and genetic methods were involved along with clinical correlations. The pathogen presence were detected through immunological (rapid test of virus antigen or antibody detection in host sample) and genetic basis (real-time PCR). However, cost effectiveness is one of major factor which decides the type of test in pandemic situation. Second factor is time of test which facilitates early decision of clinical treatment. Currently, immunological diagnostic test used extensively due to cost effectiveness and rapid results, whereas real-time PCR genetic tests as confirmatory results for starting treatment. Patients with symptomatic disease or as asymptomatic infections are identified through real-time PCR methods effectively.

9.2.2 Control Practices

Control mechanism of virus transmission is a most important action due to highly infectious nature of coronaviruses. This will help the public to understand how sanitization-based control measures for the prevention of COVID-19 diseases are put into first place at several control levels of the public health model. Second things to start immediate treatment of genetically positive cases, including the homes or surrounding persons found to be clinically ill based on watching up to incubation time of virus (2–15 days).

9.2.2.1 Sanitization

The spread of coronavirus infections is very fast due to human behaviors of greetings (handshaking, etc.) sneezing, etc. at public places or at home. At first instance, corona positive living area should be sanitized for the complete eradication of viruses so that next related persons not get any infections. Second isolation precaution for close distant persons. Standard isolation practices up to incubation time period and regular sanitization with alcohol-based mechanism is highly recommended (CDC n.d.; Berardi et al. 2020). Purpose of sanitization also fulfill if protective measures such as masks, gloves, and gowns used by persons in containment zone, however removing physical method of pathogen removing or ventilation process or isolation is more effective (Morawska et al. 2020).

9.2.2.2 Treatment

The vital importance part of global researchers to understand disease mechanism of COVID-19 and design pathway related drugs after clinical trial results. Anti-COVID-19 therapeutics should involve the evaluation of virus attachment molecules, pathway molecule inhibitors etc. Currently, there is no specific antiviral treatment recommended, and oxygen therapy represents the first step for addressing respiratory impairment (Cascella et al. 2020). Among other therapeutic strategies, systemic corticosteroids, Antiviral agents, Antiviral/immunomodulatory drugs, Inflammation inhibitors were used (Cascella et al. 2020).

The important pathogenic molecules in the viral life cycle can be considered for treatment-target either through as inhibitor or enhancer or degradation practices (Zhai et al. 2020). Effective treatment practices ensure complete returning to normal clinical features most importantly improvement in respiratory function. Currently, several drugs were under practices based on target actions with significant results. Importantly, recent pandemic situations generate opportunity to clinical researchers to test the efficacy of several drugs and establishing it under treatment practices.

9.3 Challenges of SARS-CoV-2

Pandemic adding to several woes, from diagnosis to treatment due to mismanagement, scarcity of health facility, high cost, more time involvement, attitude and behavior of stakeholders. Sudden outbreak of the SARS-CoV-2 created fears, which circulated regularly in absence of standard healthcare model. Due to lack of adequate diagnostic kits, sufficient hospitals and effective treatments, prevention is the only best option. Recent expose of missing standard healthcare practices and services for COVID-19 across developed nation too indicated existence of several challenges. Best healthcare awareness, full disease information, standard healthcare management, real-time diagnosis, and effective treatment are the only required solutions.

9.3.1 Phylogeography and Clinical Features

Evolutionary patterns of COVID-19 and patients clinical features understanding face the high technical challenges due to less understanding of disease progression and mechanism. Genetically diverse virus pathogen spread differentially across globe. Further, these pathogens have different pathogenic affect due to expressed variants. Due to zoonotic risk hosts have risk of cross species infection proof by sequencing (Lu et al. 2020a). Importantly, human susceptibility also varies and immunogenetic regulations decide the clinical features extensively. Asymptomatic condition was generated due to host-pathogen interaction. The molecular mechanism of asymptomatic behavior is not clear, which also impart transmission possibility for further infection. These challenges should be bring by analyses at the immune-genetics level for complete understanding. Such virulent virus is responsible for varied clinical incidence in different populations and different region due to host–pathogen and gene–environment interactions. Evolutionary adaptability and phylogeographic patterns will help us to understand the pathogenic effects and disease severity.

9.3.2 Mass Community and Healthcare Management

Public health policy has work division and certain priority for regional and global disease programs of infectious and noncommunicable diseases. Healthcare management has to work under certain limitation to fight for various infectious diseases. COVID-19 pandemic and sudden outbreaks have imparted global burden on healthcare facility even in developed nations. WHO standardized the protocol to address specific needs and considerations for essential health services useful in Healthcare management (WHO n.d.-c). Public health authorities have to make community connection stronger than ever to makes it easy to search for even single infections based on test and clinical features and deliver services that help public at local ground. Pandemic situation generate highest health crisis, which reach within community to affect each person's at same probability until and unless they follow standard control practices. COVID-19 outbreak has demonstrated the worldwide unpreparedness to face unwanted death and risk (Coccolini et al. 2020). Ultimate goal is to divert limited healthcare facility to highest needy in the cost-effective manner. In pandemic situation, centralized mechanism of diagnosis, sanitization and treatment required extensively. Absence of standard healthcare management system create high rate of infections, mortality and clinical complications. During

COVID-19 epidemic effective coordination and management is useful for combating (Barro et al. 2020). The management based on mass healthcare facility offers a variety of useful facility, like diagnosis and treatment and stop COVID-19 disease. Effective mass healthcare practices also depend on attitude, behavior, and knowledge of mass community, which also not clear for new emerging pathogens such as SARS-CoV-2. Overall, only technology-based support system have capability to deal and ensure public healthcare management correctly at single stakeholder's level.

9.3.3 Transmission and Distancing

Pandemic situation open possibility of infection at each region in the community. The spread of a COVID-19 virus caused by the releasing droplet nuclei through infected persons via air over long distances. Understanding distancing, masks, and eye protection on virus transmission in healthcare practices is useful to make public health model (Chu et al. 2020).

Stopping airborne transmission via isolation (home quarantine, etc.), lock down (market, travel, regional restrictions, etc.) hoping to control the spread of further infection or slow down the rate extensively. Social distancing applies to all apparently healthy people, which ensures to take all precautions given by public health department or government organizations.

9.3.4 Diagnosis and Treatment

Currently, routine testing for the COVID-19 is based on immunological and genetic methods. However, immunological test are less sensitive when compared with molecular-genetic method. Healthy positive and complex disease clinical features adding complication in clinical decision. Diagnosis along with healthcare management is best strategy for pandemic condition (American Thoracic Society n.d.). In rapid tests, the specificity and sensitivity of detection were also less. Absence of standard biomarker for the diagnosis has been revolutionized by the development of molecular research, mainly with the applications of advanced nanodiagnostics. Presently, point of care diagnostics has major implication in healthcare diagnostics of mass healthcare (Konwar and Borse 2020). Cost effectiveness and time of testing is another parameter, which helps the early decision of treatment. There are no clinically approved drugs available specifically for SARS-CoV-2, at time of disease outbreaks first time in December, at Wuhan, China (Mishra et al. 2020a). Its, important to established most effective drugs through clinical trials, as it will protect patients from possible harm from experimental treatments. Understanding progression of disease through molecular research can reveal exact target region to design effective drug. Therapy of a community in high prevalent area may consist of selective or mass treatment. In mass therapy, effective drugs are administered to the total population. In mass treatment, viral diagnosis via real-time PCR and clinical correlations may be omitted in order to make the treatment cost-effective.

9.3.5 Disease Modeling Approaches

Epidemiological data analysis along with risk factor monitoring is one of important approach in disease prediction. Understanding propagation of disease and healthcare requirement is one of desired area which can be figure out through advanced disease modeling research. Several applications can be utilized easily and early to get time for arranging facility and forecasting restriction such as travel (Buckee et al. 2020). Standardization of modeling through capable of measuring and forecasting the impacts of social distancing, also one of challenge should be address before adopting in public health model (Bertozzi et al. 2020). To present an up-to-date algorithm is missing for COVID-19 prediction, risk assessment and incident chances. Incorporating recent advances regarding disease information for high-risk assessment is important for developing standard healthcare management.

9.3.6 Data Security Concerns

For mass healthcare solutions the data privacy, security, and handling is a major concern. The healthcare information is a completely data-driven concept, where huge volume of data generated. Quality check of databases, authenticity of the data, reliability of information's also major concerns with the data management. Collected data come under cyber attackers if poorly handled and become malware in the network complications. Full flaze utilization of bluetooth technology, Wi-Fi wireless networks, Cloud computing, Web Service, IoT, AI, ML in handling and analyzing big database generated during COVID-19 is absent for further disease modeling research.

9.4 Advanced Technologies

The far-reaching effect of advanced technologies in prognosis was one of important utilization in COVID-19 pandemic.

As the SARS-CoV-2 progresses its infection across globe, multitude of technological development emerge to provide healthcare services in faster pace. These emerging technologies products were based on AI, IoT, ML, sensors, genomics, etc. bringing several facilities at the forefront (Vafea et al. 2020). According to the WHO and the CDC, digital technologies can play an essential role in improving public health response to the COVID-19 pandemic (Mishra et al. 2020a). In the following sections, we discuss the aforementioned technologies and their logical impacts on the SARS-CoV-2 pandemic.

9.4.1 Internet of Things (IoT)

The surge of IoT initially brings advanced applications of mobile devices integrated with IT systems. IOT included in medical devices and offer vast range of healthcare services through several software's packages. Applications are broad (NS Health Care 2019) and for COVID-19 it may covers:

- Monitoring and tracking from distant location
- Integrated in healthcare devices and transmit information to the cloud or server for universal use and analysis by professionals

Specifically designed unique models optimized for IoT, along with AI, able to handle metadata, time series data in efficient manner in COVID-19 (Vaishya et al. 2020). Owing to their broad applications and potential in healthcare field, IoT utilized extensively in COVID-19 pandemic for better healthcare management.

9.4.2 Artificial Intelligence (AI)

Since its inception, AI has become advanced technology used broadly in computational healthcare, security, environment and energy field due to its inherent properties fitted in everywhere. This landmark technology covering analysis, data interpretation, accurate decision and insure works implementation. Healthcare technologies and healthcare management work efficiently with AI and recent advancement has found that AI is a highly effective tool against the SARS-CoV-2 pandemic (Vaishya et al. 2020; McCall 2020; The Council of Europe 2020; Bansal et al. 2020; Lalmuanawma et al. 2020).

Table 9.1 described details of AI utilization in combating COVID-19 (McCall 2020; The Council of Europe 2020; Bansal et al. 2020; Lalmuanawma et al. 2020), their wider application (Davenport and Kalakota 2019; Mak et al. 2019; Fleming 2018; Fitzpatrick et al. 2020), source of information for conducting research and technology (Hutson 2020; COVID-19 Open Research Dataset n.d.; Special Issue on Artificial Intelligence and Data Science 2020) and utilization in another disease (Roberts et al. 2020; Yan et al. 2019; Troyanskaya et al. 2020; Huang 2020; Zoie et al. 2020). Healthcare field utilize the AI as diagnosis (screening, identification, correlations, etc.) and indicate severe symptoms, scan health fitness, temperatures, etc. under real-time manner. Harnessing data analyses in real-time manner and give instant idea of SARS-CoV-2 is the potential contribution of AI found to be effective in combating the SARS-CoV-2 pandemic. Figure 9.3 representing use of AI in healthcare.

Table 9.1 Details of AI utilization in combating COVID-19, wider application, source of information, and utilization in other diseases

S. No.	Resource	Artificial Intelligence (AI) applications	Reference
1	COVID-19	Protecting healthcare workers and curbing the spread	McCall (2020)
		Tool to support the fight against the viral pandemic	The Council of Europe (2020)
		Utility of AI amidst the COVID-19 pandemic	Bansal et al. (2020)
		Applications of machine learning and AI for COVID-19	Lalmuanawma et al. (2020)
2	Application	The potential of AI in healthcare	Davenport and Kalakota (2019)
		Drug development	Mak et al. (2019)
		Drug discovery	Fleming (2018)
		Infection prevention	Fitzpatrick et al. (2020)
3	Knowledge Source	Tools aim to tame the coronavirus literature	Hutson (2020)
		COVID-19 Open Research Dataset (CORD-19)	COVID-19 Open Research Dataset (n.d.)
		Special Issue on Artificial Intelligence and Data Science	Special Issue on Artificial Intelligence and Data Science (2020)
4	Different diseases	Complex disorder affecting many body systems	Roberts et al. (2020)
		Cardiovascular diseases and future medicine	Yan et al. (2019)
		Cancer	Troyanskaya et al. (2020)
		Cancer diagnosis and prognosis	Huang (2020)
		Infectious disease Big Data analytics	Zoie et al. (2020)

9.4.3 Databases and Analytics

Big Data Analytics (BDA) is one of current requirement to handle, understand, predict and make strategies for the purpose of constructing valuable information. In healthcare sector, it's now a trending practice to adopting with BDA for clinical research and life style data analysis and as a tool to improve operational efficiency. Big data technology can store data about COVID-19 virus and analyze effectively for healthcare management purposes (Zoie et al. 2020; Haleem et al. 2020). BDA can enhance decision-making process via available tools and setup in several categories like volume, variety, velocity, and veracity by data scientist.

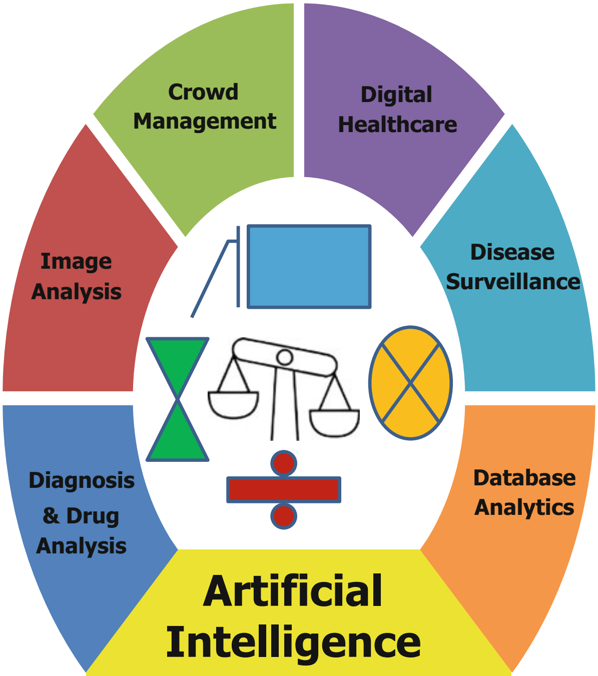

Fig. 9.3 AI and border applications in healthcare field

9.4.4 Advanced Genomics and proteomics

Advanced genomics and proteomics helps to understand about entire genomes, including the nucleotide sequence, organization, interactions and protein information, structure and functionality and abnormality. Due to advent in DNA sequencing technology genomics and proteomics are revolutionizing our understanding of disease progression and mechanism extensively. Finding host genomic factors that increase susceptibility of COVID-19 and utilized this information to improved patient care is best strategy (Murray et al. 2020). Studies found that human genetic variants were to be associated with COVID-19, emphasizes more focus on genetic susceptibility work (Campbell 2020; Lu et al. 2020b).

Comprehensive knowledge of the genetic architecture of SARS-CoV-2, host susceptibility will provide insight into the disease severity and evolutionary mechanism and enable rational predictions of diagnosis and treatment strategies.

9.4.5 Cloud Computing and Optimization

The Significant adoption of cloud computing in the healthcare business will proceed to develop and accelerate in the coming years. Increasing usage of healthcare and the requirement to save and analyze large volumes of healthcare data to deliver both individual and community health management services requires the need for cloud computing from both a business and a technology aspect. Application optimization in mobile cloud computing has several applications to combat with COVID-19 (Ahmeda et al. 2015).

Appended to this have the frequently complicated and wide-ranging healthcare cloud service contributions possible in the marketplace, which healthcare providers force, struggle to follow as in applications. Knowledge about cloud computing optimization, foundations, applications, and challenges are now available (Mishra et al. 2020b). Cloud computing aids the purpose of technologies similar to big data analytics, cognitive computing, mobile collaboration and information exchange to expedite the transfer of excellent healthcare solutions. The purpose of healthcare management using optimization with cloud computing is to focus on health issues. Optimization techniques can be applied to improve the delivery and supply of healthcare providers to maximize service coverage, minimize riding requirements of patients, restrict the number of facilities, and maximize health or access equity.

9.4.6 Digital Medicine and Healthcare

Digital medicine field, utilized technologies for intervention in the healthcare services for mass community. SARS-CoV-2 pandemic situation required healthcare services of diagnosis and treatment at mass level. The healthcare products driven by high-quality computational, electronics support involved more accurately, broadly in the disease monitoring, diagnosis, treatment consultancy, disease prevention, and healthcare information's for major community. The digital medicine can offer video-enabled telemedicine use among patients and providers for the COVID-19 patients (WHO 2020).

Monitoring severity of illness through mobile-based technology from distant region and deliver diagnostic and treatment decisions during infectious process makes the importance of this technology. Due to highly infectious nature of virus, even healthcare practitioners were under risk of infection with SARS-CoV-2. Digital healthcare technology is mass healthcare technology, which delivers medical facility at distant locations. The application of digital technologies in pandemic management covering pandemic planning, surveillance, testing, contact tracing, quarantine, and health care is exiting (Whitelaw et al. 2020).

9.4.7 Biosensor and Bioelectronics

Biosensor-based technology is considered the best for identification at mass level. Its reliability increases due to its sensitivity and since it is easy to use. The bio-recognition component is the important part of the biosensors. This recognition component which is fixed on the surface of the electrode by physical or chemical method and communication generated through electrical signal way can be carried forward to the next level to achieve qualitative or quantitative analysis. Considering it as intelligent diagnostics tools to manage COVID-19 pandemic, for delivering a rapid, selective and sensitive detection of human beta severe acute respiratory system coronavirus (SARS-CoV-2) protein is the key factor (Mujawar et al. 2020).

The role of IoT is to close the gaps between equipment through fast delivery by logical system. Studies related to immunosensing of bacteria or biomolecules and electrochemical biosensing of molecules through use of advanced material science have already established the biosensor research at next level.

The impact of biosensing in a pandemic outbreak is enormous and required much more attention for the progress (Morales-Narváez et al. 2020; Bruch et al. 2019). The concept of bioelectronics, allowing capturing any modulation at cellular or molecular level and through use of bioelectrical communication able to enrich information in real-time manner.

9.5 Integrated Technology and Logical Products

Currently, knowledge of the core technologies, Clouds, IoT, and platforms of AI will help the healthcare field to become a true leader in the health product and market. Various start-of-the-art AI, wireless networks and Cloud technologies are introduced in healthcare management and start works on full phase with smartphone and smart device on availability of 5G mobile communications. The progress in the range of digital tools, allow combating the COVID-19 outbreak effectively (Ting et al. 2020).

Integrated technology by designing product and the processes by which product will do those requirements is the goal of advanced healthcare management. By using engineering specifications, materials, equipment, and technologies new products were designed. SARS-CoV-2 transmission control and crowd surveillance for clinical phenotypes is one of urgent requirement by pandemic condition. Secondly, maintaining hygiene and monitoring public health status is another issue generated during same pandemic situation. Technology integration becomes much more important due to pandemic across world and availability of limited healthcare facility. Figure 9.4 described the logical integration of IoT, Cloud, and AI system for efficient healthcare services.

The number of technologies has grown dramatically due to integration of concepts and field such as biology, physics, chemistry, medical, information technology, computation, electronics, materials science and advanced technologies.

Due to gathering of data and requirement, the amount of knowledge relevant to product is rapidly becoming more day by day. Managing integrated technologies with ethical and standard operating procedure and coordination task with IT management tools is important and relevant.

9.5.1 AI, Cloud, Sensor and IoT

AI Cloud and data tools help with AI softwares in making data strategy and deliver varied services. Using high performance computation, parallel processing, commodity hardware with excellent in-memory performance, one can work for nonstop

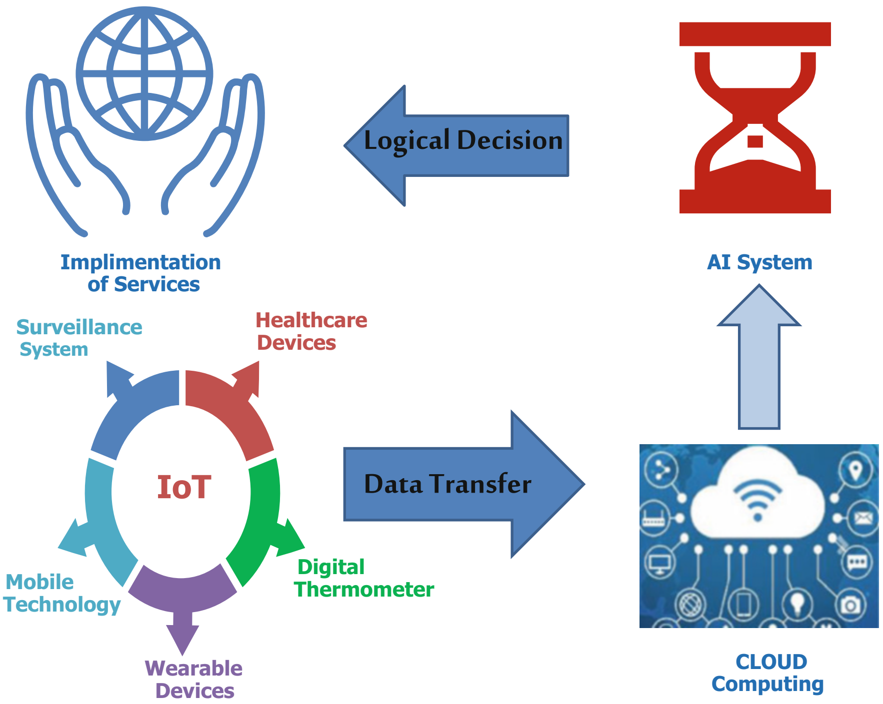

Fig. 9.4 Logical integration of IoT, Cloud and AI system for healthcare services

operations for any added tasked under self-service mode at their own speed. Application of advanced technologies is broadly discussed and for requirement basis it can be integrated in one platform for better results (Buckee et al. 2020; Bertozzi et al. 2020; Vafea et al. 2020; McCall 2020; The Council of Europe 2020; Bansal et al. 2020; Lalmuanawma et al. 2020; Davenport and Kalakota 2019; Mak et al. 2019; Fleming 2018; Fitzpatrick et al. 2020; Haleem et al. 2020; Lu et al. 2020b). In the near future almost all medical devices will include IoT modules which will use sensor data collection and control/management based on Clouds. Gathering and organizing the healthcare information through data acquisition, using analog sampled signals and converted into digital form and measuring the physical or electrical data (voltage, current, pressure, temperature, sound, etc.).

9.6 AI-Enabled Prognosis Technology, Product, and Model Description

Effective prognosis model of disease control which have combo effect of diagnosis and control is one of the effective model for COVID-19/SARS-CoV-2. The containment regions required trio action (sanitization-diagnosis-treatment) based public health model to stop immediately disease chain reactions.

9.6.1 Technology and Product: AI Analysis and Program in Healthcare

The Fourth Industrial Revolution, combined with advanced ICT technology, is expected to break down the boundaries between industries, bring about various forms of convergence and competition, and create new values. Among the industrial sectors, the healthcare industry is already growing on a significant scale, but the inefficiency in the industry is very high, which is expected to be the industry with the greatest growth potential due to the convergence of ICT new technologies.

The global digital healthcare industry is expected to continue to grow due to the aging of the world's population and the increase in the number of patients with chronic diseases. Already, the market is estimated to be worth 142 billion dollars in 2018, and is expected to grow 20.4% annually to 206 billion dollars by 2020.

First of all, artificial intelligence (AI) is expanding and evolving into various fields, but merger and financial transactions are the most active in healthcare, and the development of AI is expected to be the biggest. Although major forecasting agencies have different priorities for each industry, most data show that healthcare and medical sectors are at the top. As a result, start-up companies seeking a fortune from large companies are moving to create new industries by applying AI technology to healthcare and medical sectors, and major national governments are also providing support to revitalize the market.

On the other hand, it is predicted that AI combined with big data will have various effects on healthcare and medical fields. First of all, research that has been conducted by industry, academia and the government so far will be greatly developed by utilizing medical big data, such as innovation in medical and medical technology, such as discovery and restriction of new treatment technologies, efficiency and optimization of medical care, and optimization of medical costs. In addition, the quality of life (QOL) of patients is expected to be improved by significantly changing the process of providing medical and nursing services itself.

Recently, AI has played a very important role in the field of health diagnosis. Advanced computing resources combined with advanced machine learning technology help medical professionals to understand problems and find useful patterns that help diagnose them. Looking at how COVID-19 creates panic in the current scenario, everyone around the world can expect AI testing technology to help with the diagnosis process as well as screening patients and preventing spread.

Currently, several countries have developed a test kit that can detect COVID-19 in minutes, but most countries cannot test more people because there is not enough testing methods and it takes longer. To overcome the difficulties, Terenz proposed an AI-based screening system that could detect COVID-19 using chest X-rays in seconds with 98 s of accuracy. Figure 9.5 described the sample of dataset used for the development of the AI-based screening system. The new system not only detects COVID-19 quickly, but also provides detailed information on the progress of the disease, allowing more quantitative monitoring of the disease depending on its urgency.

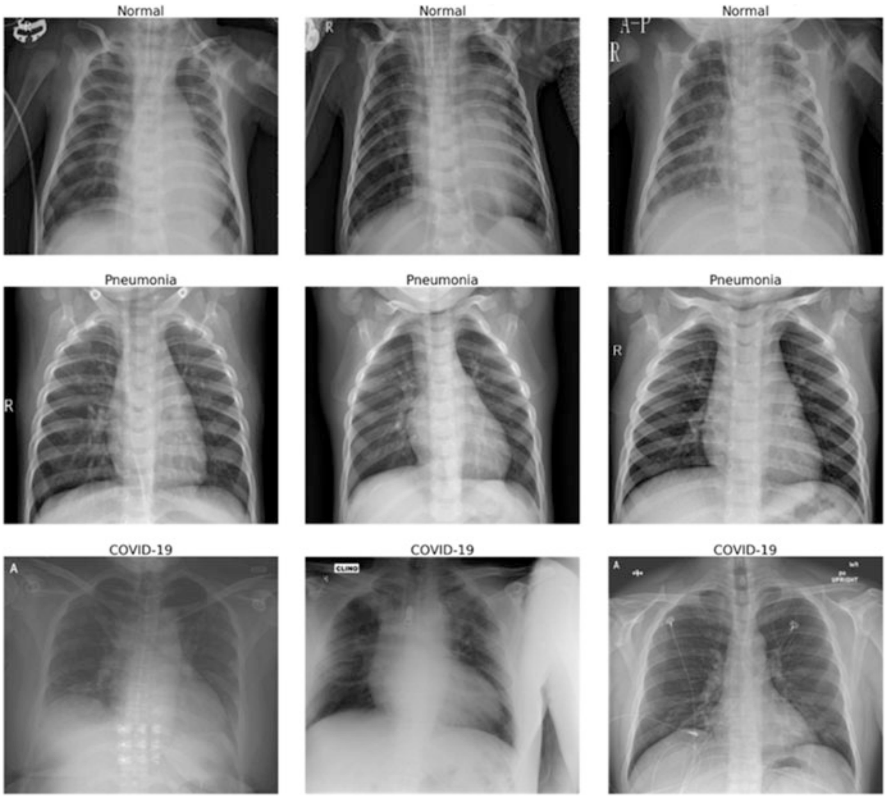

Fig. 9.5 Sample of the dataset used for the development of the AI-based screening system

The X-ray data used for the development of the AI system has been acquired from different public and private sources all over the world. Predominantly the data was acquired from three different categories i.e., normal/healthy people, pneumonia, and COVID-19. The X-ray data considered in the study were from posteroanterior view where the X-ray beam enters through the posterior (back) aspect of the chest and exits out of the anterior (front) aspect, where the beam is detected. For detecting COVID-19 and classifying the data into normal, pneumonia, and COVID-19, an AI engine leveraging Convolutional Neural Network was developed. Figures 9.6 and 9.7 show the ROC plot, case description and workflow. The CNN algorithm developed performed pretty well by plotting an overall accuracy of 98.141%. Further, it was derived from the outcomes that the recall for the COVID-19 X-rays was 100% with an AUC–ROC of 0.99.

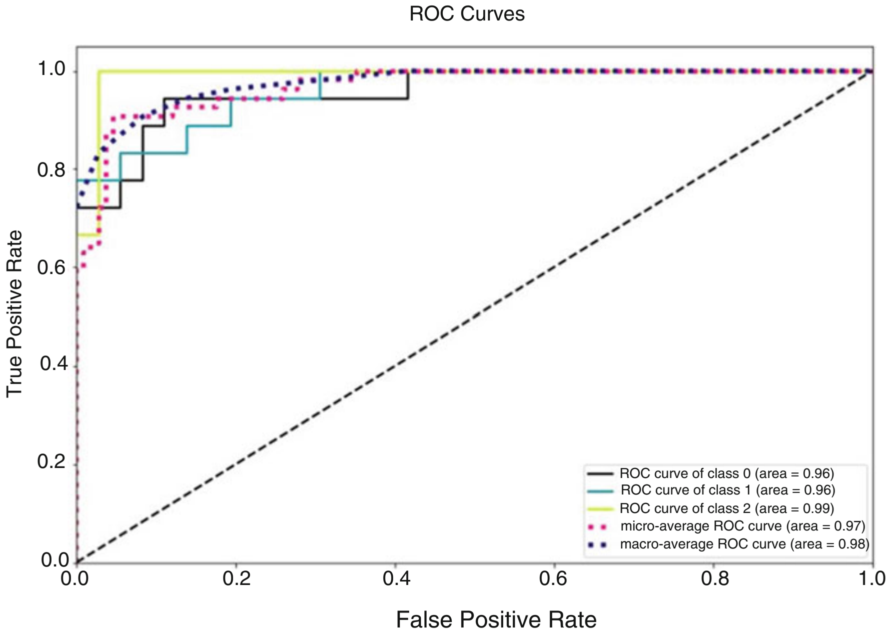

Fig. 9.6 Figure shows ROC plot for three different classes. Figure defined the various classes such as Class 0 = Pneumonia, Class 1 = Healthy and Class 2 = COVID-19 to understand the diagnosis model

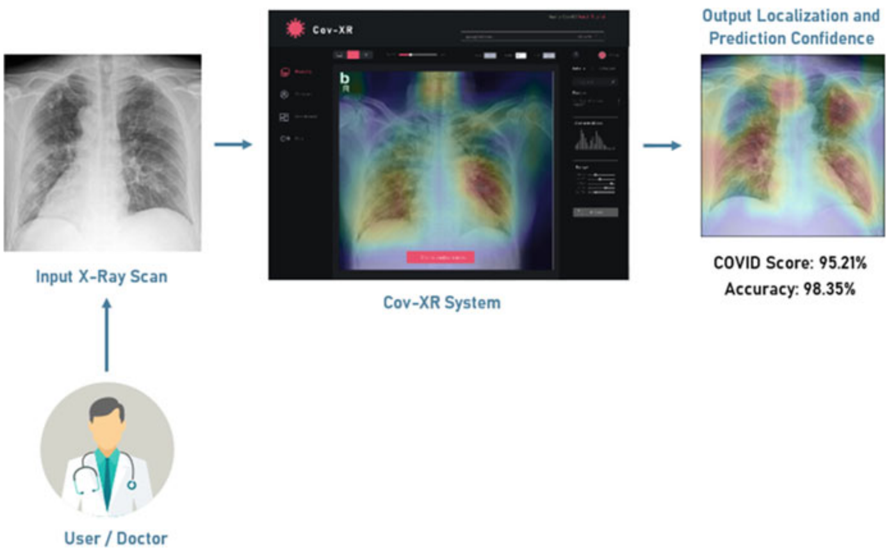

Fig. 9.7 Figure shows the Cov-XR work flow. Terenz Corporation Limited, Busan, South Korea works on Artificial Intelligence based data analytics. Cov-XR work flow developed using AI

9.6.2 Product and Technology: AI-Based sanitization Machine Using Cloud computing and Optimization

With the pandemic Covid-19 on its peak, the world is on high alert, everyone is paranoid of everyone. Several devices are being modeled by harnessing the power of AI to trace, identify, and for better understanding the rate of infection.

Over the years, artificial intelligence is being used to automate the jobs, in general or which are beyond human capabilities. These can be said a perfect replacement of human workforce. Now, this contagious pandemic crisis has incremented the deployment and familiarity of these technologies like awareness and cell phone tracking device, AI-based chest X-ray system. The AI technologies that are of high importance to healthcare are neural networks and deep learning, Natural Language Processing, Rule-based expert systems, Physical robots, Robotic process automation.

This chapter proposes an AI-based sanitizer machine in which a person can be sanitized as well as probed by going through a small diagnostic test. This will manifest whether the person is fit to proceed further or needs to see a doctor. This machine comprises four parts: Eye-Biometrics, Pulse Oximeter, Thermal Imaging, and Sanitizer. This can distinguish the suspects and store/update their information for future purpose. The block diagram of proposed model using cloud database is shown in Fig. 9.8.

The function of each parts and the working are also discussed in this chapter.

- Eye-Biometrics—Though this technology falls in the same category as face recognition and fingerprinting, but it quicker and more reliable. This offers three separate feature set for biometric use; those are iris, sclera, and retina. The Iris technique illuminates the iris and captures the unique patterns and colored circle by using invisible infrared light. Around 240 biometric features are collected and amalgamated to make a unique pattern, which are then converted into numeric digital data. The sclera or eyeprints technique provides high accuracy by capturing the unique pattern of the blood vessel present in the Sclera (whites of the eye). In retinal scanners, the infrared light is used to image the patterns of the blood vessels in the retinal tissue inside the eye. As per the researchers, the latest development in this field is that the iris can scan from a distance of up to 40 ft (12 m).
- Pulse Oximeter—This meter measures the oxygen saturation level in the body without using needles or taking a blood sample. The measured amount shown on the screen reflects the saturation of the person red blood cells with oxygen. The benefit of using this technique is that there is no risk or danger.
- Thermal Imaging system—This efficient and compact technology translate heat into visible light to analyze the surroundings even in the dark. Thermal cameras can be used to scan a number of people at once. Anyone showing an abnormal temperature stands out from the crowd and can be asked to move to a quieter area for a more accurate check.

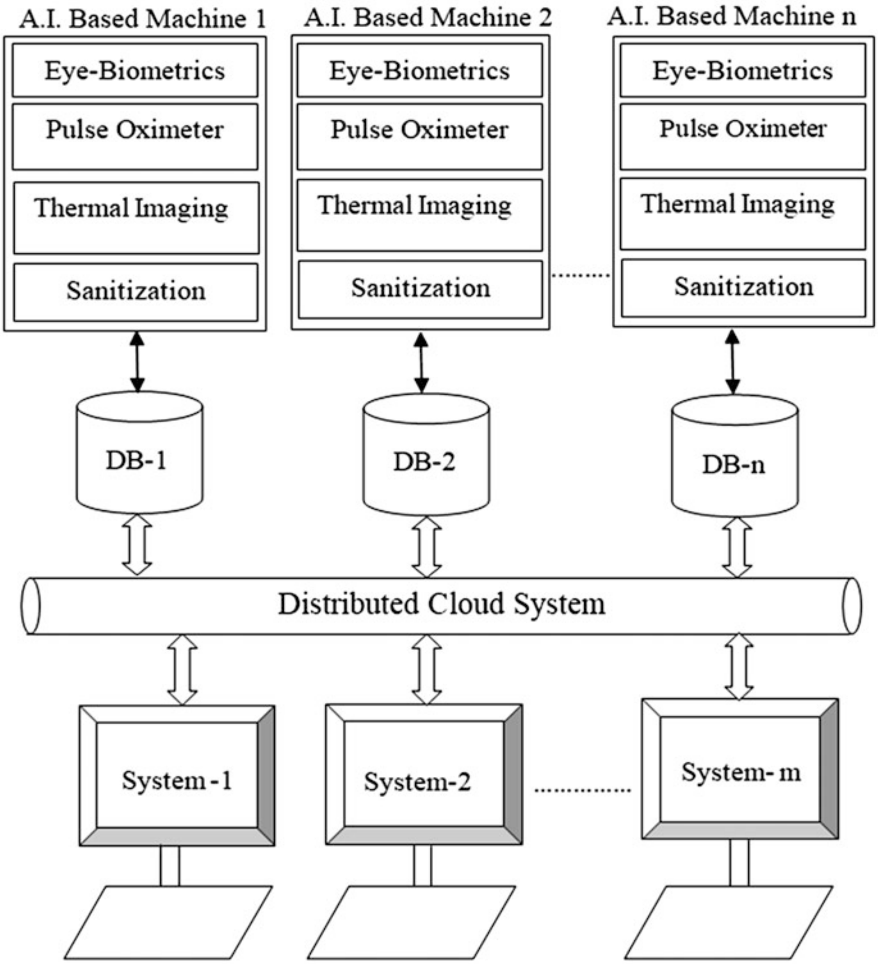

Fig. 9.8 The block diagram of proposed model using cloud database is shown above

- Sanitizer—The embedded full body disinfection sanitization system is equipped with a soap solution and sanitizer. It creates a mist of sanitizing solution to sanitize the person

The proposed model is such that when a person enters in the automated sanitization zone, the sensors are activated the person is automatically sanitized, the laser checks the symptom of the COVID-19 (high temperature), the biometric is done and the measure of oxygen is taken using the pulse oximeter. If the person is found positive i.e., oxygen level below normal or high temperature or both, there is a beep sound and the database is updated as suspect (where all their details are mentioned). When the person is treated and again tested, the database is updated again. The person's details in database can be updated from anywhere, where the system is enabled. This will have the record of all the people who are infected, treated, number of times infected. This way a treated corona negative person can be contacted in future.

In the cloud environment, all the machine database saves in the local disk and it's connected distributed in cloud services. In this model, the cloud services use in dataset stores and fetch data in directed uses. Cloud services pay as administrators to store data in administrators' end. In cloud-stored data using many different optimization algorithms in COVID-19 diseases to protect the people using some precaution.

9.6.3 Product and Technology: IOT-Based AI-Enabled Touchless Hand Sanitizer Machine

Here we propose the artificial-enabled touchless hand sanitizer machine which is capable of detecting the temperature of the person along with his/her oxygen level, the person will sanitize him/herself and the attendance of the person will be marked with the biometric punch in the system. This machine is integrated with the Wi-Fi module, which will send the data of the recorded person to the local server where the data will be optimized and send to the cloud server. Table 9.2 described the step-by-step process in IoT-based AI-enabled touchless hand sanitizer machine. The machine will have following hardware integrated with it which will work intelligently in steps and every step will be enabled with the true result of previous step.

Table 9.2 Step-by-step process in IoT-based AI-enabled touchless hand sanitizer machine

S. No.	Step number	Sensor	Function of step	Result
1.	Step 1	IR Temperature Sensor	Marking the body temperature	Step 2 is enabled if body temperature is less than 36.4 °C
2.	Step 2	Pulse Oximeter	Noting the body oxygen level	Step 3 will be enabled if oxygen level is greater than 90%
3.	Step 3	Biometric Sensor	For marking attendance	This step is accepted if step 4 is completed
4.	Step 4	Ultra Sonic Sensor	For touchless sanitization	After this step attendance will be marked and step 5 will be enabled
5.	Step 5	Wi-Fi Module	For sending data to local server	This step will be used for individual data recording to the local server

9.6.4 Technology and Model: Prognosis Healthcare Model for Mass Community

Exciting diagnostic developments especially in the immunological approaches hold the promise of a dynamic and evolving due to available more knowledge about pathogenic mechanism and immunological meaning to infer about SARS-CoV-2 infections. Cost effectiveness, ready to use, and short time of test is another advantage over costly genetic testing, which makes it more useful for mass healthcare services. Mass healthcare screening in short time period based on immunological strip test gives idea of infected persons in the specific region, which further follow-up for next weeks for clinical features similar to SARS-CoV-2 along with sanitization practices. Clinically ill persons were subject to real-time confirmatory test and further treatment process, while rest can be ignore if not showing any clinical signature for long time period.

9.6.4.1 Standard Prognosis Practices

Standard practices involved immediate diagnosis and control actions in the containment region (high incidence region) until full eradication of the diseases.

General prognosis structure proceeds in below manner, mentioned in Fig. 9.1.

- *Find out the similarity of clinical features of COVID-19*
- *Diagnosis of clinically ill person based on immunological method*
- *Sanitization of whole region based on case activity area*
- *Diagnosis of clinically positive person with real-time PCR method*
- *Start treatment of genetically positive person*
- *Follow-up of surrounding persons up to the incubation time period of virus*

The standard structure of prognosis involved diagnosis and control practices, above mentioned and proposed informational model can be followed step by step for better result (Fig. 9.9).

9.7 Adaptation of AI-Enabled Technology and Disease Research

We emphasize on the advanced technology adaptation that are capable of combating COVID-19 more effectively, specifically without risk to common public.

In addition to digital medicine other advanced technologies bring a wide range of expertise in single platform, which will deep look into the challenges and give best healthcare solutions based on artificial intelligence for mass community in a range of locations. Adaptation of digital healthcare products can help public healthcare management in many ways (Top Digital Health Technologies 2020; Healthcare platform n.d.).

This systematic review evaluate information's, discuss limitations and contribute knowledge thereby identifying potential technology avenues and focused on

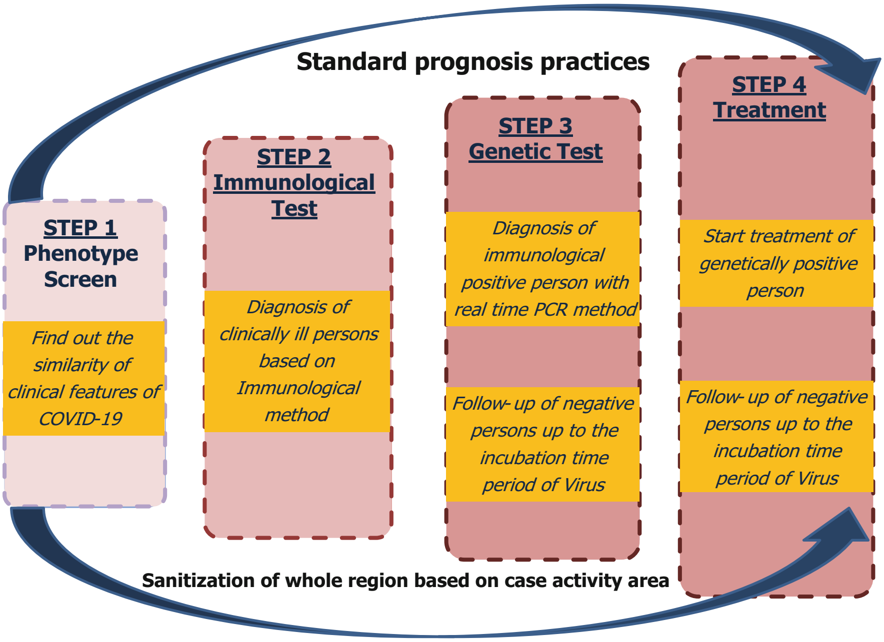

Fig. 9.9 This is graphical representation of rapid mass healthcare model in the containment region that holds the promise of diagnostics for disease eradication

implications support for the community. Thus immunogenetic profiling, diagnostic methods, healthcare surveillance for hygiene and healthcare management presented in this article has identified relevant technology support in form of artificial intelligence that have conceptually more potential in best management decision.

9.7.1 Hygiene, Distancing, and Virus Control

The hygiene maintenance from virus done through environmental monitoring, defining human activity areas and used product contact surfaces. In a hygiene monitoring system pathogens are tested or monitored routinely in human activity area. It's important to verify that cleaning and sanitation are effective during sanitization and hygiene are maintained. Study shows that effective protocol for sanitization and hand washing is important to control pathogens (https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1365-3156.2006.01734.x). Under absence of vaccines, local public health authorities and governments initiated various restrictions, which insured at least less social contacts. The point of social distancing is to ensure to check the spread of the infections over time via lockdown or curfew. User friendly, cost-effective healthcare technology and products can be adopted by government authorities and in public health care models for fast, efficient and better results of management (Public health management 2020; Bielicki et al. 2020).

9.7.2 Understanding of Pathogenic Consequences

Understanding the molecular basis of the disease progression and desire to eradicate infections is the important goal of the pathogenic study. Pathogenic mechanism covers several valuable information such as virus entry into the host, their transmission in the host, patterns of viral infection, disease progression, virulence factors, and host immune mechanism. The human has become an important host for studying COVID-19 pathogenic mechanism through genomics and proteomics approaches because it affects the human widely without regional and population barrier at first instance. With the use of advanced genomics identifying the virus genome and host genes that found to be susceptible for the disease. The genome of the virus is highly polymorphic and infect non-human hosts too such as Bat, pangoline, camel, etc. (Mavian et al. 2020). Disease severity should be correlated with virus strains or subtype in each host. In addition, detail understanding of proteomics is helpful for understanding of identification of target proteins of disease pathways and leads to drugs target and design (Bielicki et al. 2020; Gordon et al. 2020). Proteomics describe the protein expression profile and elucidate the role of pathogen in the pathogenesis of SARS-CoV-2 and its complications. The SARS-CoV-2 viral pathogen (COVID-19) can be study for human–virus protein interaction through various molecular and bioinformatics analysis. Study shows that all the structural and accessory proteins are translated from the sgRNAs of CoVs (Mousavizadeha and Ghasemi 2020).

In principal highly pathogenic virus can generate complex clinical complications and lead the host up to death in short period. Therefore, process of virus entry through molecular interactions with host and further immunological consequences in terms of defense system is co-related with virus genomics. In addition, identification of signaling pathways altered during viral infections may help to unravel the most relevant molecular cascades implicated in biological processes mediating viral infections and to unveil key molecular players that may be targeted (Catanzaro et al. 2020). The infection in an individual host must be studied for understanding of disease progression and increasing severity step by step at molecular level from both pathogen and host side. It must be studied at the site of infection, spread in the tissue, inflammatory responses, cells destruction and immune defenses mechanism, tolerance. During infection, virus particles invade mucous-covered membranes in the host, enter a cell, and start replication cycle, then damages through cell lysis by the allergic reactions.

Finally, in this article we focused on understanding of pathogenic consequences from different databases, resources, genomics, proteomics, clinical trials, and adaptation of artificial intelligence-enabled model for diagnosis and control so that to deliver technology and product of high efficient, sensitive and specific way and established regional and standard healthcare model for better results.

9.8 Conclusion

This article presents state-of-the-art technologies that help to understand robust technical decisions in healthcare field. Here, we have explored the pandemic SARS-CoV-2 epidemiology, clinical features, genomics, prognosis, sensor, advanced technologies and implementation of Artificial Intelligence for public health care management. For mass healthcare services using advanced technology and handling data based on AI supportive decision we get accuracy and consistency at big populations for SARS-CoV-2 diagnosis and control.

9.9 Future Prospects

This article brings a holistic view of global healthcare models of diagnosis and control more understandable for future implementation. Use of genomics and advanced technology for effective prognosis models along with framing appropriate policies for public health shall be helpful for all stakeholders in public health system. Overall, adaptation of artificial intelligence-based technology and knowledge of the pathogenic mechanism can only give better result in countries having limited health facility.

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Conflict of Interest All authors declare no conflict of interest.

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Intelligent Agent Based Case Base Reasoning Systems Build Knowledge Representation in COVID-19 Analysis of Recovery of Infectious Patients

10

Jagjit Singh Dhatterwal, Kuldeep Singh Kaswan, and Preety

Abstract

Coronavirus, also known as COVID-19, has been identified as a pandemic by the World Health Organization (WHO). More than 6,750,521 cases were registered at the end of this study, causing the deaths of over 395,779 people, which are growing around the globe every day. This very infectious respiratory disorder is at risk for the development both of symptoms and of asymptoms, which lead to a growing number of contractions and deaths. There is therefore a need to step up the method of early detection and treatment of this disease worldwide. The CBR model is an effective paradigm that allows the use of experience from previous specific cases, specific problems or patient cases to address new cases. It can be used to categorize new cases and even in their early stages by using the extremely rich COVID-19 database. Any simple case logic defined as a case-set case-basis file is analyzed using a Clinical Artificial Intelligence technique.

The following methodology is used for this analysis. The formalized case is therefore analyzed in a CCBR model in order to define the case positively or negatively to COVID-19 for a short period of time. This means that the CBR model uses formalized features to calculate the similarity of the new case to other cases taken from the data base of the CBR model. The proposed system has been applied with a variety of records from the Italian Medical Society and Intervention Radiology (SIRM). The results showed that the proposed approach leverages spatial and time-specific infection sites even at their earliest stages to detect cases within minutes before 14 days. In this paper, we have used CCBRS techniques for

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the development of Clinical Knowledge Base (CKBS) for the detection of infectious patients and for rapid recovery according to diagnostic medical model. 99.5% accuracy, 0.3% sensitivity, and 0.2% specificities were achieved by the proposed scheme. Research have shown that the proposed model can assist physicians in effectively diagnosing and isolating patients, decreasing infection, and misdiagnosed rates in certain regions of the world.

Keywords

AI · Multi-agent · Case base reasoning system

10.1 Introduction

In December 2019, China first identified a novel coronavirus disease called COVID-19. To date, the viruses have affected 213 countries and territories worldwide and two international transfers. Their pathogenicity and widespread distribution worldwide now make it considered an important concern for world health. The COVID-19 virus has grown internationally (J. T. Wu et al. 2020) since it first appeared in China in late December 2019, as a highly infectious respiratory disease. According to the Official COVID-19 Reports, by 21 April 2020 more than 2,482,598 million people had been affected and 170,484 dead, a total of 652,543 recurrently killed. In view of the explanatory growth of confirmed COVID-19 cases and the death of COVID-19, several new epidemiological model strategies to minimize expansion of COVID-19 have been suggested and implemented by the scientific and medical community. A number of new mathematical and statistical models for critical analysis of ongoing COVID-19 transmission patterns and other similar disease outbreaks were recently created. All the different epidemiological contributions to estimate the dynamics of transmission of the virus are equally important, but most of the existing models are parameter-dependent and rely on several assumptions for efficiency. In addition, since during an outbreak of an epidemic, estimating real data sets which are not readily available for experimental testing of such proposed models is often not easy and reliable.

While many of the proposed artificial intelligence (AI) literary studies in the field appear well designed in terms of estimating verified case results and predicting the speed of COVID-19 (A. R. Tuite and Fisman 2020) spread, the efficiency and accuracy of these models that decrease as a result of their high depth of dependence on many inaccurate variables in decision-making. The above limitations can therefore be believed to lead to inconsistent forecasting results which can often lead to unsatisfactory and unreliable results. This would of course have a negative effect on making plans and policing for public health. The paper offers a promising alternative diagnostic and forecasting framework for overcoming the limitations of epidemiological and AI approaches mentioned above with the goal of obtaining more precise results and avoiding previous limitations by combining the strengths of ontology-based natural language processing with case-based early detection and the rich collection of confirmed COVID-19 case studies supports the adoption of CBR as a real justification for improving the situation.

Case-based reasoning is an artificial intelligence framework (A. Aamodt and Plaza 1994) that has proved successful in medical systems and also takes advantage of case similarities in its knowledge base to find a way to solve a new case and major issue. Case(s) recovery, which is closely linked to the new case, is usually calculated using different computer similitudes, such as the Euclidean distance adopted by various researchers. However, all CBR systems have the task of extracting and officializing functionality. However it is a problem that demands optimal solutions in the light of the sensitivity of medical cases to select the best distance measurement model for compute case similarity. Case-based thinking means to understand and overcome new problems through ancient experience. A reasoner recalls a situation similar to the current one in the case-based reasoning and uses this to address the new problem. Artificial intelligence has a long tradition of case-based reasoning (CBR) and expert systems. Since the late 1970s, CBR has been worded. CBR is a way to solve and learn people and computers problems.

In the problem solving and automation of an agent's learning, case-based reasoning is useful. Due to empirical evidence that reasonings with CBR are more efficient, reasoning has become a popular and widely used way of solving people's problems through the reuse of previous cases. The combination to learning and its strong association with machine learning are a very important feature of case-based reasoning. Ben-Bassat et al. listed a few of CBR features which include: cases with similar symptoms and discoveries resulting from the disease/faults, and "Nearest Neighbor" algorithms are used to detect unknown diagnoses. Compared to RBR, CBR is useful. CBR evades the RBR knowledge bottleneck, builds past solutions, imitates human expert diagnostic experience, avoids past mistakes, interprets rules, adds weak domains models for clarification, facilitates knowledge acquisition and learning, and utilizes the database for resolved issues for learning purposes.

The idea to combine computer training and artificial intelligence techniques with the key challenges in addressing the latest coronavirus or COVID-19 pandemic is introduced in this paper. The main objective of this study is, accordingly, to apply the principle of the CBR technique of intelligent agent (IA) to the question of classifying COVID-19 cases as either positive or negative, since this disease remains in its early phase of development. A CIACCBR model was developed and implemented to extract the present scenario.

10.2 Related Work

Recently the use of artificial intelligence (AI) as a potential tool to combat a number of evolving pandemics, including Ebola hemorrhagic fever in the period 2014–2016, Swine Flu (2002–2003), SARS (2002–2003), Middle East Respiratory Syndrome Coronavirus, and new (2019–ongoing) coronavirus, has been identified. Concerning the latest coronavirus pandemic that begins in 2019–2020, hundreds of attempts have been undertaken and most papers have been published on the key to use artificial intelligence technology to avoid COVID-19 global pandemics. In this section, we selectively discuss the many significant contributions made to the use of AI technologies for combating COVID-19 and the current limitations of these contributions in recent articles. In particular, six sectors have emerged as key solutions for combating coronavirus in Naudé (2019) where artificial intelligence technologies have arisen. These areas include: (1) early warning and alerting, (2) follow-up and prediction, (3) databases, (4) diagnostics and prognosis, (5) cures and treatments, and (6) social control. The most frequent discussions in this section therefore concentrate on investigating the extent to which AI has, in part or in full, been used in the fight against the spread of the pandemic described above. Only articles published in a peer review journal are included in selected analysis discussions discussed in the present section. Preprinted articles are not covered by the current review.

In (Pirouz et al. 2020) the study of identified COVID-19 cases was investigated using a binary classification based on the artificial intelligence and regression analysis. In their research, the authors used the binary classification modeling with the group data management method neural network type to correctly estimate confirmed cases from the COVID-19 influenza pandemic. For their model construction, the study chose the Hubei province in China. The data were chosen for 30 days as the data set for the input and output variables, some important factors such as maximum, minimum and average daily temperature, city density, relative humidity and wind speed. Furthermore, the research results showed that in predicting confirmed cases in a province, the proposed binary cluster model had a higher output potential.

Al-qaness et al. (2020) submitted the use of two metaheuristic optimization techniques to improve the predictive validity of the developed adaptive neurofuzzy inferential method used for estimating and predicting, within the next 10 days, confirmation of novel coronavirus cases based on previously reported documented cases in China. The hybrid metaheuristic adaptive neurofuzzy inference-system was developed and consists of the Adaptive neurofuzzy inflection engine and two protocols, the floral pollination algorithms and the salp-swarm algorithm.

The sensing mechanism of four interlinked digital technologies to combat the broad spread of the new coronavirus was explored in Ting et al. (2020). Technologies' internet technologies, big data processing, artificial intelligence, and the block chains include these innovations. The authors offered some compelling reasons for the already strained, conventional public-health approaches to deal withCOVID-19 in the four above-noted emerging technologies (Ting et al. 2020). A few of the traditional approaches for public health that have been applied and are actively in use worldwide include: (1) control, oversight, identification, and avoidance of COVID-19 and (2) reduction of the effects of COVID-19 on healthcare indirectly.

Vaishya et al. (2020) in their studies have highlighted important roles in combating new disorders, as well as potential forecasts of pandemics, in certain new technologies, such as intelligence artificial, the Internet of Things, big data and machine education. The Author in Vaishya et al. (2020), based their discussion on briefly analyzing, planning, and fighting COVID-19 and any other related pandemics on the use of artificial intelligences platforms as a decisive technology. In their results, the disease COVID-19 spread was discussed in seven significant application areas of the artificial intelligence technology. As defined in Vaishya et al. (2020), the following areas include: Early detection and infection diagnostics, patient surveillance, case prediction and mortality, drug and vaccine production, reducing health workers' workloads, and disease prevention.

Leung and Leung (2020) discussed the way forward for the mitigation of epidemics by crowd-sourcing data. The authors examined various sources of feasible COVID-19 lists. The authors examine sources such as data clearance centers and secondary databases and official sites or social media accounts of the various provincial and municipal health commissions on the continent of China.

In the diagnosis and treatment of a number of health problems, the CBR is an effective approach. Starting with early medical exploration by Koton (1988), Bareiss (1989) in the late 1980s and Gierl et al. (1998) in the late 1990s, CBR research has grown significantly. However, the architecture and implementation of CBR, in particular the adaptation process, still has some associated deficiencies. The findings of a systematic review of CBR applications for the health care sector have been published by Blanco et al. (2013).

In order to improve response time and the accuracy in the retrieval step of case-based reasoning in similar cases, Benamina et al. (2018) proposed the integration of the fluid logic and data mining technique. In this proposed Fuzzy CBR consists of two complementary parts, namely, the Fispro-alimented portion of the Fuzzy Decision Tree Classification (FDT) and the JColibri framework case-based reasoning. The main function of fluctuating logic is to reduce the complexity with which the level of similarity between diabetic and other monitoring programs can be determined.

10.3 COVID-19

The most recently discovered Coronavirus is the infectious disease COVID-19. Before the outbreak of Wuhan, China, in December 2019, this new virus and disease were unknown. The pandemic now affects many countries worldwide. COVID-19 (Blanco et al. 2013).

Coronaviruses are an extensive family of viruses that can cause human or animal diseases. In humans, many coronaviruses are known to cause respiratory infections ranging from common cold to severe conditions such as Middle East Respiratory Syndrome (MERS) and SARS. Coronavirus is the origin of COVID-19 (Q. Li et al. 2020), the latest discovery.

10.4 Symptom of COVID-19

Fever, dry cough and weariness are the most common symptoms of COVID-19. Many signs less common in some patients may include dolor or nose inflammation, cough, conjunctivitis, sore throat, diarrhea, taste or smell loss, or rash in the skin. These patients typically are mild and progressively begin. Others are infected and only have very minor illness. Figure 10.1 of Covid-19 below (Satpathy et al. 2021).

10.5 Artificial Intelligence

Artificial intelligence is an area of computer science that focuses on technologies that can establish actions that people see as intelligent (Leake 1996). The potential to create intelligent inventions has subsequently drawn precedents and now the dream of smart machines has become a reality with nearly 50 years of work into AI coding. Expression, approaches to winning a chess game, how the army applies AI logic to its high-tech equipment and how artificial intelligence will affect our lives in the near future (Haque et al. 2000) and other countless acts that had been inaccessible before. Scientists are working to create systems capable of imitating human thinking; (Lakshmanaprabu et al. 2019) Artificial intelligence, or AI, aims to comprehend intelligent beings (Fig. 10.2).

10.6 Machine Learning

Machine Learning is an artificial intelligence (AI) (Byrski et al. 2015) technology, which provides the ability to learn and develop knowledge automatically without explicit programming. Machine learning focuses on developing software that can access and use data on its own.

10.7 Natural Language Processing

NLP is a branch of the artificial intelligence processing natural language that deals with the study, comprehension and creation of natural languages used by people for communicating with computers using natural human language rather of machine languages in both written and spoken contexts.

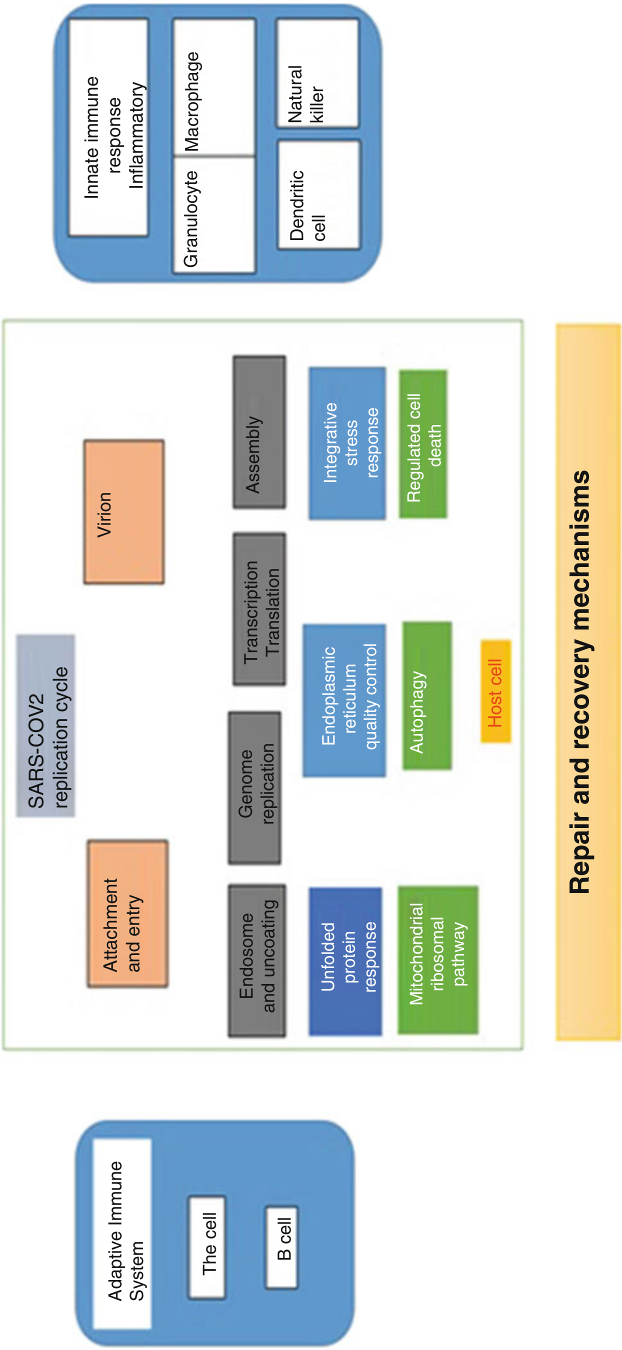

Fig. 10.1 Internal framework of Covid-19

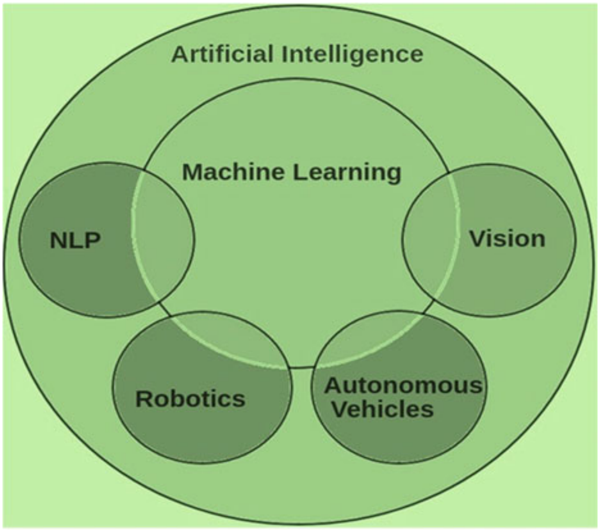

Fig. 10.2 Artificial Intelligence framework

10.8 Robotics

Technologies of Robotics inside. Robotics technology includes all the procedures required for robots and other smart machines to develop, build, and maintain. Robots are smart, autonomous robots used without any direct human interference for pilots or spacecraft management.

10.9 Autonomous Vehicles

Applications operating an autonomous car infotainment system provide knowledge and forecasts from the sensor data fusion systems. These algorithms can also integrate the movement of the driver, speech identification, and language translation with the system of the car.

10.10 Vision

Machine learning and computer vision are two different fields which are strongly connected. Machine learning has advanced machine vision for monitoring and recognition. It provides an efficient way to create, process images and focus objects in a computer vision.

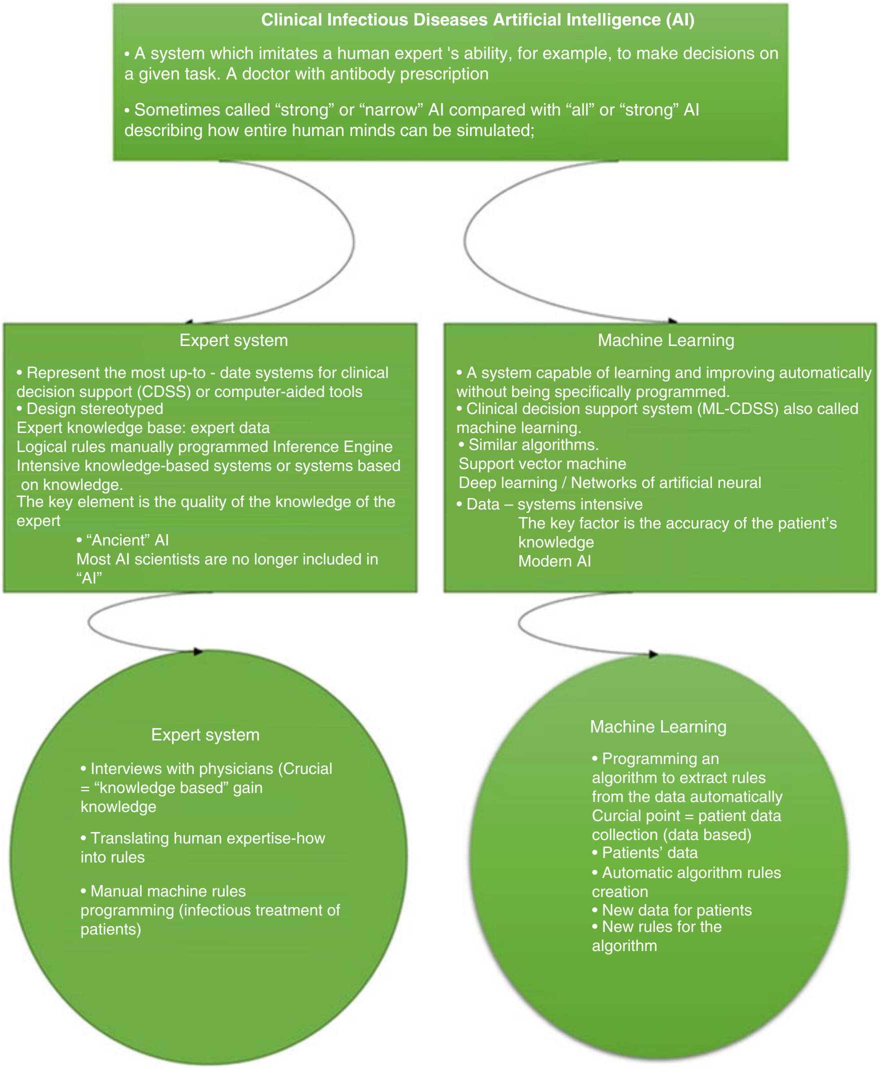

Fig. 10.3 Framework of clinical Artificial Intelligence

10.11 Clinical Artificial Intelligence

The task of obtaining, evaluating, and applying the broader information needed to address complex clinical problems is facing modern medicine used in Covid-19. Medical artificial intelligence technology was linked to the development of AI algorithms designed to help the clinician formulate diagnosis, make treatment choices and forecast outcomes. They are intended to support health workers in their daily tasks, helping them with tasks that depend on data and knowledge manipulation (Fig. 10.3).

10.12 Expert System

The expert system has the knowledge on the clinical field of dangerous virus covid-19 that the human experts in that field usually give and transcribe into principles and laws. The database is not an information base. The knowledge base is built in the context of financial, heuristical or anti-SAR—Cov 2 probabilities. The knowledge is represented as a set of rules in a rules-based expert system where each rule provides a relationship, a suggestion, a directive, a strategy, or a heuristic. Usually the form of the structure is:

IF condition the action. The ELSE clause is in most cases omitted but can only be implemented the ELSE clause is in most cases omitted but can only be implemented if a FALSE answer is found in every instance of the THEN clause. Moreover, a rule can have multiple conditions linked AND for conjunction, OR for disjunction, or a combination of both logical and logical operators.

10.13 Machine Learning

Machine learning algorithms aimed at better understanding viral propagating trends, enhancing diagnosis speed and precision, creating new and efficient therapeutic strategies and identifying the most vulnerable individuals based on human genetic and physiologic qualities. Inspiringly, the use of advanced computer teaching techniques in the taxonomic classification of COVID-19, COVID-19 identification based on CRISPR, and the prediction of severe COVID-19 patients for survival have taken place over a brief period after COVID-19 outbreak.

10.14 Intelligent Agent

An intelligent agent in artificial intelligence is an independent entity which acts, directing its activity toward achievement of objectives and an environment that uses sensors and related actuators to monitor them. Smart agents can also learn or use knowledge in order to achieve their objectives (Kuldeep Singh Kaswan et al., 2011).

10.15 Characteristic Agents

- Take step by step the latest guidelines for problem solving (Jagjit Singh et al., 2020)
- Online and real-time adjustment
- Could analyze yourself for conduct, error, and success.

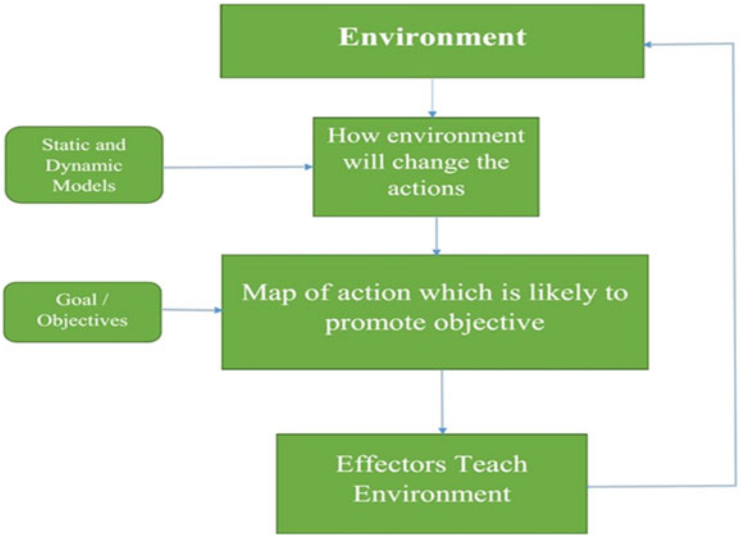

Fig. 10.4 Framework of intelligent agent

- Learning and improving environmental interaction (incarnation)
- Get to know large quantities of data quickly
- Have storage and recovery power dependent on memory
- Have short and long-term memory parameters, age, forgetting, and so on (Fig. 10.4).

10.16 Clinical Intelligent Agent

Clinical intelligent agent searches for the best vaccines and tries to develop potential therapies for patients infected with recovery (Kannan et al., 2020) (Fig. 10.5).

- ***Control Agent***: Control agent manages agent activities as below:
  - **CDR Management Agent:** Call information reported in the control agent are handled
  - **Knowledge Management Agent:** It manages to maintain knowledge of the fight against a major and severe pandemic.
  - **DICOM/Security Management Agent:** The vendor maintains pandemic knowledge and takes precautions about which chainable diseases to protect and to protect them from.
  - **Abstract Data Type agent:** ADT Agent only states what transactions should be carried out, but not how these transactions are carried out. Data are arranged in memory according to situation and which algorithms are used to perform surgery on these serious medical conditions.

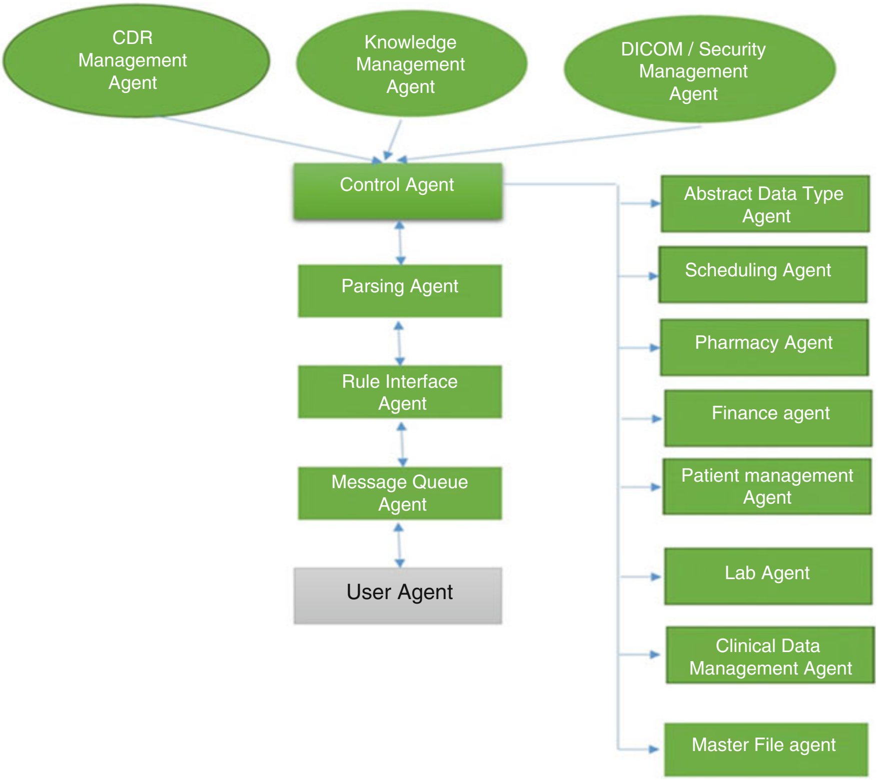

Fig. 10.5 Framework of clinical intelligent agent

- **Scheduling Agent:** This deals with the fluctuating staffing requirements when workers shift to remote locations due to COVID-19.
- **Pharmacy Agent:** Most pharmacists use different medications to improve antibodies in patient bodies and to combat covid-19 in these diseases. This agent is very helpful in these diseases.
- **Finance Agent:** Such agents helped to build knowledge and ensure so many people that they are cared for in the time of need.
- **Patient Management Agent:** This agent maintains a full record of Cov-2 patients.
- **Lab Agent:** This agent is useful and can be used for further cure in patient samples quickly. It's quick to come out.
- **Clinical Data Management Agent:** According to clinical information, certain infectious disease decisions are taken.
- **Master File Agent:** This agent shows just one record within minutes

• ***Parsing Agent***: The UPA (Universal Parsing Agent), processes text documents for further use by other software products, extracts data and stores that information in the XML markup files. This gives users more time to analyze documents automatically.

- ***Rule Interface Agent*****:** This rule-based approach comprises a set of user-programmed rules for information processing in connection with a particular mission.
- ***Message Queue Agent*****:** Request queue agent handles the request one by one
- ***User Agent*****:** This agent is happy to inquire about any problems.

10.17 Multi-Agent System

The system that communicates with various agents in order to resolve problems is multi-agent systems. MAS agents (De Mantaras et al. 2005) know when to communicate with. Complexity and integrated distribution of the multi-agent systems are common features. The allocation of multi-agent systems and its elastic nature lead to higher speed and reusability. At the network for multiple agents,

- Partial data are available for all agents
- Deviation of the controlling system
- The details are reorganized
- Computation is asynchronous

Cooperation between agents is crucial and efficient communication is required to be effective. We require a joint communication language medium. For agent-to-agent collaboration, the language and communication media is critical (Jagjit Singh, 2011).

The following address is MAS:

1. Desire, belief, and intention
2. Cooperation and cooperation
3. Organization of MAS
4. MAS communication
5. Negotiating Director
6. Distribution problem solving
7. Multi-agent learning
8. Scientific Societies
9. Fault and dependency tolerance (Fig. 10.6)

10.18 Java Agent Framework (JADE)

The java-based MAS.JADE is a software development support tool, a middleware for developing and running peer-to-peer applications which is built upon an agent model that operates seamlessly and works wirelessly. FIPA Interface Programmers and the FIPA (Jani and Mostafa 2011) Interaction Protocols Library, such as the Contract Net and the Graphical Interface, are just some of the functions of a distributor platform that is spaced to multiple machines to manage several agents of the very same Remote Management Agent. The Video 3 represents the architecture internally. Have agents with unique names living in containers within this

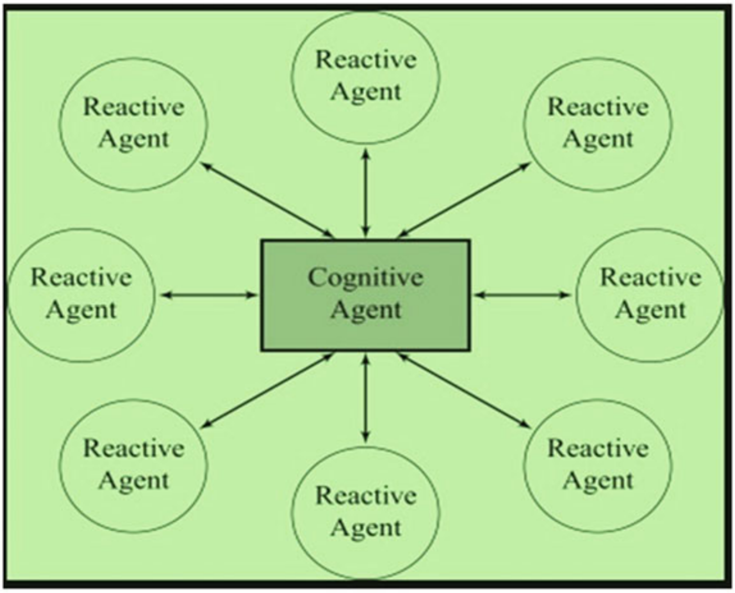

Fig. 10.6 Framework of multi-agent agent

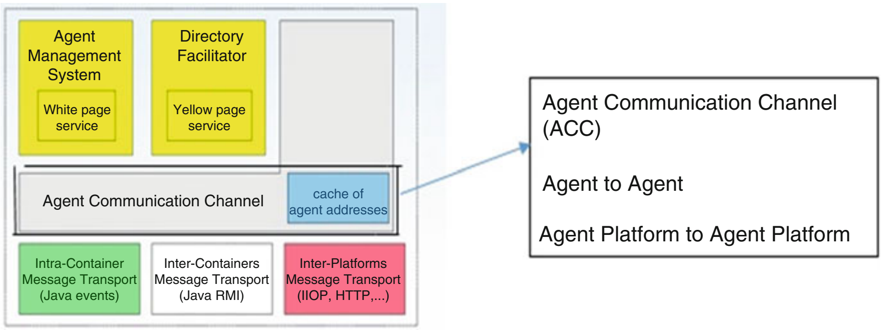

Fig. 10.7 JADE framework

architecture. The container collection is known as platform. It contains a single container known as the main one. The majority of the containers shall be identified in the main container (Fig. 10.7).

10.19 Clinical Multi-Agents

Our research began with the building of a formal model which captured the main characteristics of clinical trials. In contrast, the agents involved can determine the data format of individual bilateral data streams (Fig. 10.8).

These can be summarized as follows:

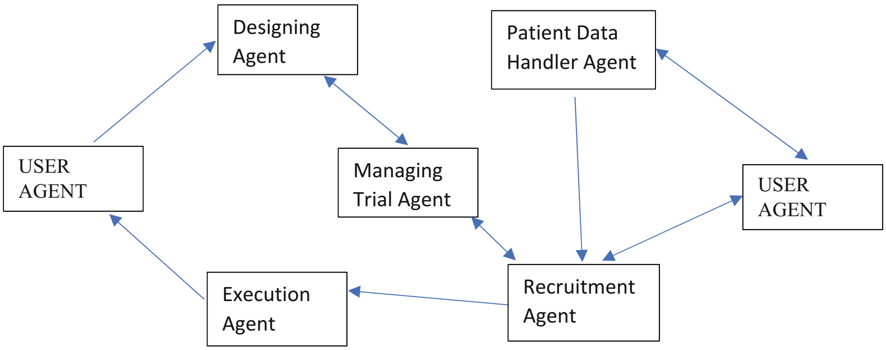

Fig. 10.8 Framework of clinical multi-agent agent

***Trial Description*:** This model includes a description of an experiment, for example, title, overview, financial institution, etc. During the recruitment phase, it allows practitioners to present details of the trial. Therefore, many of the data in this model are free-text, which can be used to produce explanations for different entities (for example, GPs, public websites, and researchers).

***Eligibility Criteria*:** This model represents a formal computable set of criteria for patient eligibility. It defines the characteristics required of any participating patients. The model is SQL-like in nature, allowing complex sets of predicates to be executed over any fields in a patient's medical record. These predicates can be used to both include and exclude a patient from recruitment. Typical predicates would include age, gender, and ailments (there are existing terminology standards for describing ailments). Often, patients with particular existing ailments or treatments would also be excluded. Note that this model does not stipulate when or where the criteria should be executed to compute eligible patients. For example, the criteria could be used in real-time as patient data is entered or, alternatively, in batches every month from a centralized database.

***Recruitment Model*:** In this model the recruitment process information is stored. It stipulates how many patients ideally should be recruited, which clinics should be approval, which GPs should be authorized and how patients, if they have an interest, should be recruited and the priority given to recruiting for each test and to recruiting schedules. This is an important element that allows the agents to understand the finer-grained requirements of the process of recruitment.

10.20 Case Base Reasoning

Some years ago, there was increasing attention to a substitute structure of reasoning and a methodology for assessing computer problems. Case-based reasoning (Ayzenshtadt et al. 2016) addresses new problems through changes to similar problems in solutions that have already been successful. Because the above problems seem to be addressed directly, CBR (A. F. Berman et al. 2018) attracts attention. Name taken into account as:

- The CBR (M. M. Richter and Weber 2016) does not need a particular domain model, so it is a task to collect cases history.
- Implementing is reduced by identifying important characteristics that describe a case that is easier to implement than to create an explicit model.
- Applying database techniques can process large amounts of information.
- CBR systems can learn to make maintenance easier by acquiring new expertise.

10.21 The CBR Cycle

The procedures in CBR can represent a schematic cycle (Jani and Mostafa 2011). The cyclical cycle of the four reasons has been defined as typically CBR;

- RETRIEVE the case(s) most similar;
- REUSE the case(s) to seek to fix the issue;
- REVISE Update if necessary the suggested solution;
- RETAIN Keep as one of today's most recent approaches assessment (Fig. 10.9).

In the case of a single fresh problem, one of the maximum comparable cases is the case. Recycled and successfully tested a remedy suggested by the related instances. The solution will certainly be revamped to satisfy the latest cases that can be maintained without closely matching the case.

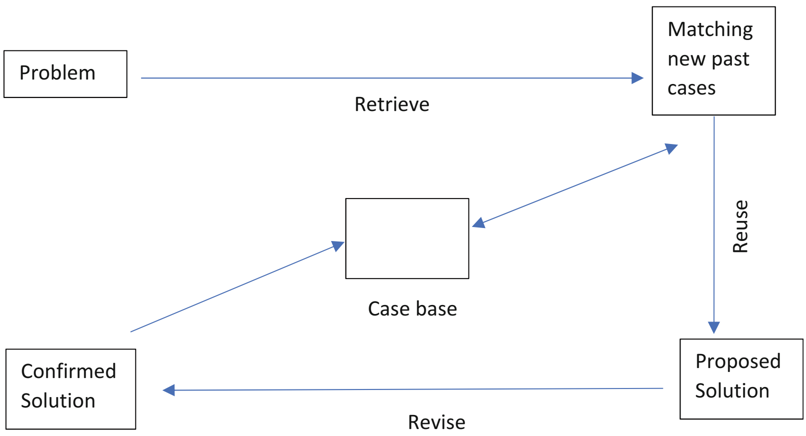

Fig. 10.9 CBR framework

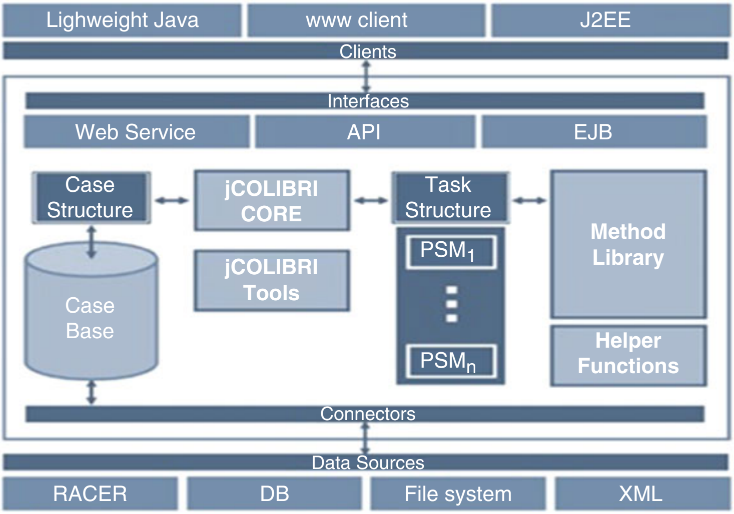

Fig. 10.10 jColibri Framework

10.22 JCOLIBRI

JCOLIBRI is open source software essential for the building of CBR applications. JCOLIBRI (Leake 1996) is a technological evolution in COLIBRI's three-stage architecture with a Java objects and a set of GUI tools for the mounting of CBR reusable components. For system designers, JCOLIBRI is intended. A GUI based setup tool can be used for the development of a CBR application. It is easy to build the app. Around the same time, software procedures must be created and integrated into a highly complex CBR framework or problem-free procedures. Alternatively, this must be introduced (Fig. 10.10).

10.23 Clinical Case Base Reasoning Systems

In the ICE system, the Case Base Reasoning System is capable of exploiting past clinical experiences of leading medical experts in order to gain an experience-oriented interpretation of clinical evidence (see Fig. 10.11). A systematic "diagnostics analysis" is intended to use clinical evidence from the Case Base Reasoning System in which clinicians may quickly refer to a collection of previous similar cases, either to validate their theory or to look for solutions that they have found to have operated in the past. Functionally, an application (for evidence) from a clinician will drive the proposed case base reasoning system.

The case-basis reasoning scheme

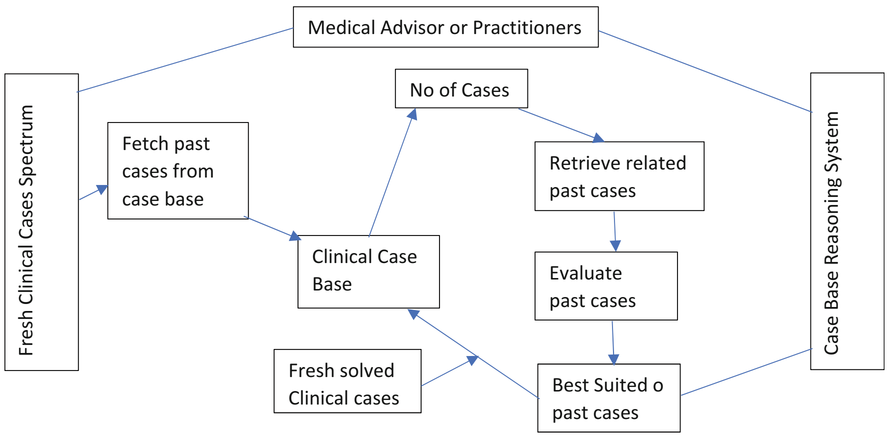

Fig. 10.11 Framework of clinical CBR

1. retrieve from the clinical case library a number of similar cases (which can be closely introspected by the medical practitioner);
2. synthesizing intelligently the solutions for all cases in the past so as to plan for that clinical case a "meta-solution;" or
3. adapt the related past clinical case(s) solution(s) intelligently in order to recommend the most convenient, experimentive clinical evidence for purposes of diagnostic support (Leung and Leung 2020).

10.24 Knowledge Base System

A knowledge base and an inference engine form part of the typical architecture of a knowledge-based system that informs its problem solving method. The knowledge base includes information collected in a specific area, for example, the medical diagnosis. The deduction engine deduces information from the knowledge base. Knowledge-based systems also include an interface where the system is requested and interacted by users (Fig. 10.12).

***Perception*:** Perception is the way of obtaining, translating, selecting, and organizing sensory information in psychology and the cognitive sciences. It includes gathering data from sensory organs to the brain interpretation. Perception is much more than "information."

***Learning*:** The activity or process by studying, practicing, being educated or experiencing something to acquire knowledge or knowledge: the activities of the person who learns: acquiring knowledge or skills.

***Reasoning In Kr*:** The process of thinking logically about something to form a conclusion or a judgment. The mind's ability to think and logically understand things.

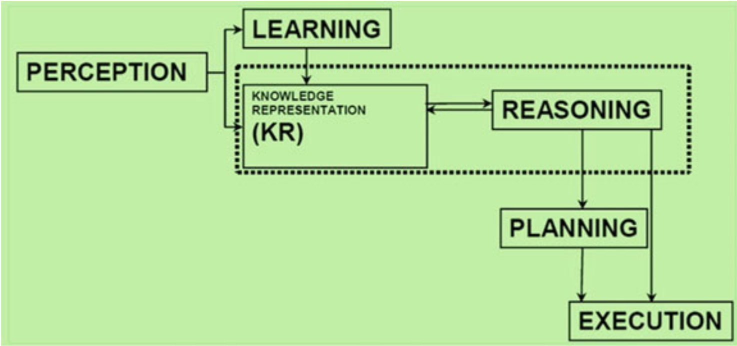

Fig. 10.12 Framework of knowledge base

Planning**:** Artificial Intelligence planning involves the decision-making tasks of robots or computer algorithms to achieve a certain goal. The planning process involves selecting a sequence of actions with great probability that the task will be complete.

10.25 Clinical Knowledge Base System

Intelligently filtered, or presented at an appropriate time, Clinical Decision support (CDS) (Koton 1988) provides healthcare and health care improvement to clinicians, staff, patients and any other persons with knowledge and person-specific information. CDS includes various tools to improve clinical workflow decision-making (Fig. 10.13).

The clinical data set contains functions which are useful for the treatment of calculus. The segmented calculi are supplied with image-extraction algorithms to detect different attributes and calculi-related properties to help them decide. The decisions cover conservative healthcare, Covid-19. The data kit contains useful parameters including the image number of viruses in the image, the calculus scale, and the position of the virus as indicated by the clinician. Calculi are the same diameter as the circle of the calculus, and the real pixel count in that region is the field of the calculus (Pirouz et al. 2020).

Texture is known as a district or block element—pixel's variance in relation to its surrounding pixels defines the texture. Calculi textures can be smooth or gross, obtainable by statistical methods. The data set also shows patient symptoms like fever and/or cough related to difficulty respirating/breathing, chest pain/stress, or speech loss prove laboratory results testing. The data set also includes the symptoms and clinical test results of the patients. There is a knowledge base in the expert's framework which includes procedural knowledge (for example, the knowledge of algorithms). Another part integrating control and inference techniques is an inference engine. The interface between the program and the end user for the consultation process is another aspect. The user-friendly and flexible interface is needed. This

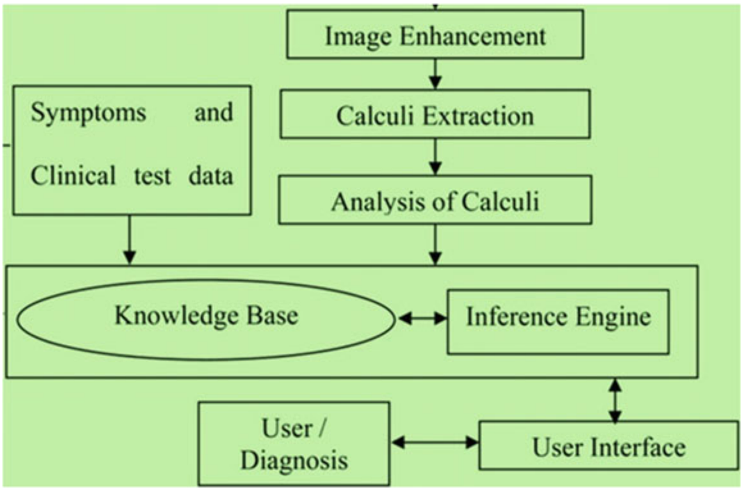

Fig. 10.13 Framework of clinical knowledge base

GUI is intended to provide details and explanations for the acquisition process. This provides the user with the ability to enter data via menus and a clear and precise explanation option.

10.26 Amalgamation OF CAI, CIA, CMAS, CCBR Using in KBSCOVID-19 Model

All clinical models (CAI, CIA, CMAS, CCBR) connect with KBSCovid-19. Its aim is that to know about patients' seriously infected disease (Cov-2). They can recover quickly with the help of best clinical care models. Framework is as given below (Fig. 10.14):

The internal architecture of coronavirus is related to the biological virus. This virus made up of protein very easily enters through nose or eye or mouth to human body and makes chain to infect other. Its complete structure insert into symptoms of clinical test data of knowledge base. Clinical Artificial Intelligence Infectious Diseases add in knowledge base already inherited CAI parts as clinical intelligent agents (CIA) and clinical multi-agents system (CMAS).

Then agents collect quick knowledge about Covid-19 and sends detail about the user's infection. How to recover axioms from infection. Intelligent agents spread their clinical agents' expert in SAR-Cov-2 to examine their behavior, sensing infection, and discover rapid cure for recovery. And also if it is possible to make new case enter in the case base for future use. And case base maintains record of recovered patients.

Clinical Case Base Reasoning system makes case of three stages:

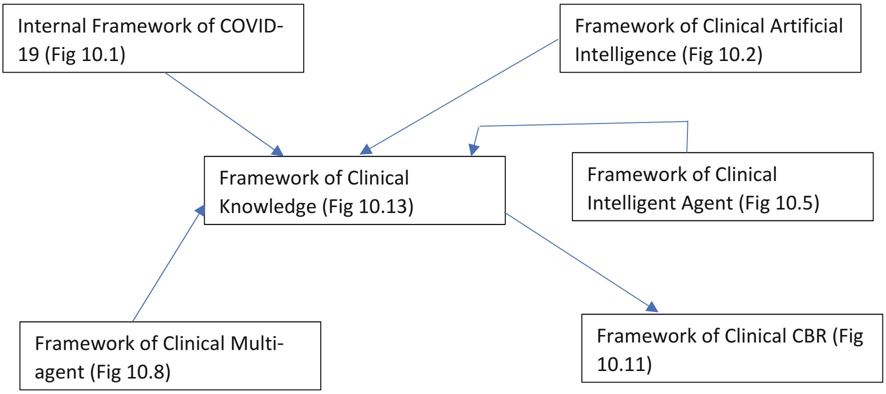

Fig. 10.14 Framework of intelligent clinical group (CAI + IA + MAS + CBR + Covid-19 in KBS)

1. Starting stage of infected patient: intelligent agents handle easily and early recovery
2. Middle stage of infected patient: intelligent agents increase diagnostic and it takes time to recover
3. Third stage of infected patient: intelligent agents use effective cure and try to recover patient's life

In the above model, three user input details are in the model at the same time

1. User insert detail in intelligent agent
2. User insert detail in multi-agent
3. User insert detail in knowledge base

Many research models have to ask query and result at one end but this model have three mode for insert query most of patient easy to solve their disease problem around world because Cov-2 pandemic is very serious problem this disease is hunting numerous people. So, as above model will helpful for fight Cov-2 pandemic.

10.27 Implementation of MASCBR-Based Knowledge Base Patients Recovery from COVID-19 Pandemic

It is a very huge data set (.csv file) and takes data sets sample use for test. People take good nutritious diet to improve their antibodies and fight with virus infection disease (Fig. 10.15).

Every field of data set is sent to agent environment. Every agent learns knowledge about good diet and which patient is taking such diet to quickly recover from the disease (Fig. 10.16).

1	101	A	EAT HEALTHY BREAKFAST	MASK SENTI SD
2	102	B	AVOID SHARING PERSIONAL ITEM	MASK SENTI SD
3	103	C	NO SUGARY ITEM	MASK SENTI SD
4	104	D	GOOD SLEEP	MASK SENTI SD
5	105	E	DRINKING LOT HOT WATER	MASK SENTI SD
6	106	F	NO JUNK FOOD	MASK SENTI SD
7	107	G	QUIT SMOKING	MASK SENTI SD
8	108	H	SERIALS	MASK SENTI SD
9	109	I	EATS FRUITS AND VAGETABLES	MASK SENTI SD
10	110	J	AVOID COOLING SUB	MASK SENTI SD
11	111	K	MINIMIZE STRESS	MASK SENTI SD
12	112	L	MACRO NUTRIENTS	MASK SENTI SD
13	113	M	HERBS AND SUB	MASK SENTI SD
14	114	N	WORKOUTS	MASK SENTI SD

Fig. 10.15 Data sets

Fig. 10.16 Framework of data sets enter in agent environment

Agent environment sends data sets to case base reasoner. CBR manages query when user asks to reasoner for best treatment and case base shows them the best suitable nearest cases (Fig. 10.17).

When user enters in any field of the query box, then query shows him particular diagnosis or nearest diagnosis shown in below Fig. 10.18.

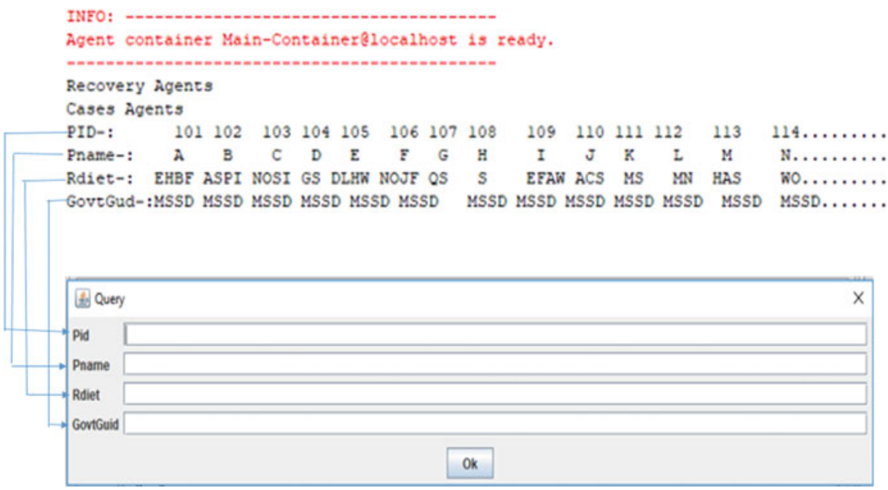

Fig. 10.17 Framework of agents sends data sets in CBR

Fig. 10.18 Framework of patient ask query

10.28 Conclusion

The main aim of this study is to apply a CBR definition to the question of classifying cases of COVID-19 as positive or negative even though the disease is early in this case. A model MASCBRS was designed and implemented to extract the feature of the presented case. The innovation of the work presented here is the extraction of the peer of functionality for all previously declared characteristics. In addition, an interesting performance of the system was supported by the case recovery similarity method applied to the CBR framework proposed by this study. Meanwhile, the representation of knowledge (archives of case in the proposed CBR) was made through the ontological method of the formalization of knowledge in the proposed framework. In addition, new cases have also been formalized with ontologies to ensure that case comparisons are on a homogenous basis. The results show that we carried out state-of-the-art CBR trips with similar approaches to those found in this study in our proposed system.

10.29 Future Work

We intend for our performance on different similitude/distance measurement metrics of our recovery algorithm. This enables potential research to easily choose or even combine similarity metrics using ontology and the CBR paradigm. We also want to use machine learning methods which allow application classifying algorithms such as the SVM to hybridize the method proposed.

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Part III

Machine Learning Solicitation for COVID 19

Epidemic Analysis of COVID-19 Using Machine Learning Techniques

11

Rashmi Agrawal and Neha Gupta

Abstract

Corona virus disease (COVID-19) has impacted the entire world and researchers across the globe are working day and night to identify and predict the patterns related to it. Hundreds of clinical trials are underway to generate the possible cure of the disease. Devastating and uncontrolled worldwide spread of COVID-19 triggered unprecedented global lock-downs and massive burden on healthcare systems. WHO World Health Organization has recommended immediate research study of the existing data to understand the care and measures required for COVID-19. Machine Learning (ML) and Artificial Intelligence (AI) can play a key role in identifying and predicting the COVID-19 patterns. ML approaches have been used in the past as well for the formulation of pandemics e.g., Zika, Ebola, norovirus, cholera, H1N1 influenza. Machine learning analysis of COVID-19 patients can help the identification and prediction of people who are susceptible to COVID-19 infection and who are resistant to it. In the present chapter, we had analyzed and listed the use of various AI with ML models to predict the pattern of the disease based on various parameters. We had also analyzed two real time COVID-19 datasets based on geographic distribution of countries across the globe to understand the outbreak of corona virus.

Keywords

COVID-19 · ML · AI · Pattern identification · Clustering · Classification

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11.1 Introduction

Corona virus disease (COVID-19) is the new form of viral disease that is detected in human beings in 2019. Because it has never before been reported earlier that is why it is known as novel Corona Virus. The virus COVID-19 spreads primarily through goutlets of salivate or from nasal release during the coughing or sneezing by an infected person. No particular vaccines or therapies are currently available for COVID-19. However, several clinical trials are under ways that are testing alternative therapies to develop the medicine or the vaccine for the disease.

On 12 January 2020, the World Health Organization (WHO) confirmed the presence of Corona Virus in a cluster of people in Wuhan that was the cause of a respiratory illness in those bunches of people. Millions of people across the globe are already infected by this disease that has resulted in a global pandemic (Huang et al. 2020). Many countries have declared this pandemic as global emergency and have also quarantined thousands of people. Most of the countries have declared nationwide lockdown to reduce the spread of the virus.

The fatality rate of COVID-19 was much lower than SARS2003 but transmission from one person to another was significantly higher leading to higher number of infected patients. Thousands of research teams across the globe are integrating their data collection activities and working hard to get the possible solutions. Due to its tremendous propagation capacity and possible damage, the new Corona Virus has posed a major threat to human health and safety around the world. Many researchers are studying COVID-19's transmission law, including the pre-emptive measures, and are generating many meaningful outcomes based on their studies (Mizumoto and Chowell 2020; Shao and Wu 2020; Riou and Althaus 2020).

This present chapter aims to study the effect of various features on the spreading of Corona Virus COVID-19 across the globe on actual gathered data and available reports. The chapter will discuss the use of various machine learning approaches that can be used to build the forecasting models.

Section 11.1 of the chapter is introductory in nature having emphasis on the basics and background of coronavirus. Section 11.2 will discuss various AI and machine learning approaches to be used to predict the patterns of COVID-19 based on associated parameters. In last section, the correlation between the variables has been discussed.

11.2 Related Work

Artificial intelligence (AI) detects trends from big data, and can play an important role in detecting and analyzing the patterns of COVID-19. Advances in AI applications such as speech recognition, natural language processing, machine learning, data analytics, deep learning and others such as chat-bots and facial recognition were not only used for diagnosis but also for contact tracking and for the development of vaccines (Zumla et al. 2020). AI has unquestionably flourished in monitoring the COVID-19 pandemic and succeeded mitigate its worst impacts.

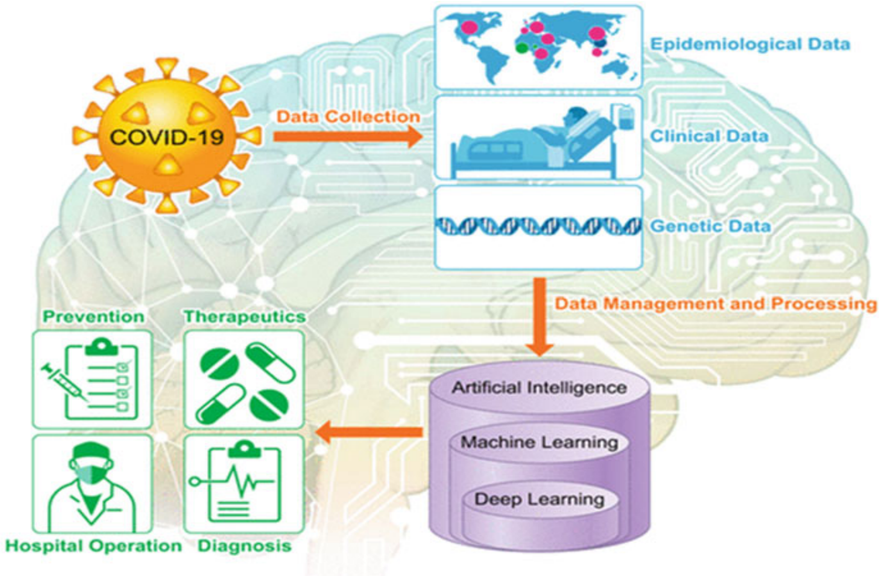

Fig. 11.1 Application of AI and ML in COVID-19

COVID-19 is a global pandemic and will expose some of the key shortcoming of AI. Machine learning works by recognizing patterns in historical training data. Under current situation, gathering the new training data is tedious task. However, AI has the ability not only to surpass humans by speed but also by identifying trends in the training data that human have ignored (Mizumoto and Chowell 2020).

Study of inherited variants from asymptomatic, moderate or extreme COVID-19 patients can be carried out to identify and determine the people based on their resistance of the infection, while the model of machine learning model can also identify these priority genetic variants as important functional and mechanistic features in their decision-making process (Fig. 11.1).

ML approaches have been used in the past as well for the formulation of pandemics e.g., Ebola, cholera, pig fever, Zika, norovirus, H1N1 influenza, dengue fever, but in the literature there is a divergence from the COVID-19 peer review articles. Table 11.1 demonstrates impressive ML methods used in the prediction of outbreaks. The key approaches for MLs are: genetic programming, random forests, neural networks, Bayesian networks, Naïve Bays, and regression tree (CART). ML is a standards tool in natural disasters modeling and weather predictions but it is still in early stages to be used in the modeling of outbreaks.

Table 11.1 ML methods used in the prediction of outbreaks

S. No	Disease	Machine learning approach used outbreak prediction
1	Swine fever (Anno et al. 2019)	Random Forest
2	Dengue fever (Liang et al. 2019)	Neural Network
3	Influenza (Tapak et al. 2019)	Random Forest
4	Dengue/Aedes (Raja et al. 2019)	Bayesian Network
5	Dengue (Iqbal and Islam 2019)	LogitBoost
6	H1N1 flu (Koike and Morimoto 2018)	Neural Network
7	Oyster norovirus (Chenar and Deng 2018a)	Neural Network
8	Oyster norovirus (Chenar and Deng 2018b)	Genetic Programming
9	Dengue (Agarwal et al. 2018)	Adopted Multi-Regression and Naïve Bayes
10	Dengue	Classification and Regression Tree (CART)

11.3 Pattern Identification for COVID-19

Seeing the current scenario, it is very important to identify the patterns in patient infection. These patterns can be identified on the basis of below mentioned parameters:

1. Patient gender
2. Patient age
3. Pre-existing conditions of a patient
4. Demographic profile of a patient
5. Nationality of patient
6. Response to a drug
7. Death rate and its relation with age and gender
8. Socioeconomic status of a patient
9. Quarantine measures

We have tried to list some of the general parameters. Advanced parameters can also be taken into consideration such as:

10. Virus–host–protein interaction
11. Protein folding
12. Drug combination and testing
13. Virus seasonality

Most of the governments are collecting the clinical data to identify and understand the pattern of the virus. For example: As published by Indian website (Covid19india.org), from a sample of 5207 patients across the country, 66% of the infected patients are male while only 33% are female which largely shows the inclination of males to get infection easily (Young et al. 2020).

Similarly, the data is analyzed to check the effectiveness of quarantine measures. A MIT team has developed a machine learning model using Corona Virus data and a neural network to assess the efficiency of quarantine steps and to predict the progression of the disease (Guan et al. 2020).

11.4 Experiment Analysis

In this section, we have analyzed the data related to Covid-19 outbreak using two different data sets and then established the correlation on various features of the dataset. The implementation has been done using python. The first dataset contains data related to COVID outbreak of the countries across the world and second dataset contains data of US only. Detailed discussion on the same is shown below:

11.4.1 Dataset 1: Based on Geographic Distribution (https://www.ecdc.europa.eu/en/publications-data/download-todays-data-geographic-distribution-covid-19-cases-worldwide)

We downloaded the dataset on April 23, 2020 based on the geographic distribution of COVID-19 cases worldwide. The following snapshot in Table 11.2 shows the first few lines of the dataset. We can see that it contains the features like data, day, month, no of case per day, no of deaths per day, country and its territory information.

We applied tail function to extract the few last lines of data. Table 11.3 shows the snapshot containing last lines of the dataset.

From these above two figures, it can be concluded that in the dataset, data of all countries are arranged as per the name of the country. It can also be identified that there are 12,595 instances in the dataset. The same can be verified by executing the command df.count(), which provides the details of instances available in each column as shown below in Fig. 11.2.

11.4.1.1 Description of the Dataset

Statistical analysis of any dataset plays a major role in research which is used to evaluate the credibility and usefulness of the information. This helps in better decision-making. Figure 11.3 presents the statistical summary of the dataset where we have find out the count of cases, mean, standard deviation, minimum and maximum values along with the quartiles of the data. From this data we find out the maximum cases as 37,289 which is also verified using the command df.cases.max().

Table 11.2 Snapshot of data showing first few lines of data

S. No.	Date	Cases	Deaths	Countries and territories	geOld	Country territory code	popData2018	ContinentEXP
0	23-04-2020	84	4	Afghanistan	AF	AFG	37172386.0	Asia
1	22-04-2020	61	1	Afghanistan	AF	AFG	37172386.0	Asia
2	21-04-2020	35	2	Afghanistan	AF	AFG	37172386.0	Asia
3	20-04-2020	88	3	Afghanistan	AF	AFG	37172386.0	Asia
4	19-04-2020	63	0	Afghanistan	AF	AFG	37172386.0	Asia

Table 11.3 Snapshot of data showing first few lines of data

S. No.	Date	Cases	Deaths	Countries and territories	geOld	Country territory code	popData2018	ContinentEXP
12591	25-03-2020	0	0	Zimbabwe	ZW	ZWE	14439018.0	Africa
12592	24-03-2020	0	1	Zimbabwe	ZW	ZWE	14439018.0	Africa
12593	23-03-2020	0	0	Zimbabwe	ZW	ZWE	14439018.0	Africa
12594	22-03-2020	1	0	Zimbabwe	ZW	ZWE	14439018.0	Africa
12595	21-03-2020	1	0	Zimbabwe	ZW	ZWE	14439018.0	Africa

https://www.ecdc.europa.eu/en/novel-coronavirus-china/sources-updated	12596
day	12596
month	12596
year	12596
cases	12596
deaths	12596
countriesAndTerritories	12596
geoId	12556
countryterritoryCode	12462
popData2018	12493
continentExp	12596
dtype: int64	

Fig. 11.2 Instances in Dataset 1

	day	month	year	cases	deaths	popData2018
count	12596.000000	12596.000000	12596.000000	12596.000000	12596.000000	1.249300e+04
mean	15.653938	2.935773	2019.994681	205.486662	14.513179	5.747734e+07
std	8.471115	1.269893	0.072741	1479.377532	115.632723	1.882847e+08
min	1.000000	1.000000	2019.000000	-9.000000	0.000000	1.000000e+03
25%	9.000000	2.000000	2020.000000	0.000000	0.000000	2.866376e+06
50%	16.000000	3.000000	2020.000000	1.000000	0.000000	1.018318e+07
75%	22.000000	4.000000	2020.000000	24.000000	0.000000	3.797855e+07
max	31.000000	12.000000	2020.000000	37289.000000	4928.000000	1.392730e+09

Fig. 11.3 Statistical summary of Dataset 1

11.4.1.2 Correlation Between the Variables

The below Table 11.4 displays the correlation of number of corona virus infected cases and number of deaths with respect to number pf days, months, and year.

11.4.1.3 Generating Heat Map of the Correlation

Heat map of correlation is generated to show a 2D correlation matrix (table) which is based on the two discrete dimensions or event types. Here the heat map is generated to show the correlation between number of cases w.r.t days, months, and year as shown in Fig. 11.4.

```
df2 = df[df['cases']>=100]
df2.count()
```

It gives the value as 1751 means that there are 1751 instances available on which the case count is more than 10. By performing the filter

```
df2[df2['countriesAndTerritories']=='India']
```

Table 11.4 Correlation in Dataset 1

	Day	Month	Year	Cases	Deaths	popData2018
Day	1.00	−0.05	−0.13	−0.005	−0.01	−0.01
Month	−0.05	1.00	−0.52	0.07	0.08	−0.08
Year	−0.13	−0.52	1.00	0.01	0.01	−0.01
Cases	−0.005	0.07	0.01	1.00	0.83	0.10
Deaths	−0.01	0.083	0.01	0.83	1.00	0.07
popData2018	−0.01	−0.08	−0.01	0.10	0.07	1.00

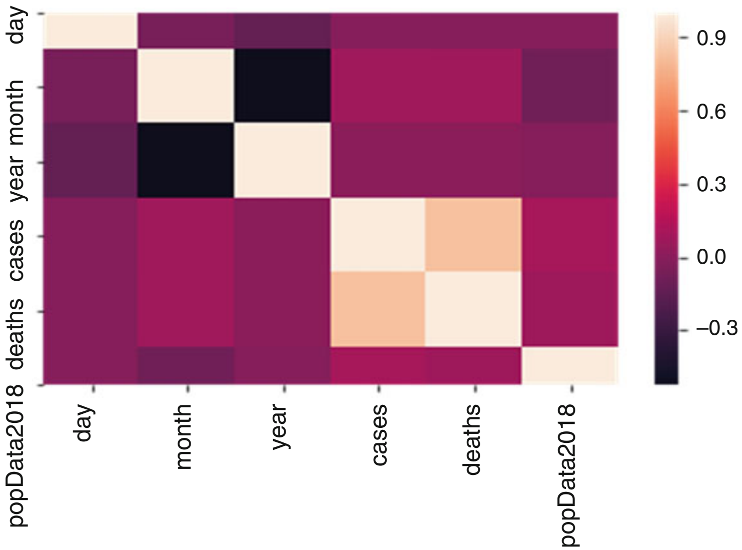

Fig. 11.4 Heat map Dataset 1

We find that there are 27 days on which the number of Covid cases have been reported more than 100.

Figure 11.5 represents growth rate in cases in India (day wise) where the *X* axis represents the days and *Y* axis represents the count of cases each day. The graph shows the COVID cases occurred in 50 days where the no of cases per day was very limited in initial days but grow logarithmally later on.

Figure 11.6 represents death rate in cases in India (day wise) where the *X* axis represents the days and *Y* axis represents the count of deaths each day. The graph shows the death due to COVID cases occurred in 50 days where the no of deaths per day was very limited in initial days but grow linearly later on.

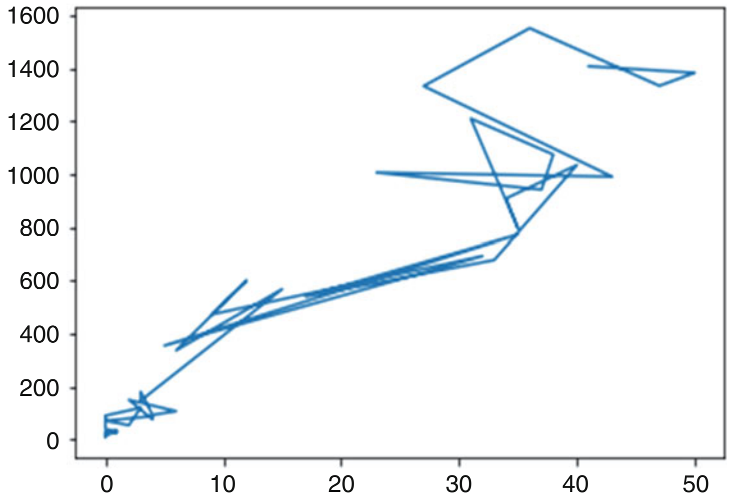

Fig. 11.5 Growth rate in cases in India (day wise)

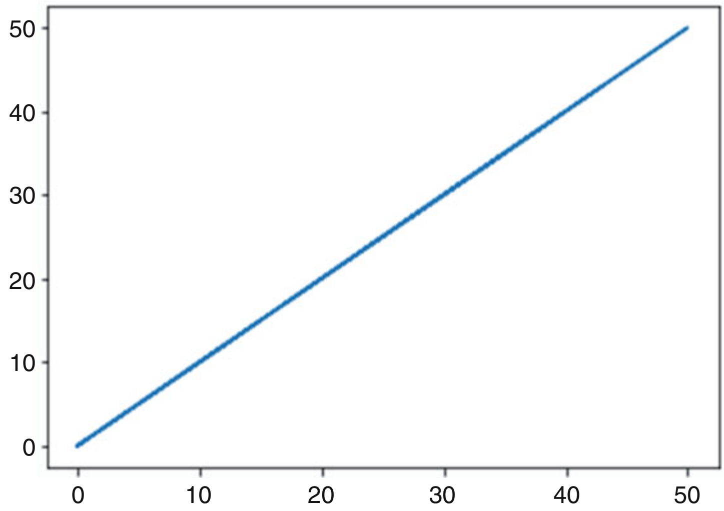

Fig. 11.6 Graph representing death rate in India (day wise)

11.4.2 Dataset 2 (https://raw.githubusercontent.com/nytimes/covid-19-data/master/us-counties.csv)

Data Downloaded on April 25, 2020 based on the geographic distribution of COVID-19 cases for US Countries.

Table 11.5 Attributes of Dataset 2

S. No.	Date	Country	State	Fips	Cases	Deaths
0	2020-01-21	Snohomish	Washington	53061.0	1	0
1	2020-01-22	Snohomish	Washington	53061.0	1	0
2	2020-01-23	Snohomish	Washington	53061.0	1	0
3	2020-01-24	Cook	Illinois	17031.0	1	0
4	2020-01-24	Snohomish	Washington	53061.0	1	0

Second data set is downloaded for COVID 19 affected US countries, which is based on the cumulative data related to coronavirus cases and deaths. This data is updated on daily basis. State and county files contain FIPS codes, a standard geographic identifier, to make it easier for an analyst to combine this data with other data sets like a map file or population data.

The above dataset is the outcome of loads of journalists working transversely several time zones to monitor news conferences, analyze data releases and seek clarification from public officials on how they categorize cases.

Dataset Info

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 84143 entries,
0 to 84142
Data columns (total 6 columns):
date 84143 non-null object
county 84143 non-null object
state 84143 non-null object
fips 83099 non-null float64
cases 84143 non-null int64
deaths 84143 non-null int64
dtypes: float64(1), int64(2), object(3)
memory usage: 3.9+ MB
```

11.4.2.1 Snapshot of the dataset

Table 11.5 below epitomize the snapshot of our second dataset in which we can see various features of the dataset.

Using the python we plotted one bar plot of US countries COVID 19 Data based on deaths and fips (Federal Information Processing Standard—a standard geographic identifier) features which is shown below in Fig. 11.7.

The next figure corresponds to Count Plot which has been plotted State Wise based on the COVID-19 data set of US (Fig. 11.8).

As we have many instances in this dataset, hence it is difficult to understand the whole picture at once. To simplify this, we created one plot for only first 100 rows (Fig. 11.9).

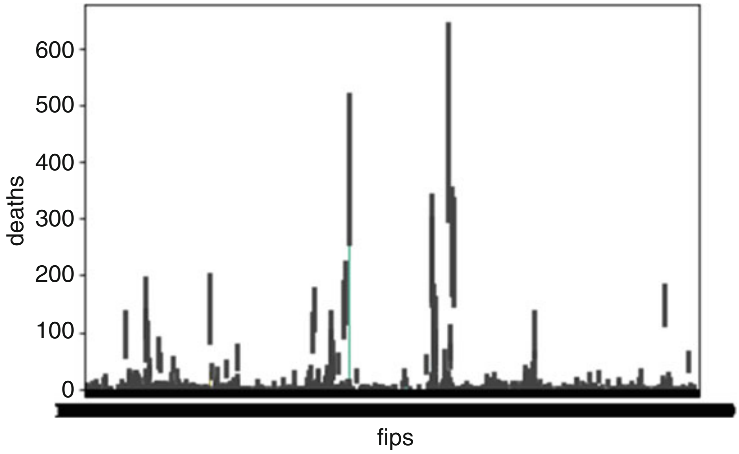

Fig. 11.7 Barplot of US countries COVID-19 Data based on deaths and fips

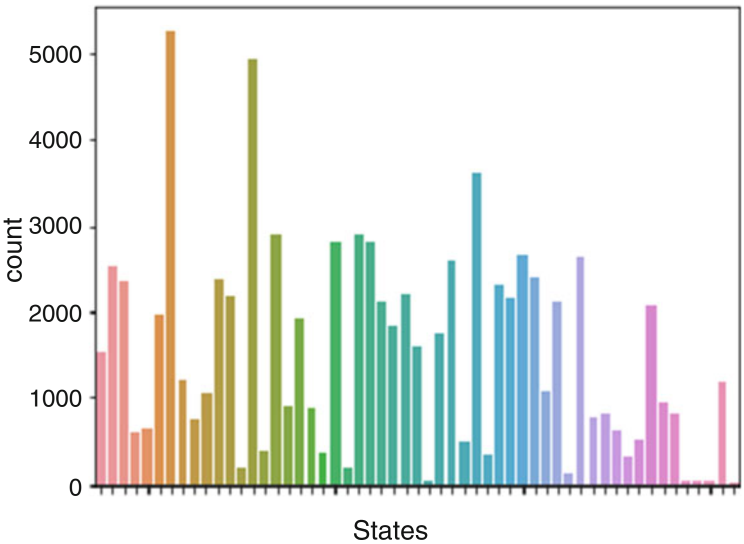

Fig. 11.8 Count plot-state wise

11.4.2.2 Generating Pair Plot

Pair plot is used to understand the best possible set of features to comprehend a relationship between two variables or to form the most separated groups. Pair plots are a great method to identify trends for follow-up analysis and can be easily implemented in python. Pairplots are created using the seaborn library and calling pair plot function. Figure 11.10 exhibits the pair plot of the dataset 2.

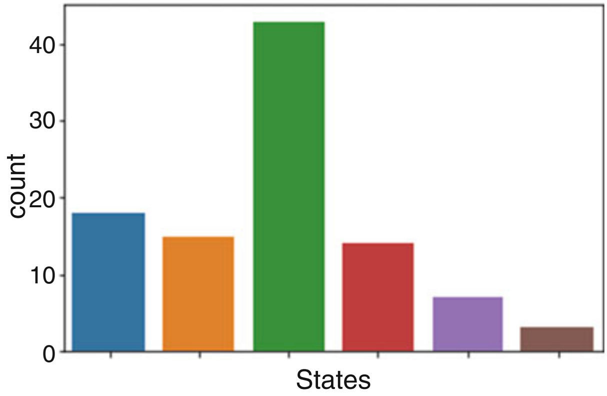

Fig. 11.9 Count plot-state wise (Only first 100 rows)

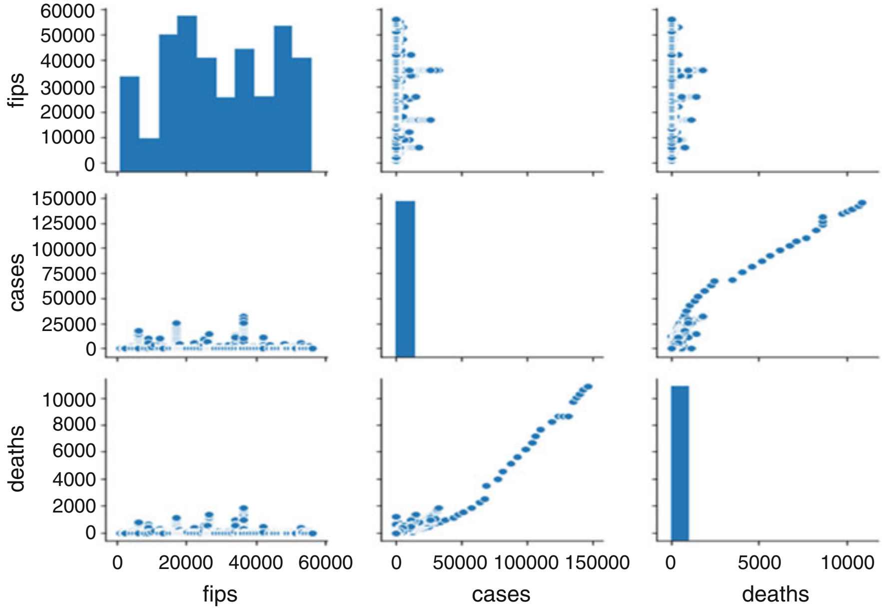

Fig. 11.10 Pair plot

Next, we identified correlation in the features of the dataset. Table 11.6 represents the correlational table and Fig. 11.11 appear as heat map of the correlation generated for this dataset.

The heat map is generated to show the correlation between number of cases w.r.t days, months and year in coordination with Federal Information Processing Standard (FIPS).

Table 11.6 Correlational values in features of Dataset 2

	Fips	Cases	Deaths
Fips	1.000000	0.010272	0.013734
Cases	−0.010272	1.000000	0.959837
Deaths	0.013734	0.959837	1.000000

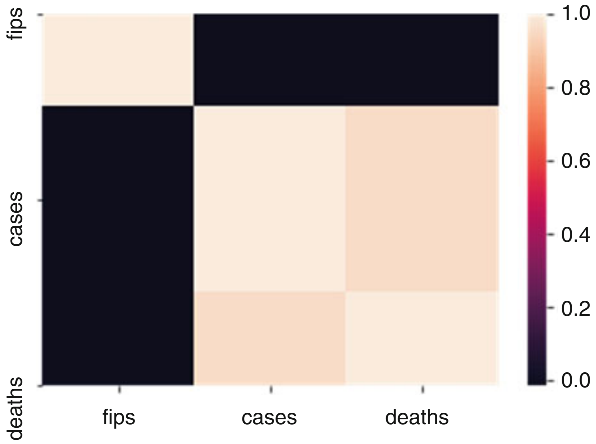

Fig. 11.11 Heat map of the correlation

11.5 Pattern Prediction of Covid-19 Using Machine Learning Approaches

In this section, we present various AI and machine learning approaches that can be used to predict and analyze the patterns related to COVID-19. Some of these approaches which have been used by researchers are (Wang et al. 2020):

1. Time series analysis to analyze the effect of quarantine measures
2. Classification algorithms can be implemented to monitor the number of active cases
3. To monitor the geographic distribution of cases, clustering algorithms can be implemented
4. Linear and non linear patterns of the virus can be analyzed using time series analysis
5. Logical regression can be used to measure the death rate
6. Virus seasonality can also be monitored using time series analysis and linear regression.
7. Structured data classification and Classification algorithms can be used to identify the number of cases treated at home
8. Binary classification algorithms can be used to check the availability of therapy (treatment using a particular drug) based on severity of infection

Table 11.7 Effectiveness of machine learning techniques in predicting parameters of COVID-19

S. No	Machine learning technique	Parameter to be predicted
1	Time series analysis	Effect of quarantine measures
		Linear and non linear patterns of the virus
		Virus seasonality
		Death rate
		Virus–host–protein interaction
		Bouncing of economy
2	Classification algorithms	To monitor the number of active cases
		Number of cases treated at home
		Relationship of death with age and gender
		Pre-existing conditions of a patient
		Demographic profile of a patient
		Nationality of patient
		Areas with community transmissions
3	Clustering algorithms	To monitor the geographic distribution of cases
		Socioeconomic status of a patient
		Areas with community clusters
4	Logical regression	To measure the death rate
		Disease prevention steps
5	Linear regression	Virus seasonality
6	Binary classification algorithm	Treatment using a particular drug
		Virus–host–protein interaction
7	Decision trees	Risk mitigation
8	Correlation	Effect of regular sanitization of places

9. Death rate and its relation to age and gender can be predicted using classification and time series analysis

Table 11.7 shows various AI and machine learning techniques and their effectiveness in predicting parameters of COVID-19.

11.6 Conclusions

The worldwide pandemic of Corona Virus 2 (SARS-CoVID-19) respiratory syndrome has become many nations' primary national security issue. Providing insights into the spread and effects of the infection is important in creating accurate prediction models for the outbreak. The high levels of uncertainty and lack of critical data have shown low degree of accuracy in the long-term forecasting of traditional epidemiological models.

The COVID-19 outbreak has taken the world completely unaware, exposing the vulnerability of public health systems in coping with infectious disease pandemics. While there are many apocalyptic predictions about COVID-19 is going around the world but it's a wakeup call for each one of us, individually or as a society. The time has come to change, to find new ways, to get more insight into research so that the world as whole can collectively come out from this outbreak. In fact, almost all countries are fighting toward finding means against this virus. Machine learning techniques may prove as a boon in this difficult situation.

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Machine Learning Application in COVID-19 Drug Development

12

Ranjan Ganguli

Abstract

An old virus named SARS-CoV-2, caused a disease named COVID-19 which infected a nearly quarter a billion as confirmed positive cases as of September 3, 2020 and made a tremendous impact in almost every aspects of human life and many parts of world economic region has come to a standstill from the last few months. In this regards, the world genius minds come together along with the latest technologies to develop a preventive or curative drug to save the human civilization. In this chapter, we will start with brief discussion on drug discovery with general expenditure overview and extends with pipeline techniques for automated drug development. Also, some recent steps are taken by pharma-based companies to deal with COVID-19 situation. We will also discuss machine learning approaches with repositioning in AI and deep learning in drug development process. At the later part, we will discuss quantum computing involvement for speeding up drug development process. Finally, we will try to highlight the international cooperation of AI potential in fighting COVID-19 and future pandemics.

Keywords

Drug · COVID-19 · Development · Machine learning · Artificial Intelligence

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12.1 Introduction

We know that developing any new drug requires bulk processing of biotic data and is a harder task to find a model that explores data and to understand the full mechanism of any disease. Machine learning approaches along with all kinds recent advancement in artificial intelligence along with various models of computational and systems biology, continuously accelerating and enhancing to cope up with disease identification method and finding a solution. Many of us agree that drug development starts with learn of biological target (like protein, genes, enzyme, etc.) that appears in a biological process with identification of dysfunction disease like Alzheimer's in patients and leads to drug discovery first and creates steps for development.

12.2 Drug Discovery Process: An Overview

Normally, discovering a new drug goes through addressing following points:

- A kind of new context or insight in understanding disease process that helps to design the product in order to stop or reverse the spreading of disease.
- Several test on drug molecular compounds to find the benefits against large number of cases or diseases.
- Following existing treatments that shows abrupt changes.
- Any sophisticated technologies to target a particular site within the body for a new specific product or to manipulate any genetic information.

So, discovering or finding a new drug during any pandemic situation that can cure a disease is a time consuming and costly process and is like searching for a needle in a haystack. Patient's safety along with drug effectiveness works side by side to ensure the sustainability of overall development process and creates a long procedure. Hundreds of literature are being published each day in order to address the speedy drug development process especially in this COVID-19 situation. Big pharma-based companies with some strategic partners are trying hard to reduce existing time and cost in drug development process.

12.2.1 Drug Procurement: Time, Cost, and Risk

Discovery and then development are two key important things in proceeding of any new drug process. Once the drug discovery is done first, drug development is the next step. Drug discovery is actually identifying a new drug that able to handle the disease Based on whether developing a small compound (known as New Molecular Entity-NME) or a protein, gene therapy, an antibody or other kinds of biological medicine (collectively called New Biological Entity-NBE), roughly, more than one decade (from target identification to marketing) or 1/3rd duration of any professional

Drug Development Process: Time consuming, expensive and Risky

	Target to Hit	Hit to Lead	Lead Optim	Non-Clinical	Phase 1	Phase 2	Phase 3	Sub to Launch
# per Launch	24.3	19.4	14.6	12.4	8.6	4.6	1.6	1.1
P(TS)	80%	75%	85%	69%	54%	34%	70%	91%
Cycle time (yrs)	1.0	1.5	2.0	1.0	1.5	2.5	2.5	1.5
Cost/launch ($mil)	$94	$166	$414	$150	$273	$319	$314	$48
P(TS)AD[1]					28%	8%	1.8%	100%

Costs are capitalized based on 11% cost of capital and in 2010 dollars.

Fig. 12.1 Several stages with time and cost estimation in discovery and development process

career with an investment of more than ~$1 billion required for a new drug to put into the commercial market with various approval process. Figure 12.1 shows the stages and average time required to develop a new medicine along with estimated cost in each stage (DiMasi et al. 2016; Paul et al. 2010a) along with clinical transition probabilities or "probability of technical success" calculated (Cummings et al. 2014) with reviewed of all 244 unique compounds studied in one decade (2002–2012) for clinical trials of Alzheimer's Disease (AD); as no separate drug development available and showed lesser advancement of AD drugs as compared to other developing drugs in therapeutic areas. It also depicts numbers of molecules required to generate a new medicine (whose therapy and cure currently does not exist) at each stage of the development process.

Thus, thousands of potential compounds may appear as a part of next stage in development process but after early testing, only a small fraction of compounds look promising and requires further study. Historically drugs were found traditionally by identifying any active constituents in a medicine or sometimes by chance through trial and error method that can cope up with the diseases.

12.3 Drug Development: Current Context

Generally, the drug development is a pipeline process of various stages or phases (Fig. 12.2) starting from Phase 0 to Phase IV where each phase contributes something for the next phase. Phase 0 contributes in fundamental research at the primary level with clinical trials and little span on side effects and dynamic comparison (Phase I); Cure or Drug proceedings calculation (Phase II); molecular division

(Phase III) with post drug marketing and monitoring for long term side effects (Phase IV; optional) and cure or drug accumulation with several therapies.

12.3.1 Pipeline Techniques in Drug Development

The pipeline shows the timeline from minimum 5 dedicated years required to complete (Eliopoulos et al. 2008) and leveraged up to maximum of 15 years (Xue et al. 2018). Preclinical to clinical test (Phase 0 to Phase III) covers less time to set up which includes study design, patient's selection, analyzing data and results and so under wet-lab (a laboratory that handles various kinds of wet or hazards) experiments. The average clinical development time consumes 6.5 years (from Phase I) that showed up for the drug approved 2005–2006 and increased up to 9.1 years (2008–2012) for drug candidates (Schuhmacher et al. 2016). Also, in a flip side, there is rate of possibility of failure (in the pipeline) during activities performed entirely in the drug development process and normally occurs in clinical trials and is always a serious concern at the overall process. In between one decade of 1998–2008, clinical trials has made a tremendous impact with a generated rate of failure as 54%, especially in Phase II and III (Hwang et al. 2016) in the pipeline process and was quite substantial and the reason pointed as failing selection of suitable cure candidate (57%) and obeyed safety issues (as 17% approx); and generates serious side effects or increased death numbers. So, advanced death risk or any sort of side consequences had become a serious major issue in failure of Phase II and Phase III that was happened in 2012 and 2019 (Lowe 2019). Actually, in Phase II that addressed drug performance assessment after first patient dose is discriminatory and works as 14% vs. 64% (drug candidate vs. drugs in pipeline) ratio and moves on to Phase III and ultimately commercially put into the market. When drug pipelining started working between 2015 and 2017 (Thomson Reuters 2014), only 62% of drug pipelines were approved in Phase III and brings only 25% from Phase II as drug challenger or candidate.

12.3.2 Estimated Cost Measurement: Drug Development

The overall cost from discovery to development a new drug to bring into the market is from discovery to clinical trials and carries up to approval. Large pharma-based and their collaborated partners invest millions of dollars for drug procurement process from starting to finished goods (as a drug) but, most complexities lie not only includes out-of-pocket expenses through clinical trials on Phase I–III but also to sustain expenses (capital cost) for a period of a decade (10 or more years). A study showed both on capitalized and out-of-pocket cost around $1.79 billion and $869 million respectively (Paul et al. 2010b). Also, a recent study shows that in 2020, the estimated median cost for a suitable medicine or drug to bring into the operational commercial market as more than $984 million with mean calculated cost around 1.29 billion in compared of $2.8 billion; as considered in previous studies

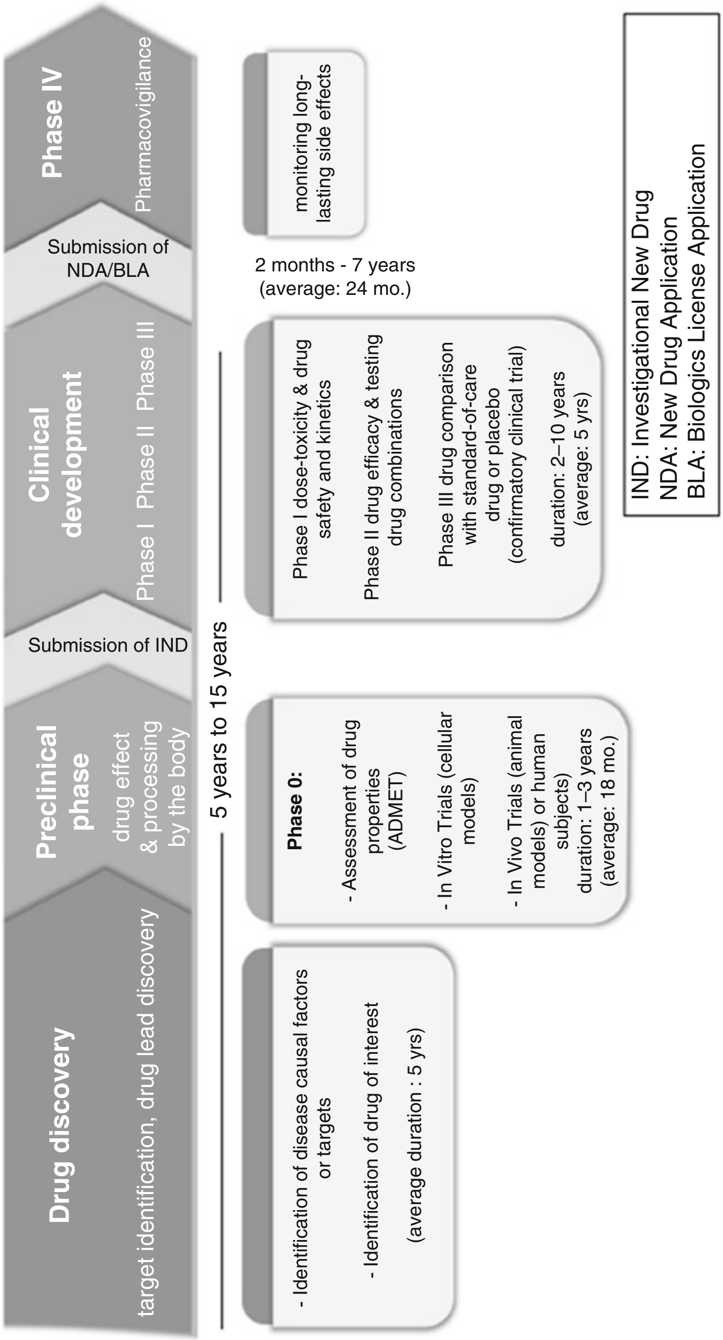

Fig. 12.2 Pipeline of drug development including four different phases

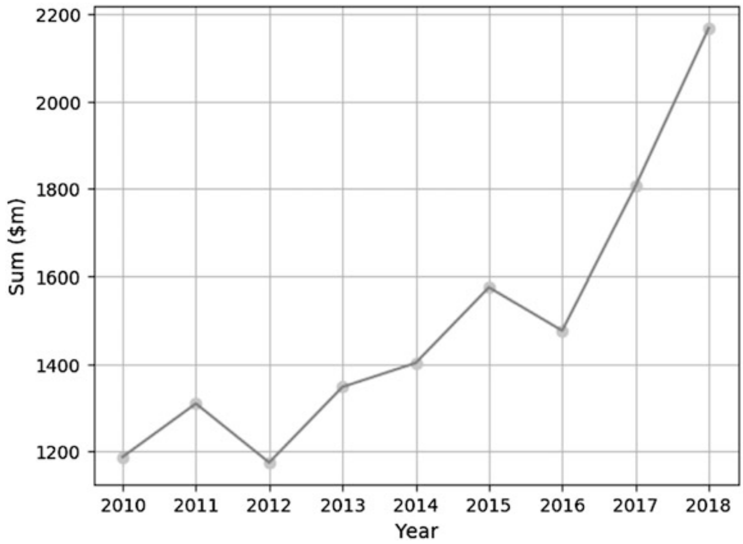

Fig. 12.3 Average cost (in million dollars) of development different pharma lab in 9 years

(Wouters et al. 2020). Besides that, there is a large variation on development of drugs types like in case of HIV; it was around $477 million in respect of $935 million for a new arthritis drug (to protect damage of tissue) (Wong et al. 2019).

The skyrocketed development cost of 12 large pharmaceutical labs (2010–2018) is shown in Fig. 12.3 estimated to carry the value ($2000+ approx) and reached doubled within 8 years.

It is to be noticed that 22% dropped (Deloitte Centre for Health Solutions n.d.) in discovered molecules which crosses the clinical testing time or age and restricts to clinical testing and rapid drug development with sufficient increase delay of patient positioning or recruitment in relation to cost and time incurred. This generates a chance of financial loss and increased rate of failure under development of drug as a product. So, to bring into summary, it is clear that the drug development moves through various non-removal intermediary stages and made it a lengthy, time involvement, boring and even considering R&D as well. Various measures were taken to handle such situations (Specially, Phase II and Phase III) but there are more things to do in terms of study planning (Fogel 2018) or efficient designing for preclinical testing.

12.4 Tackling COVID-19 Scenario

12.4.1 Various Approach of Pharma-Based Companies

There has been a significant improvement underway by the pharmaceutical companies to fight against COVID-19 globally to prevent spreading viruses, it's possible cure and diagnosis from the potential corona virus. Many pharma based partners with their expertise of deep scientific knowledge acquired through a decade and experience in dealing with similar virus, opened a new window for companies researching vaccine candidates with more focusses on R&D in a very stipulated time.

There are four different areas (Fig. 12.4) under which most pharma companies and their collaborated partners working together worldwide to fight against COVID-19 situation collectively (The Association of British Pharmaceuticals n.d.) and are discussed as follows:

12.4.1.1 Treatment Development

As of month May 2020, more than 1000 clinical trials with over 150 treatments. Table 12.1 shows few of the pharmaceutical companies working with prioritizing in COVID-19 related diagnostics, treatments, and vaccines with existing potential treatments.

12.4.1.2 Vaccines Development

Till mid-August 2020, it was reported that more than 167 confirmed vaccine projects are being implemented globally out of which 29 were clinical trials. As of April 2020, these projects were led by pharmaceutical industry (72%) and public sector unit (PSU), academic institution and non-profit organization (NPOs) (28%). Normally, vaccines and molecule treatment must complete the first three phase of clinical trials when approved through different regulatory pathways. Experts believed that at the initial time of the pandemic, it would take around 1 year or

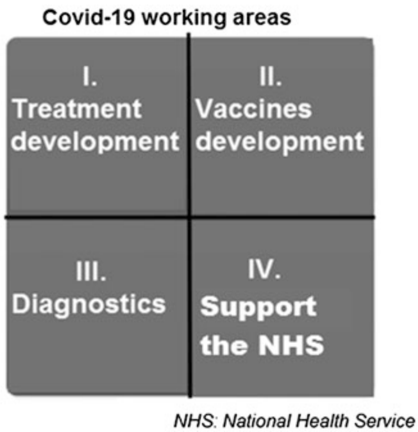

Fig. 12.4 Four quadrants of COVID-19 working areas

Table 12.1 List of few Pharma based companies working with COVID-19 situation

Pharmaceutical company	Working areas
AbbVie	This company works in finding the advantage of HIV drugs and brings that into action in treating COVID-19 in partnering with global authorities. They widely support in fundamental research and working closely with high level governing bodies like European authorities and Food and Drug Administration (of United States of America) and including other authorities to coordinate the overall efforts.
Alexion	A biopharmaceutical company initiated Phase III clinical trials with their medicines to the hospitalized patients affected with severe Acute Respiratory Distress Syndrome (ARDS) or COVID-19 pneumonia. Also, NHS centers started their own clinical trials with this company made medicine.
Amgen	They are developing a neutralizing antibodies specifically targeting SARS-CoV-2 and extends to work for COVID-19. The allies partner is Adaptive Biotechnologies (USA).
Boehringer Ingelheim	This company working in a project with more than 100 scientists, researchers, and R&D for finding a potential solution for COVID-19 and collaborated with Gates foundation for a therapeutic accelerator and other pharma companies, committed to contribute 11,000 more hours in R&D. It has also opened a portal opnMe.com to support scientists worldwide with six antiviral and with 43 sophisticated pharmacological tools available at free cost to access for a rapid early testing.
Pfizer	They completed an initial assessment of certain antiviral drugs that are previously created; causing similar effects in COVID-19 cultured cells. It also tied up with a third party to accelerate the timeline and outlined a 5-point action plan which integrates sharing various clinical information, monitoring and regularize expertise to support and enhance into action of various other companies; performing activities against the virus causing COVID-19 situation.

18 months before a vaccine to be brought into market. Typically, experimentally showed that one out of ten vaccines make it a way to authority approval and thus various others companies available with their different approaches to search for a vaccine and creates a big chances to "shot on goals."

12.4.1.3 Diagnostics

To slow down or prevent spreading the new corona virus is key step in going through proper diagnostic process. However, sudden increase in rapid spread of virus has put a huge demand for fastest testing kit to develop worldwide but mostly in European Union and USA with large population based countries includes pharma companies; everyone trying their best to ramp up their testing capacities. Huge companies like "AstraZeneca & GSK," "Randox," "Roche," "Takeda" has put a tremendous effort globally to put forward diagnostic systems collaborated with reputed universities.

12.4.1.4 Support the NHS

Health and life sciences department has played a major role in tackling COVID-19 situation throughout the world both in diagnostics and treatment of patients. Major companies need to come together with their experience, knowledge and facilities to support healthcare across the world. UK-based companies like AstraZeneca (donated nine million face mask around the world to healthcare workers), Boehringer Ingelheim (donated EUR 5.8 million for emergency aid like protective mask, inhalers, medicines, etc.) and many others tried helping in reaching fastest aid delivery at this critical time.

12.5 Machine Learning Automation Approach

12.5.1 An Algorithmic Search for Therapies

We know that Machine Learning (ML) is a branch of computer science and a subfield of Artificial Intelligence (AI). Generally, any ML algorithm designates a job of computations where results are expected from previous actions or observations that are used to predictor improve future decision-making. It is also popular in various drug development processes through automation and analysis of high-dimensional, noisy form of biological data. Based on various activities or task performed on various biotic data, machine learning can be divided into four fundamental parts: (a) Supervised learning—the main objective is to find the labeled of an unknown or new data (using a prediction model) through a large database of already labeled examples. Support Vector Machines (Schölkopf et al. 2004), Deep Neural Network (Chen et al. 2018; Kannan et al. 2020; Satpathy et al. 2021) have been applied in context of biotic data for fast analysis and its results. (b) Unsupervised learning—the aim is to predict or detect underlying hidden relationships or pattern in unlabeled set of data. Principal Components Analysis (PCA) falls under this category and used for dimension reduction in the context of drug development along with Clustering (grouping of similar objects or data), collaborative filtering and density estimation. Others like (c) Sequential learning, where an agent and an environment are key role player interacts with each other and the agent have to make a first choice in particular time on the basis of earlier observations of the environment (from where carried data is generated) under their several interactions. Multi-Armed Bandit Or MAB algorithms (Lattimore and Szepesvári 2020) were severely applied to various clinical trials and makes it a popular and flexible in nature for all kinds sequential decision-making. Here, a collection of actions (called arms) and an agent is available where an agent (Fig. 12.5) select an arm and sequentially interacts with its environment. Each arm selection interpreted as reward (initially unknown to the agent) produces few noisy observations. The prime objective is to maximize the total reward of an arm (through several arms) gathered through iterative selection methods (Thompson 1933). Various recommender systems are closely linked with MAB and is used to design sequential system. A large part of it nowadays is used in drug discovery and development process and belong to ML methods.

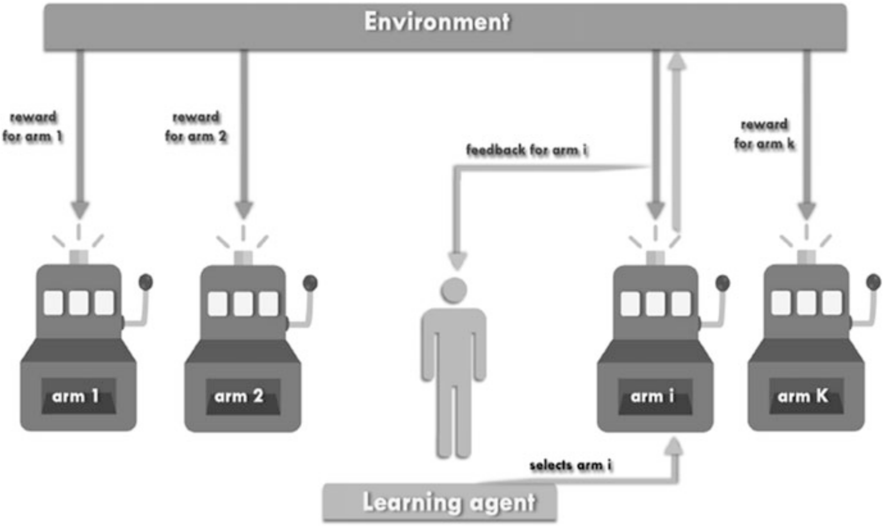

Fig. 12.5 K-arm bandit where an agent interacts with environments and updates strategy

12.6 Machine Learning in Drug Development

ML algorithm can be pseudo chronolized in the drug development order under a pipeline of drug discovery, drug repositioning and drug testing.

We have seen normally that in the pipeline process, discovery is the first step that leads to development of a new drug. A variety of supervised, unsupervised, and other ML-based algorithms were extensively used throughout a decade in all kinds of biotic-based problems but the most overwhelming growing interest were appeared in Deep Learning (DL) techniques. A recent breakthrough using Generative Adversarial Networks (GAN) (Goodfellow et al. 2014) in protein design has made a tremendous traction in biomedical areas. It is made of two concurrently executed and trained neural network (NN) where a "Generator"—that is actually a sampled instances (also called generated instances) and a "Discriminator"—that acknowledges the instances based on a probability sampled value through a training set. The objective is to make false instances that can "fool" the discriminator (Fig. 12.6) based on certain discriminated represented goodness function.

12.6.1 Protein and RNA Based Approach in COVID-19 Process

With the recent application of AI on drug repositioning or repurposing for a new kinds of drug candidates with involvement of chemical entities for COVID-19 virus; the objective was to rapidly exploit the interconnected pathways (biological) or on existing medicines for safer new clinical trials. Earlier attempts showed that use of

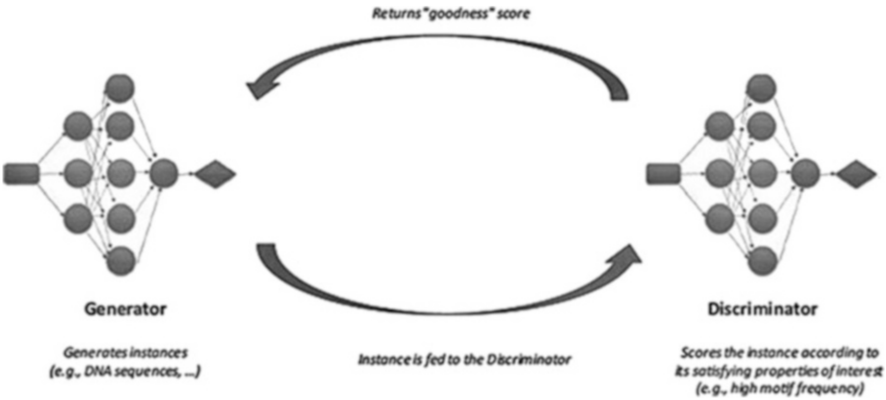

Fig. 12.6 GAN with two networks Generator and Discriminator that are trained at the same time

repositioning technique on a candidate drug identified 60+ human proteins that are severely linked with 26 SARS-CoV-2 proteins (Gordon et al. 2020). Computational analyzing using network simulation approach helped to analyzed the virus. Also, AI-knowledge graph integrates biotic data from various heterogeneous (Structured and Unstructured) sources (Richardson et al. 2020) and targeted the inhibited host protein and identified a drug helps for treatment of arthritis related issues. Similarly, Deep Learning (DL) based model (or drug–target interaction model) predicted antiviral drugs that targets the SARS-COV-2 related protease and helicase (Beck et al. 2020). So, there has been various other applications of multi-task deep learning models that can identify existing drugs and target viral proteins as protease and spike protein. With direct interactions host RNA (Ribonucleic acid)—binding protein and helicases, a complexity layer is put into the regulatory information encoded in viral RNA. This could provide an unexplored strategy that produces minimal impact in normal cells. There are number of conserved RNA elements are identified and functionally validated in the viral families. Some of which are loops in SARS-Cov-2 and elements are conserved across beta coronaviruses.

12.6.2 COVID-19 Drug Repositioning

The concept comes out to reform existing old drugs (if any) and will be used for the treatment of a never applied therapeutic problems. This is a scientific approach for identifying the investigational drug used for the treatment of other complicated diseases.

We have seen in the earlier section that normally, there are five stages or phases of any drug development in a conventional way. However, through drug repositioning, this stages can be reduced up to four stages as shown in Fig. 12.7 like (1) Compound identification from drug library, (2) Compound validation and acquisition, (3) Clinical studies and research, and (4) Market study (FDA approved) (Xue et al. 2018). A

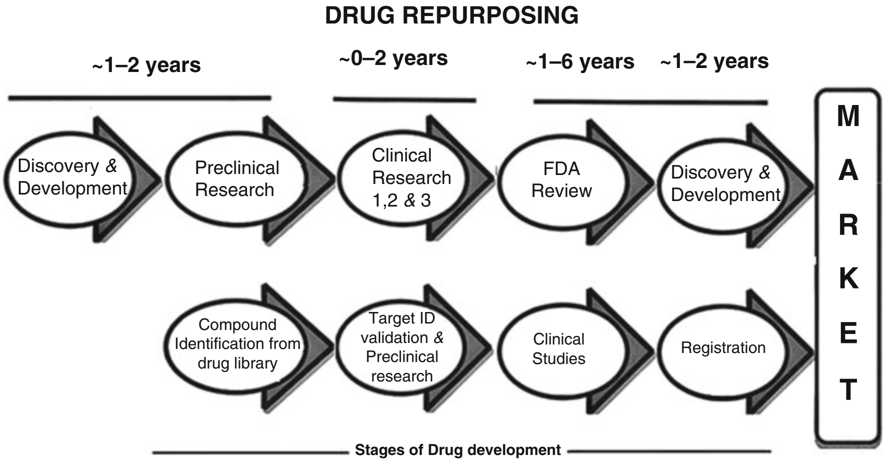

Fig. 12.7 Steps in Drug development through drug repositioning

repositioning or repurposing of a drug reduces several steps and directly moved on to preclinical to clinical testing, removing the initial steps and will helps in reducing risk and several cost factor at an optimal level. The most fundamental things keep in mind during drug repositioning is to follow a pathway at the molecular level and can be adjusted with some other diseases with diverse degree of information accessible on formulation evaluation, toxicity, etc. on trial form of clinical data of authorized or signitarized approved drugs. A potential partner for the treatment of COVID-19 through repositioning (or repurposing), two special compounds called Chloroquine (CQ) and Hydroxy analogue Hydroxy Chloroquine (HCQ) are considered as a most suitable candidate for the treatment of viral infection and having antiviral activity that showed effective result in in-vitro treatment against COVID-19. Also, Remdesivir (an another antiviral drug) were previously used primarily for the treatment of Ebola virus; showed a significant improvement against COVID-19 in in vitro. Still more studies are under process to understand abnormal behavior of corona virus. Some studies showed Vitamin C or Ascorbic acid in addition to other antiviral drugs has created a significant benchmark in the treatment of COVID-19 patients.

12.7 Artificial Intelligence in COVID-19

The challenge in drug repurposing (or repositioning) is to find a unique drug-disease relationship. Several approaches were made including AI-based method (to reduce complexity) to make the drug discovery process more feasible Researchers and Scientists have found something in common between COVID-19 and 2003 SARS virus by going through detailed analysis of SARS existing data. Some, advanced AI deployed models were extensively applied in view of a shorter time to potentially

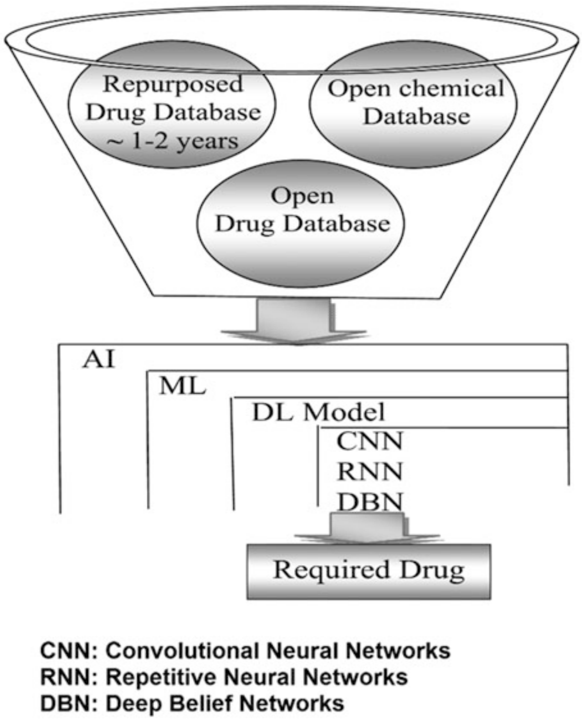

Fig. 12.8 Artificial Intelligence in Drug repositioning

treat COVID-19. Machine learning has supported this procedure and played a major role to overcome barrier of repurposed drugs, clinical or laboratory testing with drug authorization.

Another field called Deep Learning (DL) of machine learning has made significant progress (Lakshmanaprabu et al. 2019) where it uses neural networks with combination of multiple hidden layers instead of an input and output layer as shown in Fig. 12.8. The input to the model is a repurposed drug database and Open Chemical/Drug database and algorithms are applied as input to get the desired drug as output (Zhou 2020). The result depends on more calculation performed under different layers and seen as an expanding measure of information with high computing power. The most interesting feature that brings deep learning come into place the last few years is the use and design of Convolutional Neural Network (CNN), Repetitive Neural Network (RNN), and Deep Belief Network (DBN) and associated feed forward systems. Few large organizations have started to use these advance technologies for speedy quicken COVID-19 medication disclosure to a deeper view in understanding the framework that battles with COVID-19 infection. Big pharma based companies (in the month of April 2020) like GlaxoSmithKline (GSK) and Vir Biotechnology has made a significant growth in speeding up the corona virus treatment using high level computer based reasoning and Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)—a groups of DNA that is found in genomes of bacteria.

12.8 Quantum Computing in COVID-19

It is clear that pharma-based companies takes more than a decade to discover and develop a drug and bring into the market and repositioning may reduce cost and time in an effective way. In these aspects, quantum computing offers a large computing power and bridges the gap in the development process. It has changed the definition of molecular comparison to find a method for analysis of large scale molecules. Today's computers able to perform thousands of millions of comparisons; however, they are limited only to molecules up to certain size that a computer can compute. But, quantum computers open a new window for the pharma based companies that can compare molecules at a larger speed and accuracy and cures range of diseases in less a time. So, quantum simulation enables faster characterization of molecular systems than a normal computer performs. For better pandemic control, quantum computing has joined the force of technologies where supercomputer "IBM Summit" deployed by researchers for speedy identification of chemical compounds for contribution against coronavirus. An emergency computation time on the machines were afforded by the researchers to perform analysis at an unrivaled pace. "Summit" generated reports within 1–2 days as compared to normal computers that would have taken a month for the same computation to happen. Quantum computers helped to identify 77 small molecules and need further investigations to develop a cure for coronavirus that uses 200 petaflops of processing power, with 4608 server nodes (each equipped with IBM POWER9 CPU and Nvidia Tensorcore V100 GPUs). The computer simulated, more than 1000 of compounds in search of those molecules that most likely to bind the coronavirus protein to infect host cells. This creates a framework and will be used to investigate further these compounds and helpful to know whether any of them have the characteristics needed to migrate this virus. Quantum fray companies alongside D-Wave includes Volkswagen, NEC Solution Innovators, Denso, Cineca and many more to expand the computing capabilities to bring the community a deep quantum knowledge to bear or handle complex and dynamic behavior of COVID-19 situation. Quantun annealing technique (used by a leading D-Wave company) works well for simulating quantum phenomenon and leverage network systems through optimization.

12.9 Global Response in COVID-19: Artificial Intelligence Cooperation

Creation of a new kind of AI tool is in process that will be used to fight against COVID-19 and to preserve all social value and following human rights. Even though, the two normal guidelines, privacy, and ethics of design in deploying and developing of AI based solutions, practitioners are facing problem to prevent fundamental rights that includes right to privacy. In rolling out the above proposed AI solutions at a large scale, there should not be a global breach in commitments to protect rights and freedoms preventing and protecting mass surveillance and journalistic sources. To make this happen, openness and accessibility are to be maintained by the stakeholders that will constitute the heart of AI-enabled solutions. AI-based applications in healthcare sector should have equitable global access, supporting member states to achieve universal health coverage. The role of AI in in current pandemic has yet to be defined but a need of a global inclusive research to put a direct action against this pandemic and also in future one—without leaving anyone in behind. It also to be believed that the world is in a more stage of digital than ever in the post-coronavirus outbreak and AI will be a thriving force shaping the current society (UN 2019) more effectively. This pandemic put forward an urgency for the stakeholders to translate all ethical principles for AI into practice. International clinical trial named "Solidarity" (WHO 2020) has been launched by World Health Organization to help find an effective treatment for COVID-19. The solidarity sense is to encourage neighbors to maintain physical distancing, and is a vital step to suppress transmission of virus within the community. Also, United Nations Educational, Scientific and Cultural Organization (UNESCO) supports in helping to develop and deploy AI-enabled mobile app solutions with respect of fundamental rights, includes protection and privacy of data to mitigate COVID-19. Various countries developed mobile apps with different level of Human Rights safeguards for users. Among such apps will empower individuals to monitor their own health by giving an alert to them, if they crossed the paths with an individual infected by virus.

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COVID-19 Epidemic Analysis Using Linear and Polynomial Regression Approach

13

Sweeti Sah, Sujithra Kanmani, Akash Kamerkar, B. Surendiran, and R. Dhanalakshmi

Abstract

The whole world is facing the dreadful burst of SARS-CoV-2 (COVID-19) and brought a severe threat among living society. COVID-19 is affecting human life as well as bringing a loss in terms of economic, finance, and several other resources. With the help of emerging technologies, machine learning methods like regression can be adopted to analyze this epidemic situation by considering the geographic distribution of cases. Regression allows us to predict the outcome using one or more predictor variables. Thus, this chapter analyzes COVID-19 with linear and polynomial regression with the goal of considering its everyday exponential behavior along with predicting COVID-19 future reachability across nations by using the real-time dataset.

Keywords

COVID-19 · Epidemic · Linear · Regression · Polynomial · Predictor

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13.1 Introduction

In December 2019, a novel coronavirus was first found in the seafood wholesale market in Wuhan, China, and then spread throughout the world (Jia et al. 2020). COVID-19 is a pandemic disease, and it is triggered by SARS-CoV-2. It was named COVID-19 by the World Health Organization (WHO) (Barstugan et al. 2020). No specific vaccine has been identified to date. The indicators of COVID-19 are fever, fatigue, and dry cough, but some patients may also have symptoms like body aches and pains, runny nose, sore throat, shortness of breath, and diarrhea. One third of patients report loss of taste and smell, and it is something more specific about this virus (CDC, May 2020).

In India, COVID-19 was first detected in Kerala on 20 January 2020 (Gopikrishnan Unnithan 2020). Various studies and researches have been going, on vaccines and medicines development for COVID-19 as no specific cure is being identified; thus, it is suggested to use latest technologies to analyze and predict this epidemic disease deeper. The trend and growth of the disease are widely predicted using machine learning algorithms (Tuli et al. 2020). It is also being used for the confirmation of COVID-19 cases (Bandyopadhyay and Dutta 2020).

The risk factors of COVID-19 are diabetes, obesity, weak immune system, hypertension, and those with lungs, kidney, and heart diseases; also children and adults more than 65 years of age are at risk of coronavirus infection (CDC, July 2020). It is represented in Fig. 13.1.

The regression analysis method of machine learning approach is widely used for predicting and forecasting as it deals with the relationship between dependent (x) and independent (y) variables. A recent analysis of COVID-19 uses both types of regression models for COVID-19 analysis. The linear regression model only deals with one dependent (x) and one independent (y) variable and attempts to draw the closest outcome, thereby minimizing regression errors (Medina 2020).

Polynomial regression models the relationship between x and y as nth degree polynomial; it is similar to a linear model with some advancement in accuracy by the usage of polynomial features. This model helps in arranging the nonlinear data points in a better way (Chauhan et al. 2020). Thus, this chapter involves the analysis of COVID-19 cases from the real-time dataset by applying the linear and polynomial regression, and a comparison is done toward the prediction and future reachability.

13.2 Related Works

Pandey et al. (2020) had done prediction using SEIR and regression models on data gathered from the John Hopkins University repository. The efficiency was analyzed using root mean square error (RMSE) and obtained 1.52 for the SEIR model and 1.75 for the regression model. It was also estimated that the spread of the disease would be 2.02, which will allow the government and doctors to adjust arrangements during the next 2 weekly duration. Through these models, these short-term interval

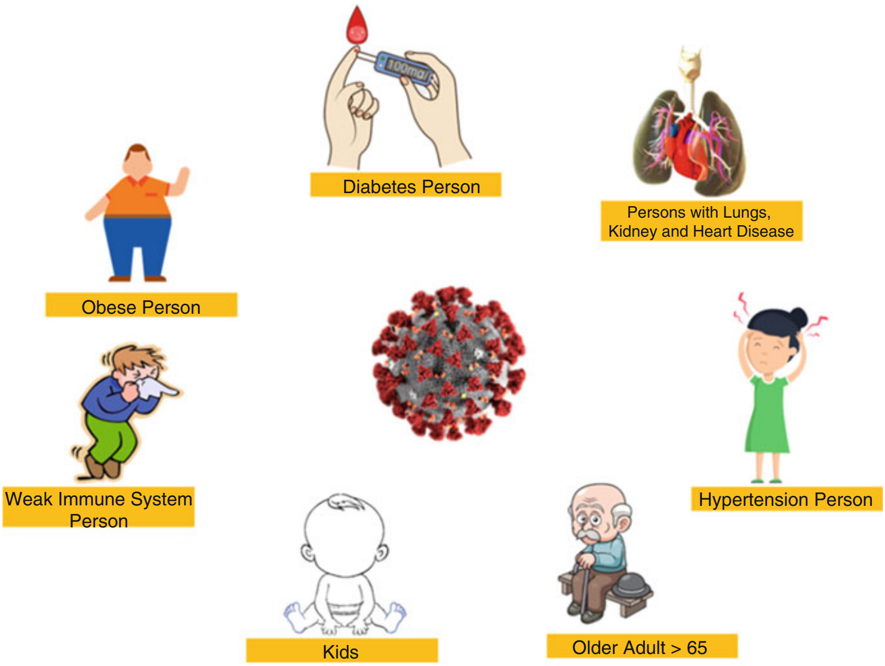

Fig. 13.1 Risk factors of COVID-19 patients

forecasts can be tune for predicting long-term intervals. Algorithms to retrieve data could be built in the future.

Medina (2020) had used simple linear regression analysis to estimate the fatality case rate of COVID-19 in the Philippines and found the fatality case rate in the Philippines to be 4.35% with a 95% confidence interval of 4.12–4.55%. This fatality rate is higher and is hoped to get controlled with the increase in community quarantine. The results of this study were made on initial available data, and it cannot be so accurate but used for analyzing the preventive control measures.

Chauhan et al. (2020) implemented linear and polynomial regression models to investigate the COVID-19 burst in India and its various states using phase interval epidemiological information up to 26 May 2020. The linear regression model is used to determine the case fatality rate (CFR) and recovery rate (RR). The polynomial regression model is used to forecast patient numbers for the next 3 weeks. The model is evaluated using RMSE and percent error and found that Maharashtra, Gujarat, Delhi, and Tamil Nadu continue to remain the most affected states in India, and 300,000 patients will be there till 16 June 2020.

Punn et al. (2020) proposed the concept of utilizing the machine learning and deep learning models for COVID-19 outbreak using data from the Johns Hopkins dashboard for analyzing the next 10 days trend of COVID-19 using support vector regression (SVR), polynomial regression (PR), deep neural network (DNN), and long short-term memory (LSTM). These simulations were evaluated using RMSE values, and PR was found with lower RMSE score. PR can be effectively used in predicting the transmission of COVID-19.

Ghosal et al. (2020) implemented the tracing of trend related to expected counts of death during the fifth and sixth week of COVID-19 in India using linear regression models. The autoregression technique was used, and by taking the input as the death count of week 5, the linear regression model predicted death count of sixth week in India to be 467. Autoregression was used for improving the predictability, and the model was evaluated with higher adjusted *R* square.

Yadav (2020) has analyzed the COVID-19 Indian dataset from Kaggle repository dated from 1 March 2020 to 11 April 2020. They forecasted the number of COVID-19 patients suffering from this deadly disease. Different regression models have been used for the analysis of data in India and calculated RMSE and observed that the sixth degree polynomial is less equated to further regression models. Hence, the sixth degree polynomial is found to be good for envisaging the patients of COVID-19 in India. For future, this model can be tuned for larger interval.

13.3 Methodology

The proposed methodology used in this work is given below.

There are seven modules involved in this proposed model, and the methodologies are as follows:

- *Step 1*: The first module consists of collection and loading of COVID-19 complete dataset for performing the analysis.
- *Step 2*: The second module involves the analysis of collecting the dataset.

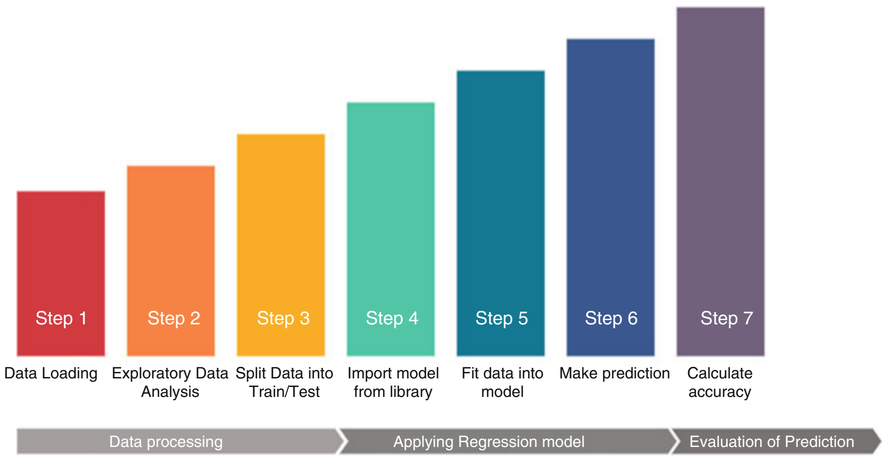

Fig. 13.2 Methodology involved in proposed model

- *Step 3*: It involves splitting the dataset into training and testing part so that cross validation can be performed for analyzing the fitting. Data processing steps are finished at this stage.
- *Step 4*: The necessary libraries needed for the model are being imported for usage.
- *Step 5*: This module involves fitting the data into the model and estimating the best fit out of it.
- *Step 6*: This module involves the prediction part after the application of the regression method.
- *Step 7*: This is the final module involved and makes use of RMSE value for calculating the accuracy level of prediction.

13.4 Experimental Analysis

13.4.1 Implementation Details

The proposed model was implemented with the required materials as shown in Table 13.1.

13.4.2 Dataset Description

The COVID-19 Indian dataset is retrieved from Kaggle. The dataset has ten attributes such as date, name of UT, latitude, longitude, cured/discharged/migrated, etc. of daily case reports, which is in .CSV format. Sample data attributes are provided in Table 13.2.

13.4.3 Results

The number of active cases distributed in India across time is being initially analyzed as shown in Fig. 13.3.

As there are growth of different kinds of cases through time, it is analyzed as confirmed, recovered, and death as shown in Fig. 13.4.

Table 13.1 Implementation details of our work

Dataset used	COVID-19 Indian dataset from Kaggle (Covid-19 Dataset 2020)
Methods involved	Linear and polynomial regression
Language	Python
System software	Co-Lab
Libraries used	Pandas, Numpy, Sklearn, Matplotlib
System hardware	16 GB RAM, WIN 10, 1 TB HDD

Table 13.2 COVID-19 dataset attributes (sample)

Date	Latitude	Longitude	Total confirmed cases	Death	Cured/discharged	New cases	New deaths	New recovered
2020-06-26	817	2872	464,612	14,894	271,697	16,570	418	13,012
2020-06-27	817	2872	500,930	15,685	295,881	36,318	791	24,184
2020-06-28	817	2872	521,020	16,095	309,713	20,090	410	13,832
2020-06-29	817	2872	541,033	16,475	321,723	20,013	380	12,010
2020-06-30	817	2872	559,836	16,893	334,822	18,803	418	13,099

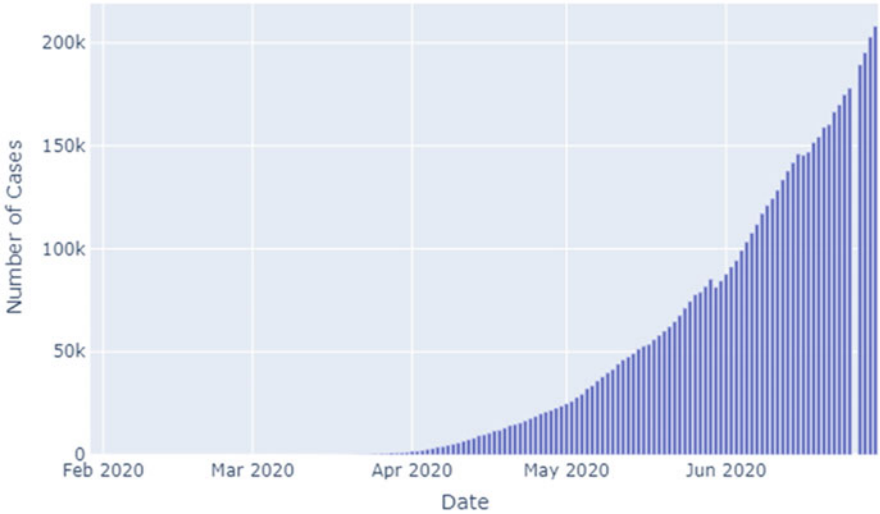

Fig. 13.3 Number of active cases distributed across time (India)

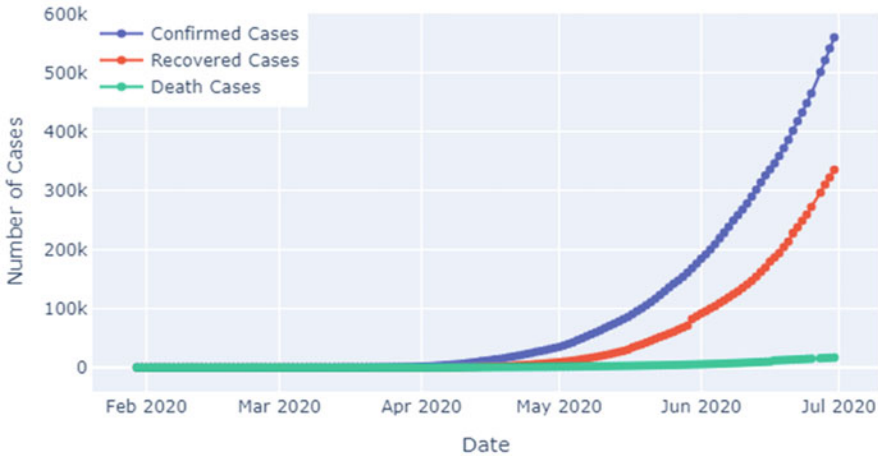

Fig. 13.4 Growth of different kinds of cases through time (in India)

Linear Regression It is the correlation among dual variables by fitting the linear equation to perceive data. The variables are explanatory variable and dependent variable (The World Almanac and Book of Facts 1993).

A linear regression is represented by the equation,

$$Y = a + bX, \tag{13.1}$$

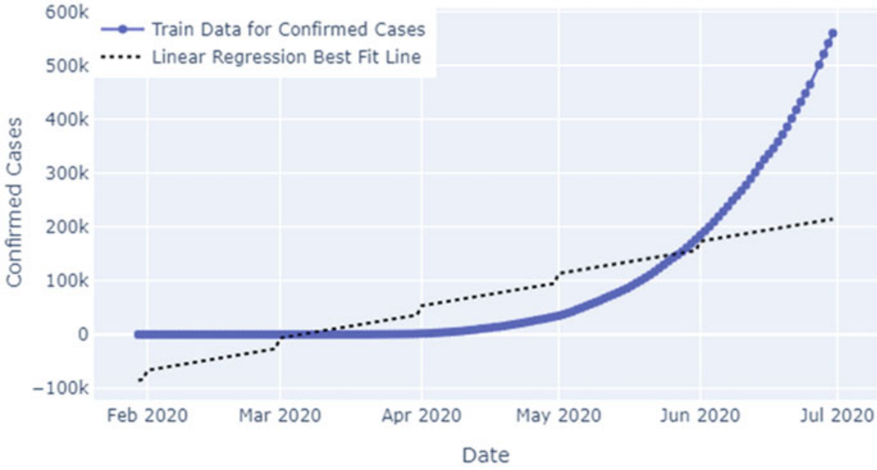

Fig. 13.5 Prediction of confirmed cases using linear regression (in India)

where the explanatory variable is given by X, and dependent variable is given by Y; slope of the line is given by b, and a is its intercept (The World Almanac and Book of Facts 1993).

But the major limitation of using linear regression models is presumed of linearity between dependent and independent variables; in the real world, it is rare for any data to be linearly distinguishable. It is prone to overfitting and noise because while building the model, it starts considering the noise when the number of observations is lesser than the number of features. It is susceptible to outliers which means linear regression is very delicate to outliers (anomalies), so it should be taken off before applying linear regression to any dataset. It is also susceptible to multicollinearity, so it has to be removed using dimensionality reduction techniques (Kumar 2019).

Linear regression is being applied, and it displays the confirmed cases predicted as shown in Fig. 13.5.

Polynomial Regression It is a notable type of linear regression in which we fit polynomial equation on the data with a curvilinear correlation between target and independent variables (Sharma 2020).

It is used in such conditions where the correlation between study and exploratory variables is curvilinear.

Polynomial regression equation of degree "n" is given by the equation (Sharma 2020):

$$Y = \underset{0}{\odot} + \underset{1}{\odot}x + \underset{2}{\odot}x^2 + \underset{3}{\odot}x^3 + \cdots + \underset{n}{\odot}x^n, \tag{13.2}$$

where $\odot_0$ is bias and $\odot_1 + \odot_2 + \odot_3 + \cdots + \odot_n$ are weights in the polynomial regression equation.

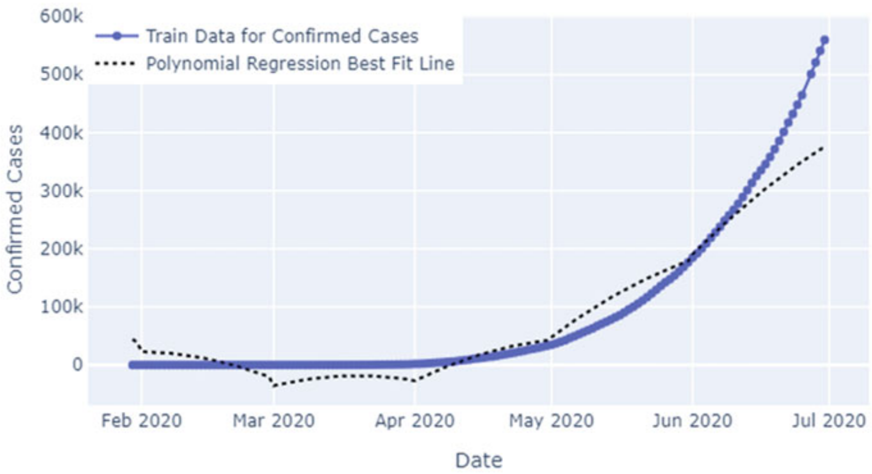

Fig. 13.6 Prediction of confirmed cases using polynomial regression (in India)

The advantage of using polynomial regression is that it provides best accurate approximation among dependent and independent variables. The wide series of function and curvature can be fit under polynomial regression as it is very flexible and effective (Pant 2019).

Polynomial regression is being applied, and it displays the confirmed cases predicted as shown in Fig. 13.6.

RMSE RMSE is used for forecasting and regression analysis, and this is given by the formula (Data TechNotes 2020):

$$\mathrm{RMSE} = \sqrt{\mathrm{MSE}} = \sqrt{1/N \sum_{i=1}^{N} (y(i) - y)^2} \tag{13.3}$$

In the above equation, RMSE is root mean squared error, MSE is mean square error, $y\ (i)$ is the mean value, and y is the predicted value.

13.5 Discussion

The above models were estimated using RMSE. It is the prediction error and conveys the line of best fit around the data. It is a measure of how efficiently the model predicts the data. Both of the above models such as linear and polynomial were applied with RMSE, and the linear regression has the value of 284,809.4, and polynomial regression has the value of 149,117.8, showing that polynomial regression performs better and display more prediction accuracy.

13.6 Conclusion

Thus, this chapter concludes with the exploration of COVID-19 and its symptoms along with the application of machine learning models in the outbreak's disease study. Regression models like linear and polynomial were used for analyzing COVID-19 with the goal of considering its everyday exponential behavior along with predicting COVID-19 future reachability across nations by using the real-time dataset. The models were evaluated with RMSE along the confirmed cases, and the polynomial regression was found to be with lower RMSE, excelling the prediction capability.

13.7 Future Scope

1. *Predicting the Contact Tracing*: Regression models can be applied further for tracing the contacts closer to the victims.
2. *Considering Specific Attributes*: The prediction accuracy can be boosted up with the consideration of community and geographic contextual attributes.
3. *Forecasting Model*: With the usage of regression, forecasting can also be made as a preventive solution provider for this disease in addition to prediction of future scenarios.

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Conflict of Interest We declare no conflict of interest.

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Prediction and Analysis of Outbreak of COVID-19 Pandemic Using Machine Learning

14

Pooja K. Akulwar and Jinendra D. Gambhir

Abstract

During the recent COVID-19 outbreak, all health professionals, scientists and other experts around the world started seeking for latest, effective and reliable source of technology to help track and tackle this situation surrounding the pandemic. Machine Learning, Deep Learning and Artificial Intelligence make a huge difference over traditional surveys and analysis. To come up with the well-being of living society, we prefer to utilize ML and deep learning models with the focus on understanding their everyday exponential behaviour in addition to the prediction graphs of further growth of COVID-2019 over the world by utilizing the available facts and dataset.

Keywords

COVID-19 · Coronavirus · Pandemic · Machine learning · Deep learning · Prediction

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14.1 Introduction

As usual, it feels like a very fine day. A few people around you are sick, and suddenly you notice that everyone is sick and it sounds very threatening. It is happening very rapidly. This is the paradox of pandemic. In this chapter, we analyse the outbreak of COVID-19 using Machine Learning.

Novel coronavirus, also known as COVID-19, is caused by SARS-CoV-2. This coronavirus is capable enough to infect dozens of people around it. The virus starts to show its symptoms after 10–12 days, which is a cause for concern. The spread of COVID-19 is not the first and last viral pandemic. However, like never before this virus kills people and spreads very massively.

On 30 January 2020, the first case of COVID-19 was reported by a Kerala-based laboratory. The patient was a student who returned from Wuhan. After some days, a 65-year-old man from Mumbai who had a travel history to the UAE is reported as the tenth victim in India. The MoHFW (Ministry of Health and Family Welfare) had their eyes closed to the 2019-nCoV situation. When ministry saw things are going worse, the Prime minister of India came up with a decision and addressed the nation on 24 March 2020. He clarified the real situation and requested to self-quarantine.

Now it became extremely important and essential to control the novel coronavirus not only in India but also throughout the world. Without getting late the WHO announced the COVID-19 outbreak as a pandemic. Now the MoHFW ministry needs to control the spread of virus and predict its risks of infection. The priority is to identify infected patients and collect as much data as possible by testing every individual.

Here the health care professionals have an important role to play. They are involved in collecting reports by doing testing, conducting vaccine research and development, and treating patients. They are also able to provide reports of death and confirmed cases, bed requirements and others (Navares et al. 2018).

The IT sector has also faced challenges during this pandemic, like collecting massive volumes of data generated by clinics and medicals. These reports are essential to analyse the outbreak, track the virus, identify the risk, understand the virus better, diagnose current patients, predict the spread of virus, predict further pandemics and most importantly securing our future (Navares et al. 2018).

All these could happen by using Machine Learning, Big Data, Deep learning and Artificial Intelligence, and those techie words will be proven soon as a trump card in this war.

Therefore, we have to first understand what coronavirus is, how it infects and how the pandemic works. In addition, how can we take help from ML, AI, Deep Learning and Big Data to fight against COVID-19.

14.1.1 What Is COVID-19? *(The Problem)*

Coronavirus spreads primary through droplets of saliva or by coughing and sneezing. This virus spreads through person to person. It is diagnosed with a laboratory test. There is no vaccine available for this virus to date.

14.1.2 How Can We Detect? *(The Symptoms)*

If a person is infected by coronavirus, this virus can be detected in the blood sample of the patient. Other ways to detect this virus are by tasting nasopharyngeal swab, throat swab or respiratory samples. Most of the people have good immunity, so they will recover naturally, without hospitalization. These types of people get only mild to moderate level of illness.

Some of the common symptoms are as follows:

1. Fever
2. Dry Cough
3. Weakness

Some of the major symptoms are as follows:

1. Breathing problem
2. Chest pain
3. Loss of speech or movement

14.1.3 How Can We Break the chain of transmission? *(The Solution)*

This virus easily spreads from person to person. If it cannot find humans to infect, it will not survive longer on surfaces. Social distancing, self-quarantine, and sanitizing are effective ways to stop infection and the spread of the virus.

14.1.4 What Is Outbreak, Epidemic and Pandemic?

COVID-19 has a unique property which makes this virus most dangerous. This virus grows **exponentially**. That means it doubles day-by-day, and unfortunately there is no vaccine available to cure the patients.

However, it cannot continue to spread. The virus will eventually stop finding people to infect and ultimate the number of infection will slow down. This is called **logistic growth**.

An **outbreak** is when the disease happens in unpredicted multitude. It may stick in one zone or expand more extensively. An outbreak can last for few days or some years. Sometimes, authorities review a single case of a contagious disease to be an outbreak. This could happen if it is a disclosed disease or virus, if it is latest to a community or if it is missing in a community for a long time (Basic Definitions for Outbreak Epidemic and Pandemic n.d.).

An **epidemic** is when a transmissible disease expands rapidly in a regional community than experts/authorities would expect. It usually infects a larger region than an outbreak (Basic Definitions for Outbreak Epidemic and Pandemic n.d.).

A **pandemic** is when an epidemic occurs across countries or continents. It infects a large number of people and takes more lives than an epidemic. The WHO announced COVID-19 as a pandemic when it became clear that the disease was severe and that it was growing rapidly over a large region (Basic Definitions for Outbreak Epidemic and Pandemic n.d.).

14.2 Environment and Tools

14.2.1 Machine Learning

14.2.1.1 Overview

ML is an emerging technology in different sectors. Nowadays 'health care' is the area where ML applications are in high demand. But the question is that, **what is machine learning?**

ML is a form of AI (artificial intelligence) that enables s/w applications to become more precise in predicting systems results without being explicitly programmed. ML is an approach of data analysis that robotizes analytical model building. It is an arm of AI based on the goal that machines should be able to grasp and self-adjust through previous experience.

The process of grasping and learning starts with analysing the data. The primary focus is to change the system and give the access accordingly to learn automation without user intervention.

14.2.1.2 Why Is Machine Learning Important?

ML can help to enhance 'health-related data management and exchange of health statistics' with the aim to technologize updated workflows, ease access to clinical data, and upgrade the precision and flow of health details.

It also contribute in pathologists to make faster and more precise diagnosis to identify patients who might require new types of treatments and therapies.

14.2.1.3 Methods of Machine Learning

Two main trendy methods of ML are supervised learning and unsupervised learning. Supervised learning is about 70% of ML, although unsupervised learning is about 10–20% of ML. Reinforcement learning and semi-supervised learning methods are less used. Gaming, finance sector, and manufacturing sector come under reinforcement learning (Types of Machine Learning n.d.).

Supervised Machine Learning Algorithms

Supervised learning is all about 'Classification' and 'Regression'. This algorithm enables fraud detection, e-mail spam detection, diagnostics and image classification. It also helps in risk assessment and scores prediction. The technic is able to issue targets for any new input after sufficient training. The machine learning algorithm further compares its output with the right results, intended output and search errors to modify and customize the model accordingly (Types of Machine Learning n.d.).

Unsupervised Machine Learning Algorithms

Unsupervised ML supports 'Dimensionality Reduction' and 'Clustering'. Dimensionality includes text mining, face recognition, big data visualization and image recognition. This Algorithm also effective in biology and city planning sectors. Unsupervised learning studies and analyzes itself in order to systems could derive a function to set out a hidden structure from unlabelled data. The system is not able to check correct output, but it can analyse the data and can draw inferences from provided datasets to describe hidden structures from unlabelled data. These algorithms do not need any pre-requirements like training with desired outcome data. Instead, they use an iterative approach called Deep Learning to review data and arrive at a conclusion (Types of Machine Learning n.d.).

Semi-Supervised Machine Learning Algorithms

This is a sort of combination of supervised and unsupervised learning and uses both labelled and unlabelled data for analysing. This type of ML can be used for methods like classification, regression and prediction. In semi-supervised learning, it will be like face and voice recognition techniques. In a typical situation, the algorithm will use a small amount of labelled data with a large amount of unlabelled data (Types of Machine Learning n.d.).

Reinforcement Machine Learning Algorithms

Reinforcement ML again uses the same methods such as classification, regression and prediction. Reinforcement learning is very different from supervised learning. This ML algorithm is all about sequential decisions, on other hand in supervised learning decision made under primary inputs (Types of Machine Learning n.d.) (Table 14.1).

14.2.1.4 The Machine Learning Process

See Fig. 14.1.

14.2.2 Deep Learning

14.2.2.1 Overview

It is an arm of machine learning. Alike ML, deep learning also has supervised, unsupervised and reinforcement learning in it. The word 'deep' in deep learning

Table 14.1 Difference between supervised learning and unsupervised learning (Machine Learning Information n.d.)

Factors	Supervised learning	Unsupervised learning
Input	Well-known and labelled data	Unspecified data
Complexity	Very complicated	Less complicated
Number of classes	Known	Undisclosed
Accuracy	Precise and authentic	Average in accuracy and reliable

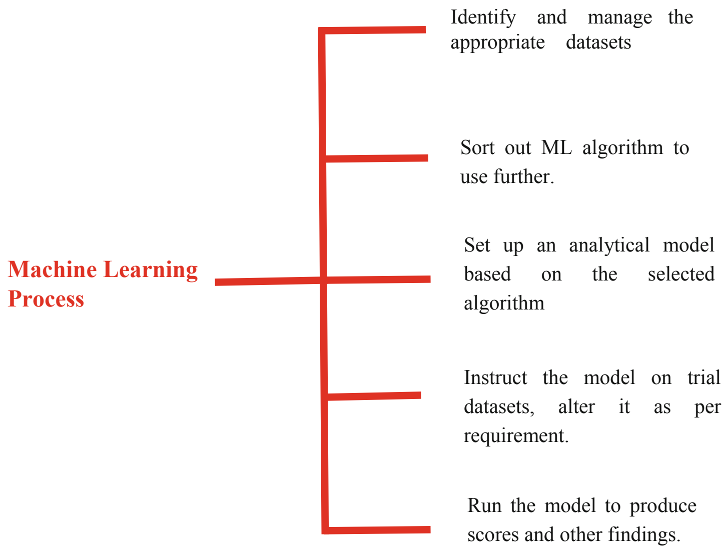

Fig. 14.1 Machine learning process (Machine Learning Information n.d.)

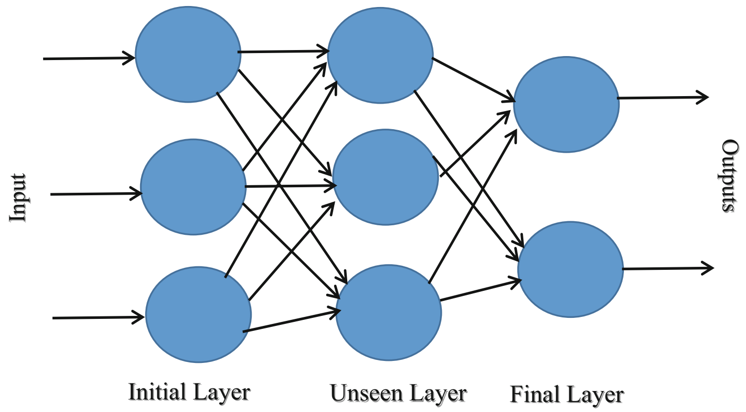

Fig. 14.2 Shallow neural network (Deep Learning Information n.d.)

indicates use of multiple layers in network. Most of the latest models are built on artificial neural network, CNN, although they also have propositional formulas sorted in layer-wise. For example, there are several layers for analysis when we process an image: like, lower layers may look for edges of an image and at the same time higher layers may identify digits or letters or it may try to identify faces (Fig. 14.2).

Deep Learning is all about integrating such unseen layers between the initial and the final layer.

14.2.2.2 Methods of Deep Learning

There are different methods implemented in deep learning. Every suggested method has a certain use case like the sort of data we have, so it is either supervised or unsupervised learning, which depends on the kind of task you would want to solve. So, it all depends on these factors, you can choose the method that will best solve your problem (Fig. 14.3 and Table 14.2).

14.3 Analysing the COVID-19 Epidemic

14.3.1 Overview

14.3.1.1 Objective

The idea is to come up with a really strong model that is able to predict how coronavirus could spread across different countries and regions.

14.3.1.2 Goal

The task is to predict the spread of the virus for the next 7 days.

To analyse the situation, we need to collect all types of medical data. On that data further, we can apply various methods, and to get a better understanding, we visualize this data graphically (pie chart, bar graphs, etc.)

Here, we use **python**, a scripting language. This programming language is very effective when it comes to analysing on big data.

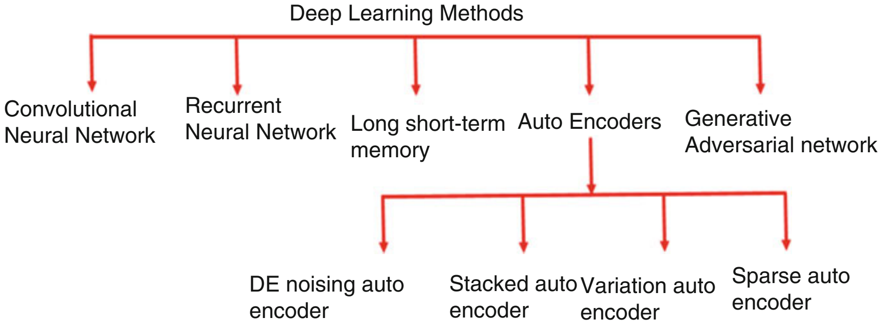

Fig. 14.3 Deep learning method (Deep Learning Information n.d.)

Table 14.2 Deep learning vs machine leaning (Deep Learning Information n.d.)

Factors	Deep learning	Machine learning
Data requirement	Requires large data	Can train on less data
Accuracy	Provides high accuracy	Gives less accuracy
Training time	Takes longer to train	Take lesser time to train
Hardware dependency	Requires GPU	Trains on CPU
Hyper-parameter tuning	Can be tuned in various different ways	Limited tuning capabilities

Table 14.3 Libraries (Barstugan et al. 2020)

Libraries	Description
Pandas	It is mainly used for data analysis and manipulation
Matplotlib	It is a graph plot library. It gives an OOP-based API for insert plots into applications by using GUI
Seaborn	This library is based on matplotlib. It is mainly used for statistical data visualization
Folium	We used this library to populate a geographical map

(a) First, let us understand why these libraries are essential and how we use it in our analysis (Table 14.3).

14.3.2 Analysing the Present Condition in India

It is important to analyse the present condition in India. As we already discussed, India is on the verge of stage 2 pandemic progression, which is why shutdown is important.

We are now finding some similarities and differences between counts of confirmed cases in India with other country's confirmed cases. But, while we compare India with other countries, we should select countries with similar trends. Therefore, we could analyse future domestic losses and we will be prepared for any other unknown risk.

We are also exploring worldwide data and keep updating our health care sector and the dataset. We already have a dataset in the form of excel file. Using that same data, we are creating a frame using ***Pandas***. This library helps us to read tabular form of data.

14.3.2.1 Track Cases in Indian States/Territories

Now, we have the names of states in India, Total confirmed cases (Indian National), Total confirmed cases (Foreign National), cured cases and death cases (Fig. 14.4).

14.3.2.2 Find Total Confirmed Cases

Now, we are finding Total No. of confirmed cases (National + International).

So, as per statistics, as of 22 Mar 2020 India has a total **562** confirmed cases (Fig. 14.5).

14.3.2.3 Graphical Representation *(Total Cases)*

Let us understand this situation more clearly by revealing the data graphically.

As per Fig. 14.6, the darker the red in each of these cells is the more the number of fatalities are. Actually here, we coloured each cell according to the fatality rate. As we can see, 'Karnataka', 'Kerala' and 'Maharashtra' have the largest number of cases 41, 109, 101 respectively. Least number of cases are in 'Chhattisgarh', 'Manipur' and 'Mizoram' with only one case each, as per 25 Mar 2020 statistics.

	S. No.	Name of State / UT	Total Confirmed cases (Indian National)	Total Confirmed cases (Foreign National)	Cured	Death
0	1	Andhra Pradesh	9	0	0	0
1	2	Bihar	3	0	0	1
2	3	Chhattisgarh	1	0	0	0
3	4	Delhi	30	1	6	1
4	5	Gujarat	32	1	0	1
5	6	Haryana	14	14	11	0
6	7	Himachal Pradesh	3	0	0	1
7	8	Karnataka	41	0	3	1
8	9	Kerala	101	8	4	0
9	10	Madhya Pradesh	9	0	0	0
10	11	Maharashtra	98	3	0	2
11	12	Manipur	1	0	0	0
12	13	Mizoram	1	0	0	0
13	14	Odisha	2	0	0	0
14	15	Puducherry	1	0	0	0
15	16	Punjab	29	0	0	1

Fig. 14.4 COVID-19 cases in India (Covid-2019 Datasets n.d.)

```
total_cases=df['Total cases'].sum()
print('Total No. of confirmed covid-19 cases till date[22/03/2020]:',total_cases)

Total No. of confirmed covid-19 cases till date[22/03/2020]: 562
```

Fig. 14.5 Confirmed cases in India (Covid-2019 Datasets n.d.)

	Name of State / UT	Total Confirmed cases (Indian National)	Total Confirmed cases (Foreign National)	Cured	Death	Total cases
0	Andhra Pradesh	9	0	0	0	9
1	Bihar	3	0	0	1	3
2	Chhattisgarh	1	0	0	0	1
3	Delhi	30	1	6	1	31
4	Gujarat	32	1	0	1	33
5	Haryana	14	14	11	0	28
6	Himachal Pradesh	3	0	0	1	3
7	Karnataka	41	0	3	1	41
8	Kerala	101	8	4	0	109
9	Madhya Pradesh	9	0	0	0	9
10	Maharashtra	98	3	0	2	101
11	Manipur	1	0	0	0	1
12	Mizoram	1	0	0	0	1
13	Odisha	2	0	0	0	2
14	Puducherry	1	0	0	0	1
15	Punjab	29	0	0	1	29
16	Rajasthan	30	2	3	0	32
17	Tamil Nadu	16	2	1	0	18
18	Telengana	25	10	1	0	35
19	Chandigarh	7	0	0	0	7
20	Jammu and Kashmir	7	0	1	0	7
21	Ladakh	13	0	0	0	13
22	Uttar Pradesh	34	1	11	0	35
23	Uttarakhand	3	1	0	0	4
24	West Bengal	9	0	0	1	9

Fig. 14.6 Graphical representation of confirmed cases in India (GitHub Repository 2019)

14.3.2.4 Find Total Active Cases

Now we have total death cases, total cured patients and sum of all. However, these data are not more relevant for our analysis.

What actually we are seeking is ***Active cases***. We only want to know the number of people who have been hospitalized at that moment (Fig. 14.7).

We can clearly see that, 'Kerala' and 'Maharashtra' have the highest number of active cases, and the total number of cases combined in India is 512.

$$Total\ Active\ Cases = Total\ cases - (Total\ Death + Total\ Cured)$$

```
#Toatl cases= Number of death + Cured
df['Total Active'] = df['Total cases'] - (df['Death'] + df['Cured'])
total_active=df['Total Active'].sum()
print('Total number of active COVID-19 cases across India:', total_active)
Tot_Cases = df.groupby('Name of State / UT')['Total Active'].sum().sort_values(ascending=False).to_frame()
Tot_Cases.style.background_gradient(cmap='Reds')
```

```
Total number of active COVID-19 cases across India: 512
```

	Total Active
Name of State / UT	
Kerala	105
Maharashtra	99
Karnataka	37
Telengana	34
Gujarat	32
Rajasthan	29
Punjab	28
Uttar Pradesh	24
Delhi	24
Tamil Nadu	17
Haryana	17
Ladakh	13
Madhya Pradesh	9
Andhra Pradesh	9
West Bengal	8
Chandigarh	7
Jammu and Kashmir	6
Uttarakhand	4
Himachal Pradesh	2
Odisha	2
Bihar	2
Manipur	1
Mizoram	1
Puducherry	1
Chhattisgarh	1

Fig. 14.7 Active cases in India

Here, we have grouped states and union territories and further we sorted them by the value of their total active cases. Again, here we used same red coloured gradient to visualize it better.
groupby():

This is a pivot function we use in excel sheets. It actually turns a wide table format into a long table format.

14.3.2.5 Location-Based Tracking *(Total Cases)*

Here, we used ***Folium*** library as *folium.map()* and we specified the location (Longitude and Latitude). We also use a red circle marker whose size depends on the number of cases in their particular region (Fig. 14.8).

As we can see, 'Kerala' and (immediately followed by) 'Maharashtra' both have very big red circles. In addition, north Indian side has a couple of circles and east side of India has less affected regions.

14.3.2.6 Confirmed Vs Recovered Cases

Here, we basically using ***seaborn*** library for visualization where we plot a couple of bar graphs to show the total number of confirmed cases and the total number of cured cases in Indian territories. Pink represents the total number of cases; similarly, cured cases are in green colour.

As we can see, again 'Kerala', 'Karnataka' and 'Maharashtra' have the highest number of cases and also 'Haryana' and 'Uttar Pradesh' show good recovery.

If we compare 'Kerala' with 'Maharashtra', Kerala despite having the maximum number of cases also has the maximum number of recoveries than Maharashtra. So, our conclusion from Fig. 14.9 is that the net percentage of affected people in Kerala is much lesser than that in Maharashtra.

14.3.2.7 Rise of Coronavirus Cases

Here, we use a scatter plot and a line plus marker for a better understanding and visualization. This graph shows actual rise of coronavirus cases in India.

In Fig. 14.10, *X*-axis indicates months; similarly *Y*-axis indicates the increasing number of cases in India. We can easily see in the graph how the figures make a jump in March (Fig. 14.11).

We also perform an analysis on a daily basis for COVID-19 cases in India to get precise values and data for further analysis and accurate prediction.

This is a bar chart where our access is date and the values are new daily cases. After getting this output, we clearly see that up until 23 February 2020 India has too little cases and only during march we started getting more number of cases in India.

On 23 March 2020, India reached a peak of 103 new cases on a particular day.

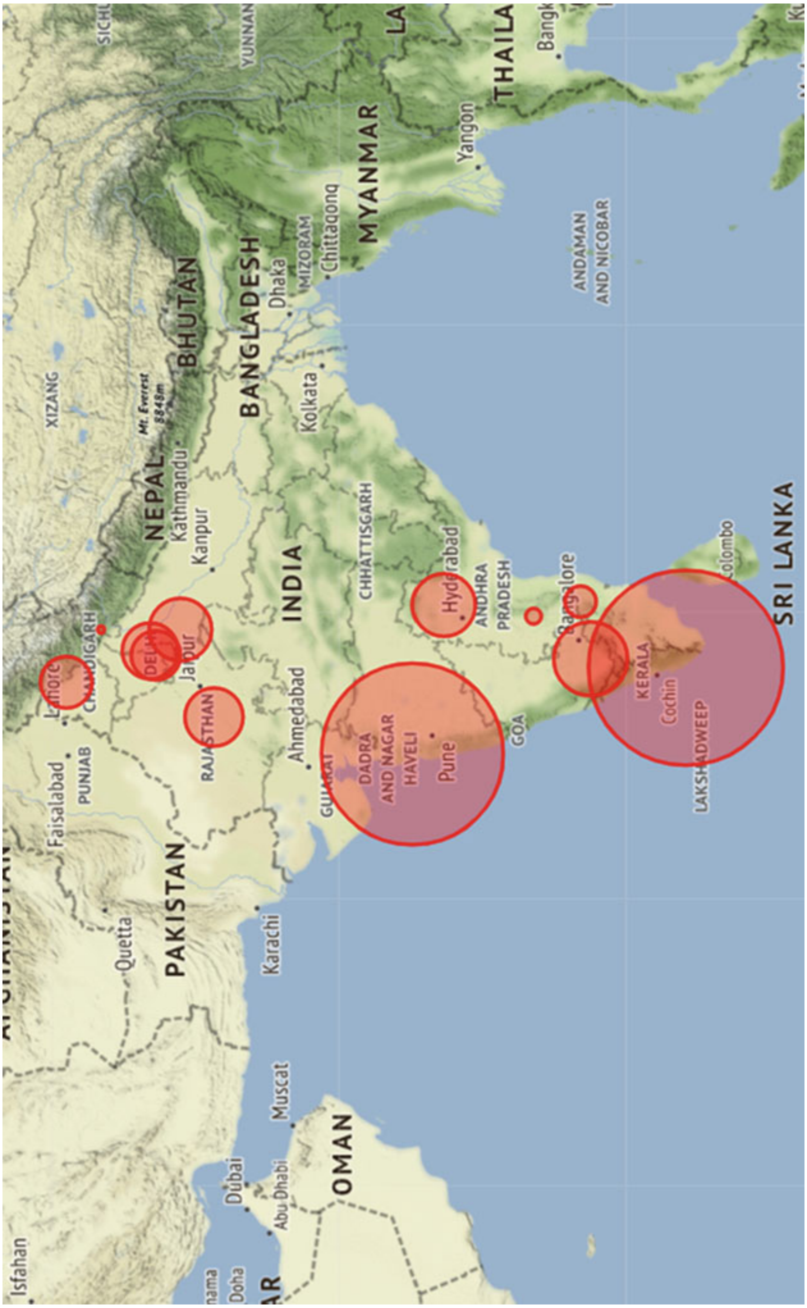

Fig. 14.8 Visualizing the spread geographically

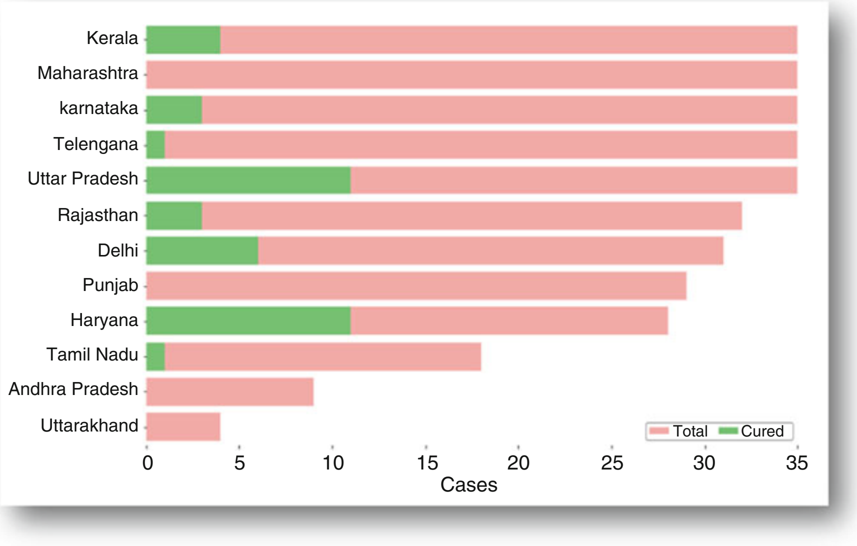

Fig. 14.9 Total cases and recovered cases

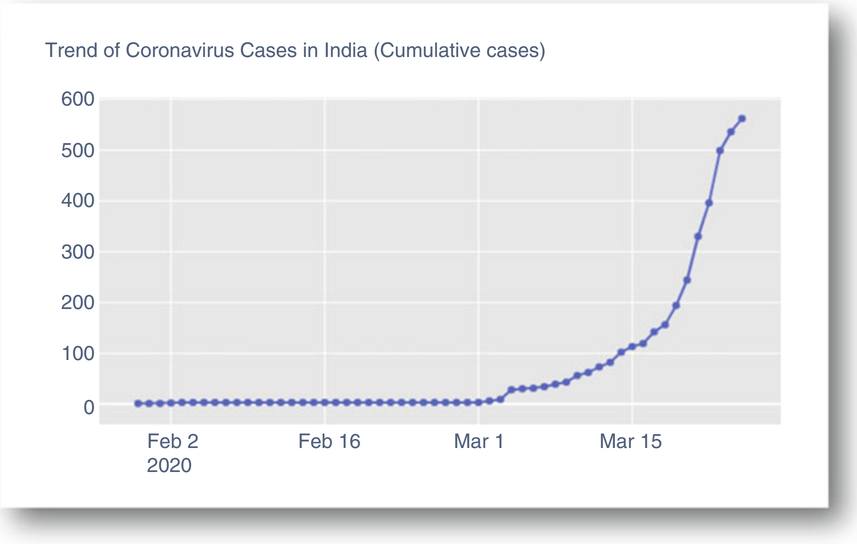

Fig. 14.10 Trend of coronavirus cases in India (Barstugan et al. 2020)

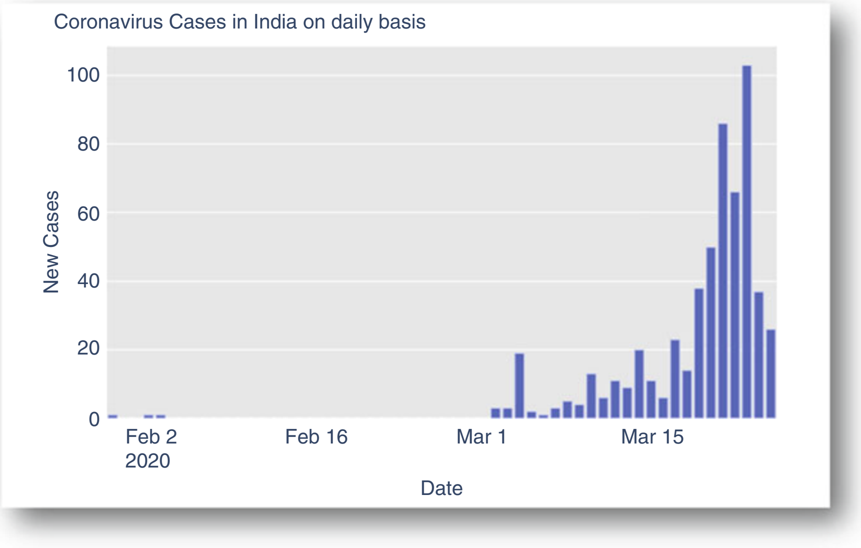

Fig. 14.11 Analysis on a daily basis (Barstugan et al. 2020)

14.3.3 India Vs Other Countries *(Analyse Countries with Similar Trend)*

At this point, India had already crossed 500 cases. It is still very important to contain the situation in the upcoming days. The numbers of coronavirus patients had started to double after many countries hit the 100 marks, and the numbers almost started increasing exponentially.

Now, we have all confirmed, recovered and death cases report and monthly-daily analysis. Up until here, our analysis was confined with datasets in India only. It is time to compare and analyse India with few other countries with similar trends.

It is more important to analyse the present condition of the world. So, we are now finding some similar situations in other countries. These data will help us to better predict and prepare.

14.3.3.1 India *(Confirmed Cases)*

For this type of graph, we imported column graph using plot Li and some colour gradient.

The more dense the colour, the higher the confirmed cases. As per the title, we are comparing India with other countries. This is the graph for India. India has exponential growth in the number of confirmed cases, and it has taken a hit since 3rd–4th of March (Fig. 14.12).

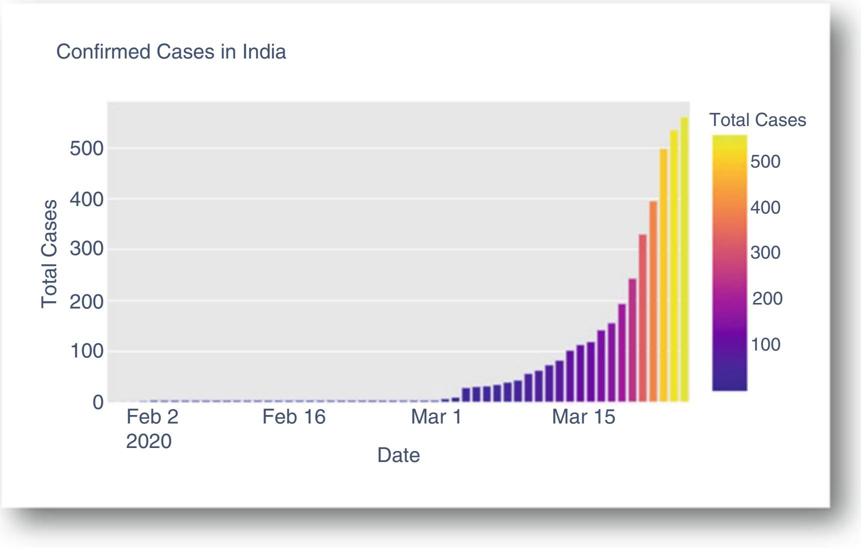

Fig. 14.12 India

14.3.3.2 Italy *(Confirmed Cases)*

If we talk about Italy's condition, we can see a sharp and exponential increase in confirmed case reports after 3rd–4th of March 2020. But, this graph looks sharp, flowsharp and streamlined; there is no breaks and kinks unlike India.

At the end of March, it shows 69k cases from Italy that is much more than India.

Italy had to face this condition because this country took too much time to do what we (India) have done at that time (Fig. 14.13).

14.3.3.3 South Korea *(Confirmed Cases)*

South Korea's graph has started to completely become a sigmoid curve since 7th of March. The actual story behind is South Korea had started extensive testing. The government took a very strong decision to quarantine anyone who got even mildest infection in this country.

This idea really worked so that the curve is almost flattened in the last few days of March. On 22nd–24th of March 2020 the number of confirmed cases seems so minimal (Fig. 14.14).

14.3.3.4 Wuhan

Wuhan's graph also followed a sigmoid pattern. On 12th–13th February there is steep rise. But it successfully started to flatten out just after 66k–67k on 3rd of March (Fig. 14.15).

China also has their own unique story; China has started to get help from some *artificial intelligent* models, which has helped them to diagnose people with flu on a very extensive scale.

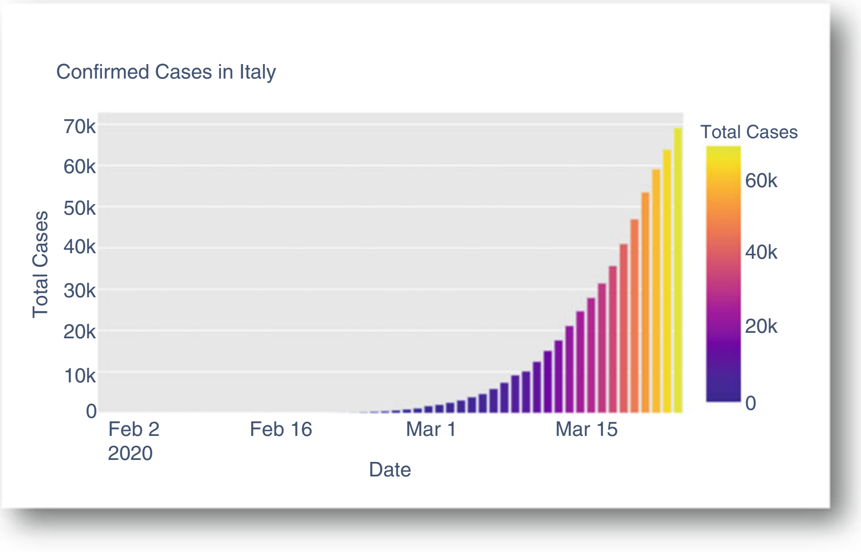

Fig. 14.13 Italy

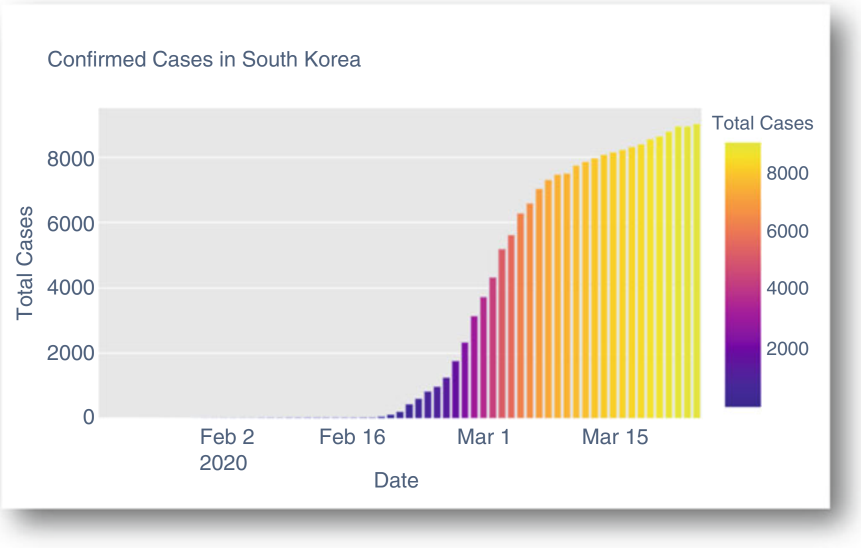

Fig. 14.14 South Korea

They used heat mapping sensors to scan bodies; these sensors are much able to pick out people even with mild temperatures, which helped them to quarantine and diagnose people and this project is at its best in machine learning.

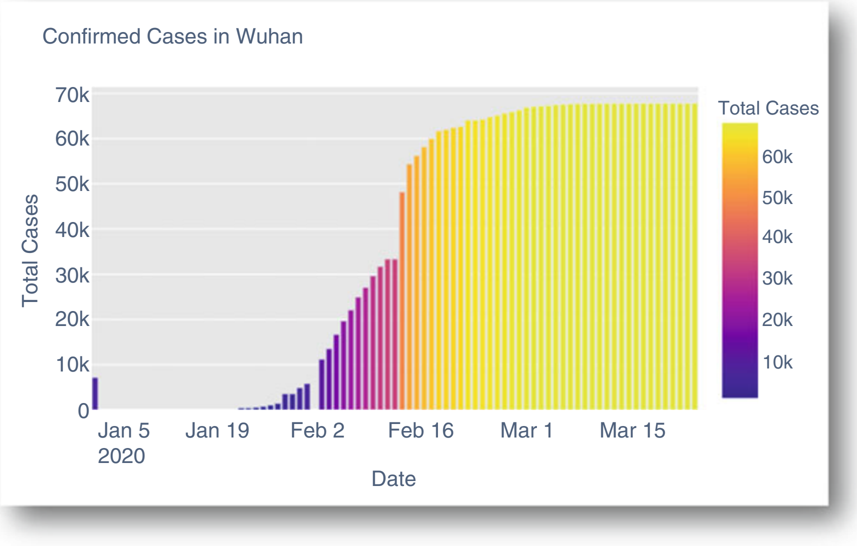

Fig. 14.15 Wuhan

From the above visualization, one can infer the following:

- Confirmed cases in India is rising exponentially with no fixed pattern (very less number of tests in India).
- Confirmed cases in Italy is rising exponentially with a certain fixed pattern.
- Confirmed cases in S.Korea is rising gradually.
- There have been almost negligible number of confirmed cases in Wuhan a week.

14.3.3.5 Overall Comparison

The more number of cumulative cases per day the bluer the graph becomes. So, we have chosen some countries such as South Korea and Italy to compare. We put all graphs into a single canvas to differentiate them properly. This type of visualization will contribute more than the previous one (Fig. 14.16).

We can see that India had comparatively fewer cases than South Korea and Italy at one particular period. At the same time, if we compare India with these countries, India has the largest population. What is the reason behind India having less number of cases? Let's figure it out.

14.3.3.6 Trend After Crossing 100 Cases *(India, S.Korea, Italy)*

As we can see, after crossing 100 cases the graph shows India has a minimum number of cases and both other countries cross the mark of 5600 (Fig. 14.17).

If we compare India with Italy and South Korea, India has the lowest number of cases when it comes to this pandemic. Why this is happening?

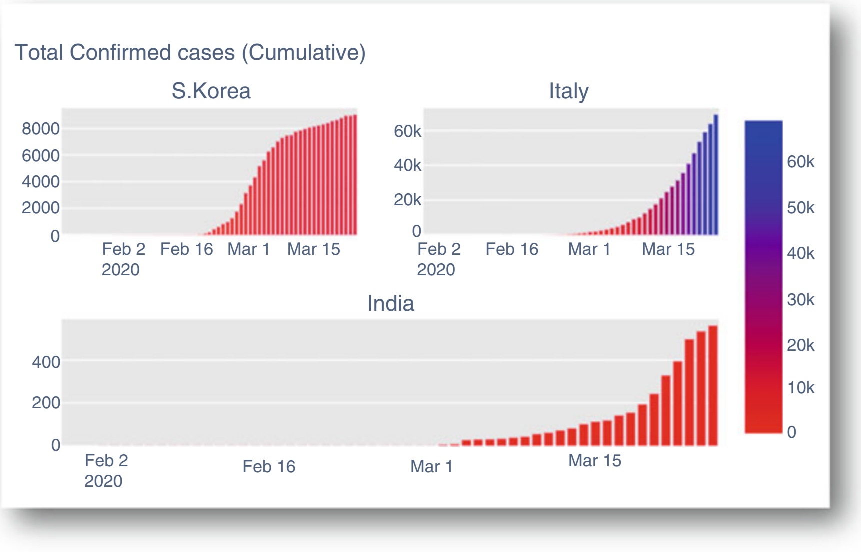

Fig. 14.16 [India: 562; Italy: 69k; South Korea: 9k]

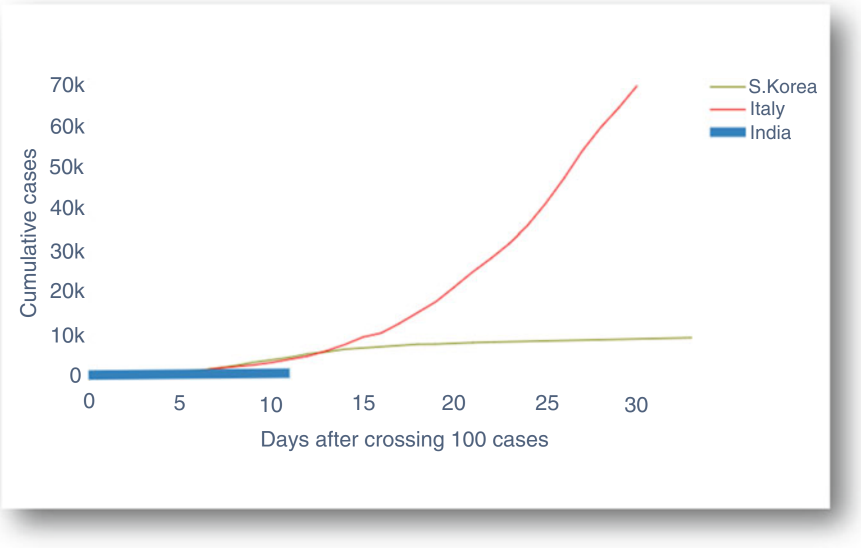

Fig. 14.17 [RED: Italy; Green: South Korea; Blue: India]

According to CNN reports, India does not test enough people to find out whether the total number of reported cases is genuine or not and why the number of tests conducted in a highly populated country with billions of people is lower.

As per experts, India has a lower testing rate because of being under-resourced and an uneven public health system.

14.3.4 Visualize Worldwide Data

Here we are using coloured lines with markers. Blue lines show the total number of confirmed cases around the world, green lines show recovered patients and similarly red line indicates the total number of deaths due to coronavirus in the world (Fig. 14.18).

As we can see, between point A and B there is a sudden rise in graph and not a perfect curve. In fact on 12th of February an organization came up with a unique method of counting affected people, but by the end of the day they realize that this is not a proper method to count fatalities. Hence, they were back to the original method of counting.

14.4 Forecasting/Prediction

14.4.1 Forecasting the Total Number of Cases Worldwide

For Forecasting and prediction, we use an open-source software called 'Prophet' which is developed by Facebook core data science team.

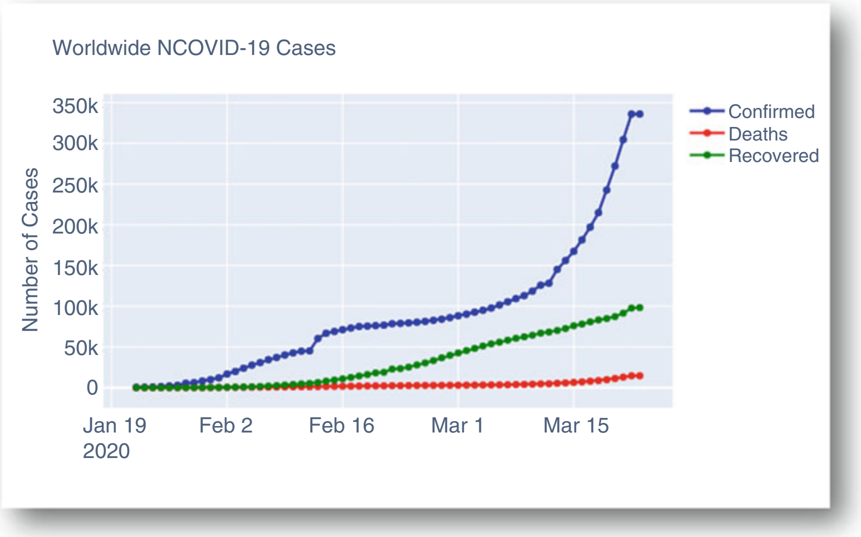

Fig. 14.18 Worldwide graph

We use Prophet for forecasting a sort of time series results-based data on an additive model where nonlinear trends are suitable with yearly, weekly and daily basis.

Why Prophet?

- **Precise and quick**: Prophet is mainly utilized in different applications in Facebook for building authenticate and valid forecasts for goal setting. It is enough quick that you may get forecasts in a bit by using Stan module. Facebook finds it better to execute than any other approach.
- **Automated**: Get a reasonable forecast on messy data with no manual effort. Prophet is robust to outliers, missing data and dramatic changes in your time series.
- **Availability**: Facebook has introduced the Prophet Module procedure with the support of Python and R programming language. Both languages share the Stan code. You can use any language that you are comfortable with.

14.4.1.1 Confirm Cases Forecast

Now, it is time to predict upcoming coronavirus cases in the world. Here we are try to find out a range within which the prediction is going to occur and in addition to that we will find the upper limit and lower limit so that our prediction and values will not deflect so much (Fig. 14.19).

- yhat: values which are predicted.
- yhat_lower: It shows the lower limit which is predicted.
- yhat_upper: It show the upper limit that is predicted.

Tolerance lies between yhat_lower to yhat_upper (Fig. 14.20).

Here we visualize the data in graph by putting some plots. We use *prophet.plot* Method to plot forecast by passing forecast frame.

As per graph, we can see that the graph's line goes beyond 24th of March. The graph is rising constantly day by day (Fig. 14.21).

	ds	yhat	yhat_lower	yhat_upper
64	2020-03-26	355136.872975	334546.613119	374775.244231
65	2020-03-27	372235.326938	352367.910827	391712.469992
66	2020-03-28	388674.964143	367586.464833	410613.983488
67	2020-03-29	405307.954675	382990.550208	427082.101462
68	2020-03-30	418529.648466	394208.184567	439971.819186

Fig. 14.19 Confirmed cases prediction

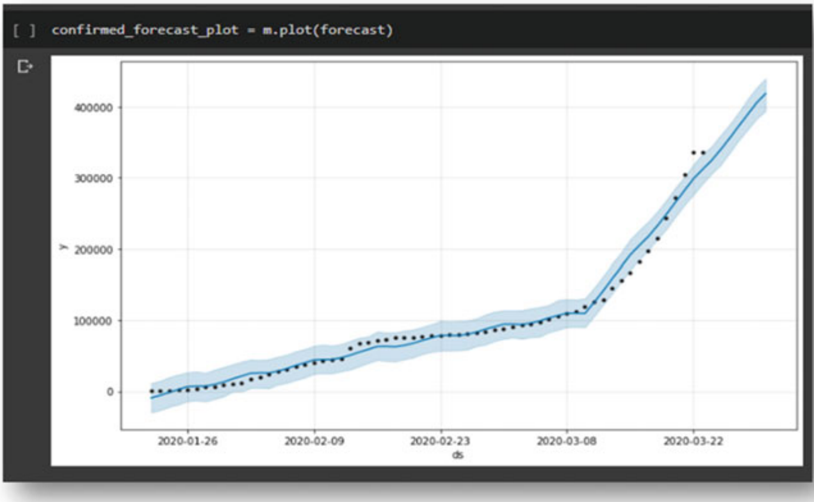

Fig. 14.20 Confirmed forecast

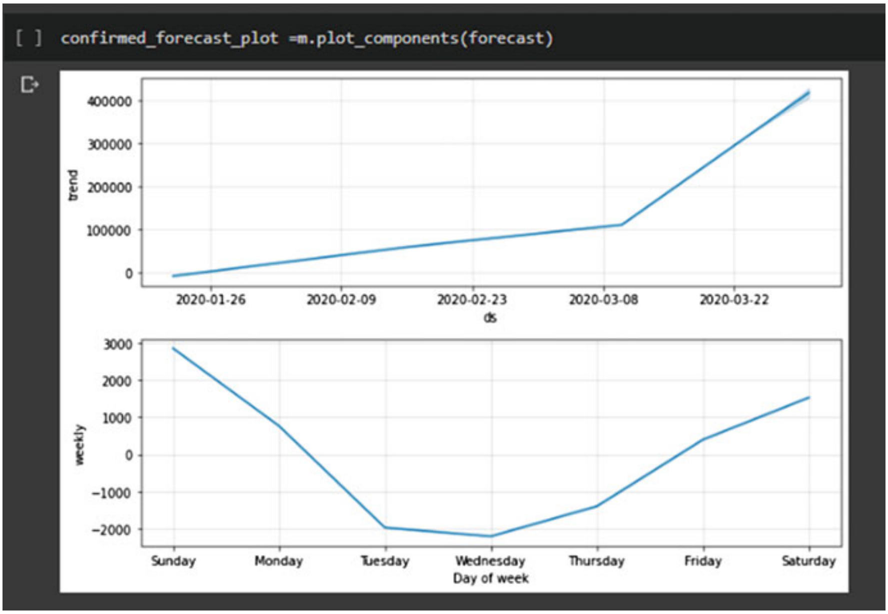

Fig. 14.21 Confirmed forecast *(weekly analysis)*

This graph actually focuses on particular days of a week. As we can see, there is a dip in Tuesday to Wednesday. This is because there is a huge dip in cases in China on that particular day.

14.4.1.2 Death Cases Forecast

Here, in this graph dots represent the actual value and the blue line represents the forecast with upper and lower tolerance as we already calculated and as we can see in the beginning it coincides with each other but after eighth of march there is a spike in death forecast (Fig. 14.22).

According to forecast, the number of deaths comes down from Tuesday through Thursday because obviously the number of confirmed cases is predicted to come down between those 3 days and after that it rises again (Fig. 14.23).

14.5 Conclusion

Do not take your cough and cold lightly as you would. If you look at the data, the number of cases in India is rising just like in Italy, Wuhan, South Korea, Spain and the USA. We have crossed 100,000 cases already. Do not let lower awareness and fewer test numbers ruin the health of our world.

Currently, India is a deadly and risky zone as there are very few COVID-19 test centres available. Imagine how many infected people are still around you and are infecting others unknowingly. If the spread of coronavirus goes along with the

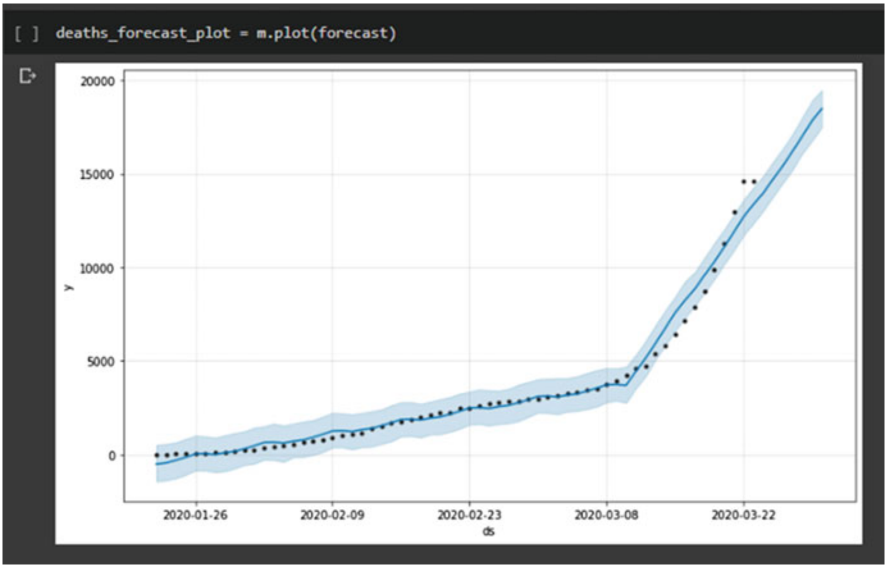

Fig. 14.22 Deaths forecast

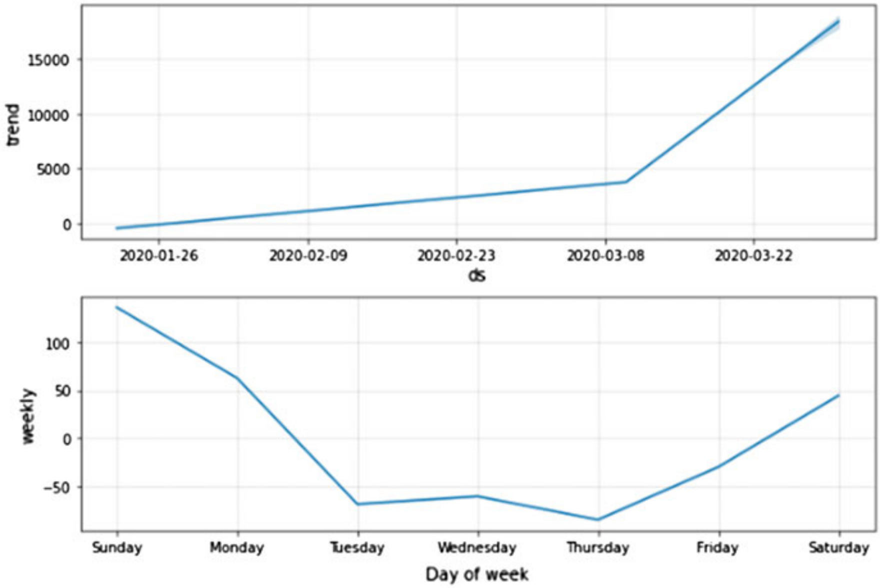

Fig. 14.23 Deaths forecast *(weekly analysis)*

forecast and as per our model, then it would come up with big loss of lives as it indicates exponential growth of the transmission worldwide.

Let us give a hand in fighting this pandemic at least by quarantining ourselves by staying indoors and protecting ourselves and others around us. Take precautions, stay indoors.

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Predictive Risk Analysis by Using Machine Learning During COVID-19

15

Naufil Kazi, Deepa Parasar, and Yogesh Jadhav

Abstract

Coronavirus disease (COVID-19) is a new virus disease caused by inflammation. The disease causes respiratory distress (such as influenza) with manifestations such as cold, cough and fever, and the problem of breathing in progressively severe cases. This chapter is dedicated to the use of machine learning techniques for prediction of safe zone during COVID-19. At this point in the collective experience of coronavirus in the world, it seems clear that travelling will take a while to return 'to normal', i.e. travellers will move across borders as freely without concern as we did before the beginning of 2020. With the increase of COVID-19 cases at an unprecedented rate, everyone wants to know exactly how safe is it to travel to any specific place. As COVID-19 stay-at-home restrictions are began to ease in our community, we might wonder how to visit public places and protect our health.

In this chapter, we propose a system which will collect the database available on government websites related to the statistics of COVID-19, and it will ease the traveller to make decisions for travelling. The application will show a list of places and when we click on a place, it will show different statistics about it. The statistics provided are total cases, total active cases, total deaths, total recovered, chances of getting infected, chances of recovery if infected and chances of dying if infected. The calculation for chances of getting infected with coronavirus is done by using an average spread rate of 1.8. A statewide spread rate can be used for more accurate calculations. Travelling history of persons will also help in predicting safety while travelling. This feature will be helpful to travellers and to

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others who come in social contact with them. Nowadays, artificial intelligence and machine learning play a very important role in prediction of diseases, and especially in the current scenario of COVID-19 pandemic. The system will be beneficial for the prediction of safety while travelling in other regions with high number of infectious cases.

Keywords

COVID-19 · Machine learning · Corona statistics app · Risk prediction

15.1 Introduction

This chapter is dedicated to the use of machine learning techniques for the prediction of the safe zones during COVID-19. It is widely accepted that there are seven steps to perform any type of machine learning (Alimadadi et al. 2020). They are as follows:

1. Data collection
2. Data preparation
3. Choose a model
4. Train the model
5. Evaluate the model
6. Parameter tuning
7. Make predictions

First, we must understand what coronavirus is. By now, coronavirus has infected more than 13 lakh people in India and is increasing at an exponential rate (Chatterjee et al. 2020; Zheng et al. 2020). The reason for this growth is the ways through which coronavirus enters a human body. There are basically two ways through which coronavirus enters our body: direct and indirect.

Coronavirus can enter our body directly through the air if we inhale the air exhaled from an infected patient (Khadidos et al. 2020; Satpathy et al. 2021). Though it is said to maintain a 6 ft distance from people passing by, it can travel longer distances if it has spread through breeze of air.

Indirectly it can travel by sticking to things we use in our daily life; as when we touch them, it sits on our finger and from our finger it enters our body. Hence, washing hands and avoiding touching mouth/nose are a necessity to fight the virus.

When the virus enters our body, it goes to our lungs/intestines and begins to multiply by feeding on the cells of their walls.

During this period, a person can or cannot see symptoms of COVID-19. The body prompts the immune system when the cell starts destroying but the virus protects itself by distracting the immune system and making it more harmful to the body.

In most cases, the immune system regains stability and gains control over the virus saving our body, though in some cases the virus wins and the immune system ends up killing the subject.

The time the immune system takes to gain stability is also to be considered, as by then the virus destroys a lot of our lung cells, which make them vulnerable to other bacteria.

Even if the immune system wins over the coronavirus, the body is much more vulnerable to catch any other disease than it was before.

Coronavirus sticks by two rules of survival, which are multiply and expand.

It multiplies by feeding on the lung cells and expands by travelling through air/resting on various objects. Hence, until an antidote is found, it can be easily said that the virus is here to stay.

15.2 Existing Work

15.2.1 Aarogya Setu

Aarogya Setu (Gupta et al. 2020) is an Indian open-source COVID-19 app for contact tracing, syndromic planning and self-evaluation. It is basically a portable application for digital assistance, created by the National Informatics Center under the Ministry of Electronics and Information Technology (MeitY).

The expressed reason for this application is to spread consciousness about COVID-19 and to associate fundamental COVID-19-related well-being administrations to the individuals of India. This application increases the activities of the Department of Health to contain COVID-19 and offers best practices and warnings. It is a tracking application which utilizes the cell phone's GPS and Bluetooth to highlight coronavirus contamination and COVID-19 hotspots. The application is accessible from Android and iOS. With Bluetooth, it attempts to decide the hazard in the event that one has been close (less than 6 ft of) to a COVID-19-infected individual, by looking over an information base of known cases across India. Utilizing area data, it decides if the area one is in has a place with one of the contaminated zones dependent on the information accessible.

15.2.2 Other International Apps

15.2.2.1 China

China is the country where the COVID-19 pandemic began. It was also one of the countries to control the growth of coronavirus efficiently. The Chinese government, related to Alipay and WeChat, has conveyed an application that permits residents to check on the off-chance that they have been in contact with individuals who have COVID-19. It is being used across in more than 200 Chinese cities. Exiles taking trips to China are likewise required to show the QR code demonstrating their well-being qualification to load up before the flight.

15.2.2.2 Italy

The greatest fear spread during the early days of COVID-19 was attributed to Italy's shockingly high number of deaths every day. On 1 June 2020, the Ministry of Health introduced the implementation notification arrangement of the Italian Government, 'Immuni [it]', an iOS and Android touch after extending the application on the head of the Google/Apple API. The arrangement was recognized by the special Commissioner for the COVID-19 crisis (Chair of the Council of Ministers) in a joint effort with the Ministry of Health and the Ministry of Agriculture.

15.2.2.3 Australia

COVIDSafe is an advanced contact tracing application announced by the Australian Government on 14 April 2020 to help fight the ongoing COVID-19. The application is based on the BlueTrace convention created by the Singaporean Government and was first released on 26 April 2020.

15.2.2.4 Austria

Stopp Corona is an application published by the Austrian Red Cross on behalf of the Federal Ministry of Health. The app is supported on both Android and iOS devices. The source code was released as open source on GitHub on 24 April 2020.

15.2.2.5 Bahrain

BeAware Bahrain is the official flexible framework developed by the Information and eGovernment Authority (iGA) for Android and iOS, as a team with the National Coronavirus Combating Task Force (COVID-19). After attempting to distinguish and monitor each complex case and its contacts, the program attempts to minimize the COVID-19 spread. This application provides warning to the user when they are near a containment zone, that is, the geographical location where the spread of coronavirus is more rampant. It also publishes worldwide COVID-19 health tips and live information.

15.2.2.6 Bangladesh

The Government of the Republic of Bangladesh announced and propelled a flexible application in Google Play Store called Corona Tracer BD in May 2020. However, there are also several truly effective non-governmental portable apps and sites that are used to tell Bangladesh individuals which spots are affected by COVID-19 and how many COVID-19 patients are there at a spot. Robi, Bangladesh's late telecom agency, improve the COVID-19 administration which someone from anywhere in the world might know the possible response that coronavirus affects him/her or not.

15.2.2.7 Canada

The legislature of Canada released 'COVID Alert', a presentation notice application, for restricted delivery in Ontario beginning 31 July 2020. After testing in that area, it is relied upon and became available in nearly all Canadian provinces.

15.2.2.8 Colombia

CoronApp is the portable Android and iOS application developed by the Colombian government—also available from Huawei AppGallery. This application provides information about nearby containment zones and spread of coronavirus in that area. CoronApp promotes the continuous monitoring of information obtained at the *InstitutoNacional de Salud* (National Health Institute, INS) Emergency Operations Center. The Colombian government will return 1 GB per month and 100 min for customers of prepaid lines who implement it as an extra benefit of the service.

15.2.2.9 Denmark

Smittestop is an advanced communication application created by the Ministry of Health and the Elderly, the Danish Patient Safety Department, the National Health Board, the Danish Serum Institute, the National Digitization Board and the Netcompany. It was released to help tackle the ongoing COVID-19 pandemic on 18 June 2020. The application uses Bluetooth to alert the user in case a COVID-19-positive person was within 1 m for more than 15 min. On the Google Play Store and Apple store, it is available.

15.2.2.10 France

The French National Assembly confirmed StopCovid [fr]'s arrival on 27 May 2020 to help combat the COVID-19 pandemic. StopCovid is a computerized application that has evolved amazingly, which uses bluetooth-based tracing. It is effective from 2 June 2020.

15.2.2.11 Germany

On 16 June 2020, the authority application called 'Crown Warn-App' was made available for download, and the exact day was announced in a public interview. It was developed by Deutsche Telekom and SAP with rational advice from Robert Koch Institute (government's central institution) using open-source programming and uses Google and Apple's Exposure Notification APIs.

15.2.2.12 Israel

On 22 March 2020 the Ministry of Health published 'HaMagen', an iOS and Android contact tracing app. Hamagen tracks a client's whereabouts utilizing standard area APIs and afterward compares them to known movements of those diagnosed to have COVID-19 to check if paths crossed within the past 14 days. The Hamagen application was explicitly planned with a security-first methodology, where data about areas and times are cross-referred to on the client's gadget and not sent to the cloud database.

15.2.2.13 Jordan

The AMAN App-Jordan application is developed by COVID-19 JOTECH Group for Jordan's Ministry of Health, a group of well-informed volunteers who want to use Jordan's tech skills to combat the coronavirus pandemic. AMAN is a secure app, which also provides location details. The app was launched on 21 May 2020 and is currently available on the Google Play Store and the App Store. It is soon to be available for download on AppGallery. More people have shown interest in this app, and they will use this application once it is available.

15.2.2.14 Nepal

The Nepal Engineers Association launched COVIRA application in response to COVID-19, produced by Science Hub on 22 June 2020. COVIRA was built on a multidisciplinary system, where the risk level is considered to be provided by a few variables. It can very well be used for specific hazard assessment that can be surveyed from all over the world, and territorial hazard in palika level is given to Nepal. This can be viewed on the web application portal.

15.2.2.15 New Zealand

The NZ COVID Tracer was pushed by the Health Ministry on May 20, but a few customers reported that they had the option to get to the app on May 19. The app is available on Apple's App Store and Google Play Store. NZ COVID Tracer application provides a very useful feature, that is, they are allowing clients to select their own QR code.

15.2.2.16 Qatar

Ehteraz (application) has enabled residents and inhabitants of Qatar to travel easily and attentively within the nation while helping the specialists to prevent coronavirus spread (COVID-19). A Cabinet option that came into force on May 22 requires residents and visitors to incorporate and enact the flexible application on their mobile phones compulsorily when going out in some way, shape or type. From that point on, an ever-increasing number of cases in the nation made it compulsory for customers and visitors to be allowed to show the green status on the Ehteraz application board at their premises. Apart from hypermarkets and other retail outlets, banks in Qatar have in place comparative steps, including a few industrial systems and workplaces, to help prevent the spread of COVID-19.

15.2.2.17 Saudi Arabia

Crown Map Saudi Arabia is the official, portable application created by the National Health Information Center (NHIC) for the Internet, Android and iOS. It is a smart guide program that allows clients to trace all of the COVID-19 cases on the planet with measurements and diagrams and the ability to converse with a chatbot named BashairBot to respond to COVID-19 inquiries. Over 130,000 customers have downloaded the software.

15.2.2.18 Singapore

An application called TraceTogether is being used. It utilizes a computerized contact tracing convention called BlueTrace, created with an open-source reference usage called OpenTrace.

15.2.2.19 Spain

The authority program, named Radar COVID, was delivered for a pilot test in La Gomera by the Ministry of Economic Affairs and Digital Transformation for Android and iOS. This application relies on the DP-3 T convention and uses Apple/Google API for communication, and in September, it is secure to make it easier for Spanish areas. A group of volunteers has developed another program called OpenCoronavirus. This app uses the data collected from uncentralized locations by using conventions such as MFP-3 (Cho et al. 2020).

15.2.3 Problem

First and foremost, most, if not all of these, apps are government controlled and thus have access to a constantly updating database (Dhar 2020; Morley et al. 2020). With the help of this database, they use mapping to predict zones of danger. This is good, but it is restricted to larger areas like entire cities.

We intend to make software that could span an area as small as a society and give decent if not accurate results. For smaller areas, which we intend to target, these apps seem to rely on user inputs, which is an unreliable source. Though it must be noted that this approach was an astonishing success in South Korea, but there, the data privacy laws are quite strong as compared to India.

The government may not use our data for personal reasons, but Indians are concerned about data privacy because their data which is collected by government might be used for another purpose; therefore users are not showing interest to use this app.

Just the thought of being away from our family for 20 or more days stops many people from speaking out. The fear of coronavirus has caused many people to hide it when they notice the symptoms for themselves.

This method is famously called as the survey method, and historically, it has seemed to fail mostly.

Hence, we decided to take a different approach for our project. With this project, we decided to go with the pattern analysis method. This in simple terms means analysing patterns in cases to make predictions.

Pattern analysis and survey are often used together to improve prediction accuracy but that we intend to keep as a future scope of the project. For the first stage, we shall rely on pattern analysis itself for making the predictions.

Before we go on to analyse patterns, we need to collect data in order to search for patterns in them. This we do by breaking down what we understood about Coronavirus into what can we get out of it.

15.3 Things to Consider Regarding Coronavirus

For starters, coronavirus spreads directly through the air. This means that places with higher population density are more affected by the spread of the virus. Urban cities, entertainment hubs, gatherings, etc. are a few examples of this (Qasim et al. 2020).

The population of a place is often seen to increase in direct proportion to the increase in the development. Hence, developed places are prime targets of coronavirus.

We also know that factors such as a good breeze can increase the range of the virus. In some cases, it has travelled for up to 14 ft due to a good breeze carrying it. This makes the places having good flow of air more prone to be infected by coronavirus.

The chances of getting infected are high in a place next to the sea, a mountain range or even on a mountain. Other than this, a restaurant or any place where there is a directed air conditioner can also cause this effect.

Since coronavirus spreads indirectly through resting on the things, an unhygienic place is more likely to spread coronavirus than a hygienic one. Coronavirus also has different survival times on different types of materials; hence, it is likely to spread in a favourable environment.

For example, coronavirus stays alive for 4 days on the surface of glass; hence, if an infected person had transmitted the virus to a glass and you come in contact with the glass surface within 4 days' time, you can be infected with coronavirus.

We know that COVID-19-positive individuals may not show symptoms while the virus is multiplying in the lungs. This is, in fact, true for almost 40% of the infected people, which make them a silent transporter of coronavirus.

This means just because someone looks fit, it is not necessary that they do not have coronavirus.

This information may seem vague, but we must consider that people with less or decent incomes often decide their health condition based on how they are feeling at the moment. This makes the lower income group a better target.

People with lower income or unstable income such as businessmen are often in contact with many people. The reason can be a jam-packed colony, a business outlet, etc.

Add to this they are also not willing to stop working as that stops their income. Hence, people with lower/average income and businessmen are great potential targets for coronavirus.

Though lower-income people or businessmen spread coronavirus to a smaller area, there are people who can spread it to a much wider area. They are travellers/ tourists.

One may not even know if he/she was the sole reason for spreading coronavirus in an entire city because they never noticed the symptoms while they were travelling. Thus, places with a high number of travellers are more prone to the spread of coronavirus.

Finally, we also did notice that people with stronger lungs or better immune systems have a good chance of getting rid of the virus.

Thus, healthier people are less likely to die even if they contract the virus. Old people are more at risk because of their weakened organs and immune system overtime (Ioannidis et al. 2020; Singh and Adhikari 2020).

Testing for COVID-19 is also something we should consider, but it is more complex than any other topics I mentioned above. This is because testing if someone is COVID-19-positive or not depends on various factors.

The amount of testing kits available, the time taken for a test to be performed, the demand from people to get tested, the delay from being tested to getting results, etc. are some of the things that we will need to take into consideration.

One cannot directly point which place is more vulnerable because of the number of testing kits, but it can be said that a place with enough testing kits and people willing to get tested as soon as they notice a symptom can help a lot to control the spread.

Thus, based on the analysis we did, the following data is necessary to identify the probability of the spread of coronavirus:

1. Location
2. Development
3. Population density
4. Cleanliness
5. The number of restaurants, malls, tourist attractions, theatres, etc.
6. Number of lower/average income people and businessmen
7. Incoming and outgoing travellers/tourists
8. Number of already unhealthy people
9. Number of old people
10. Number of testing kits available
11. The ratio of testing kits to a number of people willing to get tested

Now, since we have understood where to look, we must start looking for data, and this is a very difficult part. We could not get all the 11 datasets we wished to get, but we did improvise through our data collection phase getting a surprising amount of data.

15.4 Data Collection

In previous sections, we made a list based on the knowledge available about coronavirus, which could help get potential data about it. The first element on the list is location. To make things simpler for the initial stage, we went on and gathered information about states and union territories of India for the first prototype.

A future implementation of getting automatically updated from the government website will be discussed, but to keep things simple at first we begin with a csv file holding the data (Table 15.1).

The second thing on our list is development. This is where things began to get complicated as no state in India is completely developed. To tackle this problem, we

Table 15.1 State-wise statistics of coronavirus

State	Total	Deaths	Recoveries	Active
Gujarat	20,070	1249	13,635	5186
West Bengal	8187	396	3303	4488
Madhya Pradesh	9401	412	6331	2658
Telangana	3650	137	1710	1803
Maharashtra	85,975	3060	39,314	43,601
Delhi	28,936	812	10,999	17,125
Meghalaya	36	1	13	22
Uttar Pradesh	10,536	275	6185	4076
Rajasthan	10,599	240	7641	2718
Punjab	2608	51	2106	451
Andhra Pradesh	4708	75	2682	1951
Chandigarh	314	5	273	36
Himachal Pradesh	413	5	224	184
Karnataka	5452	61	2132	3259
Jammu and Kashmir	4087	41	1216	2830
Ladakh	103	1	50	52
Uttarakhand	1355	13	528	814
Tamil Nadu	31,667	269	16,999	14,399
Kerala	1914	15	803	1096
Jharkhand	1099	7	490	602
Haryana	4448	28	2134	2286
Bihar	5088	30	2480	2578
Chhattisgarh	1073	4	283	786
Odisha	2856	9	1894	953
Assam	2565	4	615	1946
Tripura	800	0	192	608
Goa	300	0	65	235
Nagaland	118	0	8	110
Puducherry	99	0	36	63
Manipur	172	0	52	120
Arunachal Pradesh	51	0	1	50
Dadra and Nagar Haveli and Daman and Diu	20	0	2	18
Mizoram	34	0	1	33
Sikkim	7	0	0	7
Andaman and Nicobar Islands	33	0	33	0
Lakshadweep	0	0	0	0

will consider the number of developed cities in a given state. The only problem here is that even if we consider metropolitan cities as developed cities, there are just 12 of them. Hence, we must bend the definition of developed city and consider urban agglomerations instead of it. The data received after making this compromise is

Table 15.2 Numbers of urban agglomerations

State	Number of urban agglomerations
Gujarat	4
West Bengal	2
Madhya Pradesh	4
Telangana	1
Maharashtra	6
Delhi	1
Uttar Pradesh	7
Rajasthan	3
Punjab	2
Andhra Pradesh	2
Chandigarh	1
Karnataka	1
Jammu and Kashmir	1
Tamil Nadu	4
Kerala	7
Jharkhand	3
Haryana	1
Bihar	1
Chhattisgarh	2

surprising. All of these urban agglomerations have a population of more than one million and together consist of 43% of India's population (Table 15.2).

The next thing on our list is population density. Following is the population density state wise (Table 15.3).

The next topic is cleanliness. This, just like development, is a subjective matter and varies vastly within a state from region to region. Unlike development, we could not draw a direct line as to how many cities to consider from the top-ranking cities. Since cleanliness is more a city-centric topic, we will omit it for our current implementation.

The next couple of topics include the number of restaurants, malls, theatres, etc. and the number of lower-income people along with the number of business holders. Both the topics are very difficult to calculate since there are a vast number of both identified and unidentified units. Hence, to simplify the project, we will also omit these two.

Now, next in line, we have old age population. As per the census, the percentage of the senior citizen in the total population of the city is provided in Table 15.4.

The next few points include the number of already unhealthy people, number of testing kits available and number of testing kits as compared to people willing to test; all these data may be available to collect but will end up being a long endless process.

While working on the project, another differentiating point was thought: this is the literacy rate of the states.

Table 15.3 Population densities of Indian states

State	Population density/km^2
West Bengal	1102
Delhi	11,297
Nagaland	119
Manipur	122
Himachal Pradesh	123
Meghalaya	132
Arunachal Pradesh	17
Uttarakhand	189
Chhattisgarh	189
Lakshadweep	2013
Puducherry	2598
Ladakh	2.8
Rajasthan	201
Madhya Pradesh	236
Odisha	269
Jammu and Kashmir	297
Andhra Pradesh	303
Uttar Pradesh	303
Gujarat	308
Telangana	312
Karnataka	319
Tripura	350
Bihar	365
Goa	394
Assam	397
Jharkhand	414
Andaman and Nicobar Islands	46
Mizoram	52
Punjab	550
Tamil Nadu	555
Haryana	573
Maharashtra	828
Kerala	859
Sikkim	86
Chandigarh	9252
Dadra and Nagar Haveli and Daman and Diu	970

A more literate population will adapt to things like social distancing and follow hygiene rules better; hence, it was considered as a factor.

After another search through the census, we found the literacy rate of various states, which is provided in Table 15.5.

Table 15.4 Population percentages of senior citizens

State	Sr. C (%)
Kerala	10.6
Manipur	10
Goa	10
Himachal Pradesh	10
Punjab	9.2
Tamil Nadu	8.9
Maharashtra	8.9
Uttarakhand	8.8
Odisha	8.3
Puducherry	8
Karnataka	7.9
Andhra Pradesh	7.7
Telangana	7.7
Haryana	7.6
Chhattisgarh	7.5
Madhya Pradesh	7.2
West Bengal	7.1
Ladakh	7
Jammu and Kashmir	7
Uttar Pradesh	7
Gujarat	7
Rajasthan	6.8
Tripura	6.7
Bihar	6.7
Assam	6.2
Jharkhand	6.2
Lakshadweep	6.1
Mizoram	5.6
Delhi	5.4
Arunachal Pradesh	5
Nagaland	5
Meghalaya	5
Dadra and Nagar Haveli and Daman and Diu	4.6
Chandigarh	4.4
Sikkim	4
Andaman and Nicobar Islands	2.5

Finally, since population varies amongst the states, we must multiply the Sr. citizen percentages and the literacy rate with the actual population, giving us the actual numbers of senior citizens and literate people.

Also, the number of recovery and death combined is total cases minus the active number of cases; hence, we made a column for that as well. Our final data is provided in Table 15.6.

Table 15.5 Literacy rate of various states of India

State	Literacy rate
Andaman and Nicobar Islands	86.6
Andhra Pradesh	67
Arunachal Pradesh	65.4
Assam	72.2
Bihar	61.8
Chandigarh	86
Chhattisgarh	70.3
Dadra and Nagar Haveli and Daman and Diu	80
Delhi	86.2
Goa	88.7
Gujarat	78
Haryana	75.6
Himachal Pradesh	82.8
Jammu and Kashmir	67.2
Jharkhand	66.4
Karnataka	75.4
Kerala	94
Ladakh	67.2
Lakshadweep	91.8
Madhya Pradesh	69.3
Maharashtra	82.3
Manipur	79.2
Meghalaya	74.4
Mizoram	91.3
Nagaland	79.6
Odisha	72.9
Puducherry	85.8
Punjab	75.8
Rajasthan	66.1
Sikkim	81.4
Tamil Nadu	80.1
Telangana	67
Tripura	87.2
Uttar Pradesh	67.7
Uttarakhand	78.8
West Bengal	76.3

The type of data in this project is in a csv file, which cannot be updated through the app. It can be updated, but we want to avoid untrusted users to reduce the integrity of the data, hence, we have not included the option yet.

Web scrapping was done mainly through the census of 2001 and 2011 and the coronavirus data provided by the WHO.

Table 15.6 Complete dataset

Id	State	Population	Number count	Literate P	Sr. Count	Population	Total-active	Recoveries	Deaths	Literacy Rate	Sr. C Percentage	Total	Active
1	Gujarat	60,439,692	4	47,142,960	4,230,778	308	48,990	46,504	2486	78	7	63,562	14,572
2	West Bengal	91,276,115	2	69,643,676	6,489,604	1102	54,408	52,730	1678	76.3	7.1	75,516	21,108
3	Madhya Pradesh	72,626,809	4	50,330,379	5,229,130	236	24,436	23,550	886	69.3	7.2	33,535	9099
4	Telangana	30,500,000	1	20,435,000	2,348,500	312	48,130	47,590	540	67	7.7	66,677	18,547
5	Maharashtra	1.12E + 08	6	92,484,076	1,000,1316	828	292,385	276,809	15,576	82.3	8.9	441,228	148,843
6	Delhi	16,787,941	1	14,471,205	906,548.8	11,297	127,321	123,317	4004	86.2	5.4	137,677	10,356
7	Meghalaya	2,956,889	0	2,207,365	148,344.5	132	269	264	5	74.4	5	874	605
8	Uttar Pradesh	2E + 08	7	1.35E + 08	13,985,864	303	54,898	53,168	1730	67.7	7	92,921	38,023
9	Rajasthan	68,548,437	3	45,310,517	4,661,294	201	31,413	30,710	703	66.1	6.8	43,804	12,391
10	Punjab	27,743,338	2	21,029,450	2,552,387	550	11,889	11,466	423	75.8	9.2	17,853	5954
11	Andhra Pradesh	84,580,777	2	56,669,121	6,512,720	303	84,360	82,885	1474	67	7.7	158,764	74,404
12	Chandigarh	1,055,450	1	907,687	46,439.8	9252	717	698	19	86	4.4	1117	400
13	Himachal	6,854,602	0	5,683,890	685,460.2	123	1573	1559	14	82.8	10	2703	1130
14	Karnataka	61,095,297	1	46,065,854	4,826,528	319	60,221	57,725	2496	75.4	7.9	134,819	74,598
15	Jammu an	12,500,000	1	8,400,000	875,000	297	13,523	13,127	396	67.2	7	21,416	7893
16	Ladakh	41,302	0	27,754.94	2891.14	2.8	1115	1108	7	67.2	7	1466	351
17	Uttarakhat	10,086,292	0	7,947,998	887,593.7	189	4523	4437	86	78.8	8.8	7593	3070
18	Tamil Nadu	72,147,030	4	57,789,771	6,421,085	555	200,615	195,483	4132	80.1	8.9	257,613	56,998
19	Kerala	33,406,061	7	31,401,697	3,541,042	859	14,545	14,463	82	94	10.6	25,911	11,366
20	Jharkhand	32,988,134	3	21,904,121	2,045,264	414	4810	4682	118	66.4	6.2	12,523	7723
21	Haryana	25,351,462	1	19,165,705	1,926,711	573	30,123	29,690	433	75.6	7.6	36,519	6396
22	Bihar	1.04E + 08	1	64,333,461	6,974,663	365	36,718	363	329	61.8	6.7	57,024	20,306
23	Chhattisgarh	25,545,198	2	17,958,274	1,915,890	189	7049	6991	58	703	7.5	9531	2482
24	Odisha	41,974,218	0	30,599,205	3,483,850	269	22,152	21,955	197	72.9	8.3	34,913	12,761
25	Assam	31,205,576	0	22,530,426	1,934,746	397	32,489	32,384	105	72.2	6.2	42,904	10,415

(continued)

Table 15.6 (continued)

Id	State	Population	Number count	Literate P	Sr. Count	Population	Total-active	Recoveries	Deaths	Literacy Rate	Sr. C Percentage	Total	Active
26	Tripura	3,673,917	0	3,203,656	246,152.4	350	3632	3605	27	87.2	6.7	5374	1742
27	Goa	1,458,545	0	1,293,729	145,854.5	394	4721	4668	53	88.7	10	6530	1809
28	Nagaland	1,978,502	0	1,574,888	98,925.1	119	653	648	5	79.6	5	1935	1282
29	Puducherry	1,247,953	0	1,070,744	99,836.24	2598	2361	2309	52	85.8	8	3806	1445
30	Manipur	2,855,794	0	2,261,789	285,579.4	122	1744	1737	7	79.2	10	2831	1087
31	Arunachal	1,383,727	0	904,957.5	69,186.35	17	999	996	3	65.4	5	1698	699
32	Dadra and	586,000	0	468,810	26,956	970	768	766	2	80	4.6	1184	416
33	Mizoram	1,097,206	0	1,001,749	61,443.54	52	258	258	0	91.3	5.6	482	224
34	Sikkim	610,577	0	497,009.7	24,423.08	86	290	289	1	81.4	4	658	368
35	Andaman	330,581	0	329,583.2	9514.53	46	250	242	8	86.6	2.5	734	484
36	Lakshadweep	64,473	0	59,186.21	3932.85	2013	0	0	0	91.8	6.1	0	0

In some cases, local political party websites and social media were used to collect data, but they cannot be trusted a lot and were used only if extremely necessary since it is a data that the political party uses to promote themselves so it may not be very accurate.

At this stage, we finally began to decide what we are going to make in terms of GUI. This was a surprisingly difficult decision to make considering the ample amount of data already available on the Internet.

We faced two questions we needed to answer; they were:

Since we have all the data about each state readily available on the Internet, what could this app possibly be beneficial for?

The project focuses on telling whether visiting a place is safe or not, but how can we tell it?

The answer to both the questions is not as simple as we thought at first. Yes, we can tell a user whether visiting an area is safe or not, but for that just the name of the area will not suffice. The user would need to enter the following details:

1. The population of the area
2. Total cases in the area
3. Total active cases in the area
4. The area in km^2

Once the user enters the details, we can feed the details into our machine learning application, and the statistics can be obtained.

Yes, this may be a bit too much to ask from the user, but all the above data can be obtained on a single phone call to a person living in the area since the number of recoveries or deaths, etc. is not required.

The application promotes usage only when it is important to visit a place and should not be used as an excuse to visit a place. Hence, asking for the abovementioned details can be considered as a step for precaution and reconsideration.

15.5 Proposed System

Our program will ask the user the following questions:

1. Which state are you going to visit?
2. Total population of the area you are going to visit?
3. Total cases in the area?
4. Total active cases in the area?
5. Area in km^2

Once the user enters this data, the program will run its ML model to identify the following things:

1. Approximately how many people have recovered in the area?
2. What percentage of the total cases is this number?
3. What percentage of people in the area are affected and detected?
4. What percentage of people are probably affected in total in the area?
5. What percentage of the population in the area is at risk of being affected?

This will be shown as an output followed by a note to not visit any area is not extremely important.

A secondary task of the project would be to show state-wise statistics regarding coronavirus. This does not really involve machine learning; we just thought to include it because we had collected the data for every state so why not share it with the users if they are willing to know.

We had already decided to use machine learning for this project, but what method we were going to use was an unanswered question (Fauci et al. 2020).

15.6 Method Used

At first, it seemed quite obvious that the model selected in this stage will be multi-linear regression.

Just to be sure though, we tried polynomial regression, but unfortunately, the model failed to deliver results fewer than 50% error rate.

To train the selected multi-linear regression model, we used the following libraries:

1. Numpy
2. Pandas
3. Sklearn

Since it is better to predict only one entity using multi-linear regression, we proceeded with predicting the number of people that recovered after machine learning is performed.

At first, we guessed that once the recoveries are predicted, we could just subtract it with total minus active cases number, but since it was a predicted number, sometimes it would cross the subtraction value giving negative values. Another approach was followed more on that later.

Since we were now pretty clear of what we wanted to make, it was time to make a model and train it.

We used the Linear Regression function from the sklearn library to perform the model training.

We split the database into 80:20 ratios for training and testing.

Table 15.7 shows the results of the test.

The error went up to as high as 43.5% but was even as low as 0.5% in some cases. The cumulative error rate was 0.9724% while the average error rate was 8.9%.

Table 15.7 Predicted vs real values

Predicted	Real
4.71e + 04	4.76e + 04
2.84e + 05	2.77e + 05
1.32e + 04	1.45e + 04
1.95e + 05	1.96e + 05
3.79e + 02	2.64e + 02
5.88e + 04	5.77e + 04
4.72e + 04	4.65e + 04
1.11e + 03	9.96e + 02

Since the average error rate is under 10%, we decided to use the model for our project.

15.7 Performance Measure

As mentioned above, the error rate went up to as high as 43.5% but was even as low as 0.5% in some cases. We needed to know exactly how reliable our method was. So we ran a small test on it to check whether it is accurate or it needs tuning?

A small test program was developed to run along with the model created and the following data were given:

1. Total number of people: 380,581
2. Total cases in area: 734
3. Total active cases: 484
4. Area in km^2: 8250

The result of this test was 373. The data used in this test was actually the data of Andaman and Nicobar Islands. The number obtained was not very close to the real number, which is 270, but was also not very far from it. Hence to improve it, we ran a number of tests to check what may be causing the difference. A study of the results concluded that the results were affected due to the huge areas of the state.

The error rate reduced as the area increased, and this was not an ideal thing for a project solely designed for measuring cases in particular areas. To counter this problem, we decided to add the data of the following cities in the database:

1. Mumbai
2. Chennai
3. Bangalore
4. Kolkata
5. Hyderabad

To make the dataset suit the cities being added, the column on the number of urban agglomerations was removed. As a surprise, no exact data was available for

Bangalore, Kolkata and Hyderabad; hence, their data were replaced by two lesser-developed cities: Agra and Nagpur (Table 15.8).

The model was a rerun, this time on the data of Raigad district. The output observed was 2907, which was pretty close to 2741, the real number.

As an additional measure, we added the data collected about Raigad district to our database as well. After a few tests were done, we observed better results. With this, we concluded the model's training and testing.

15.8 Designing the GUI

With the selection and tuning done, it was time to design the interface on which the model would run.

We decided to have a four screen interface for the program. They would be as follows:

1. Home
2. Accuracy Report
3. State-wise Statistics
4. Corona Calculator

We used Tkinter library for most of our interface design.

15.8.1 Home Window

The home page has one text box and four buttons. The text box acts as a greeting window since it is the first screen a user will see.

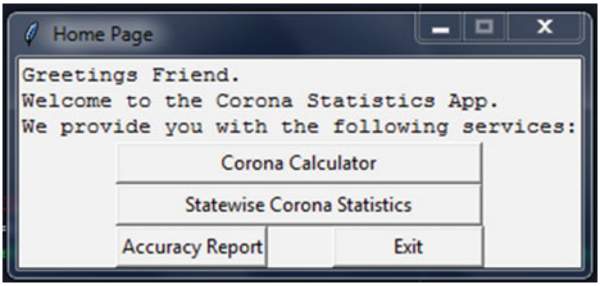
The four buttons are:

1. Corona Calculator
2. State-wise Corona Statistics
3. Accuracy Report
4. Exit
   - The first button, which is corona calculator, would take the user to the corona calculator page.
   - The state-wise statistics option will follow similar route taking the user to state-wise statistics page.
   - The accuracy report will provide the user with a sort of disclaimer regarding the accuracy of our project.
   - Finally, the exit button will close the program.

The output of home screen is:

Table 15.8 Added entries

State/ city	Population	Literate P	Sr. C	Population density/km^2	Total-active	Recoveries	Deaths	Literacy R	Sr. C Pece	Total	Active
Mumbai	18,394,912	15,139,013	1,637,147	30,485.43586	355,367	333,000	17,367	82.3	8.9	503,000	147,633
Chennai	8,653,521	6,931,470	770,163.4	20,313.42958	97,463	95,161	2302	80.1	8.9	109,117	11,654
Agra	1,590,000	1,076,430	111,300	18,275.86207	1288	1192	96	67.7	7	1441	153
Nagpur	2,410,000	1,983,430	214,490	10,593.06503	1311	1296	15	82.3	8.9	1719	403



15.8.2 Accuracy Report

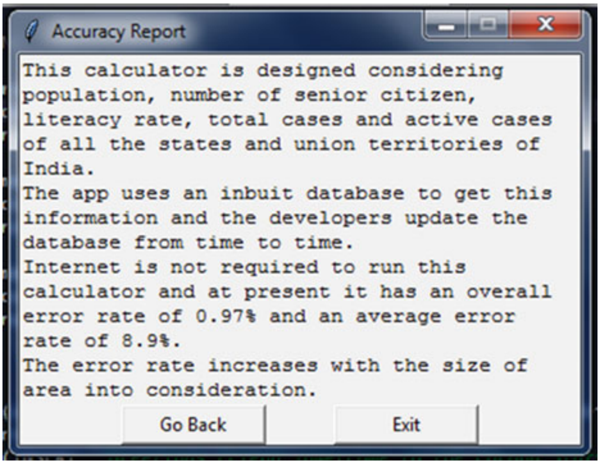
This screen acts as a disclaimer screen to warn the users of the error percentages of the app.

The message to be given is:

- This calculator is designed considering population, number of urban agglomerations, number of senior citizens, literacy rate, total cases and active cases of all the states and union territories of India.
- The app uses an inbuilt database to get this information and the developers update the database from time to time.
- Internet is not required to run this calculator and at present, it has an overall error rate of 0.97% and an average error rate of 8.9%.
- The error rate increases with the size of area into consideration. It can go as high as 47% in some situations.

There are two buttons on this screen other than the text box, which would display the message: Go Back and Exit.

The Go Back button takes the user to the home screen while the exit button closes the window and terminates running tasks. The output is as follows:



15.8.3 State-wise Statistics

The sole purpose of this screen was to display the data we have in our database in a way the user desires to see.

Since the label of this screen is State-wise Statistics, we needed to make sure only the state data part of the database is presented to the user.

To get over this hurdle, we sorted the database to keep the states above the data of cities and districts and then made a new list taking the first n number of entries (n is the number of states) and presenting it to the user to choose from.

This screen works in two stages.

In the first stage, it has three buttons: a list and a label.

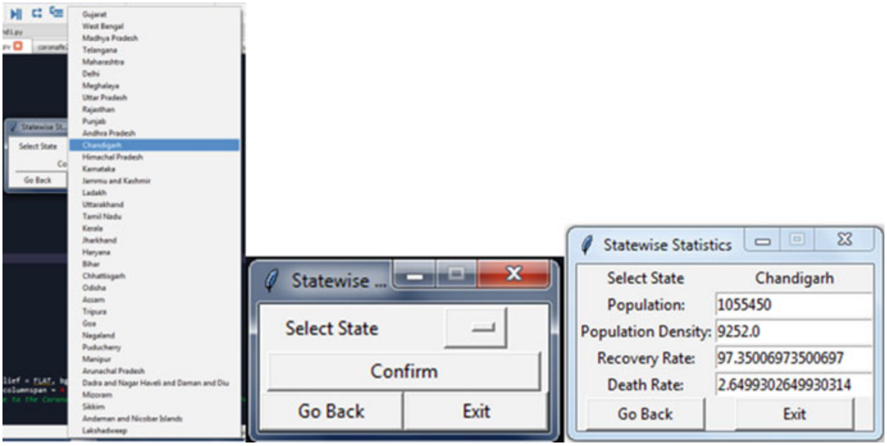
- The list is a drop-down to select state.
- The first button is to confirm selected state.
- The other two buttons are Go back and Exit.

Once the user presses confirm, the second stage of the page is activated.

In this state, there are four entry boxes, six labels and two buttons.

- The labels are selected state, name of the selected state, population, population density, recovery rate and death rate.
- The two buttons are Go Back and Exit whose tasks we have discussed above.
- Finally, the four entry tables show data based on the label next to them.

The outputs are as follows:



15.8.4 Corona Calculator

This was the most complex part of the code. This code worked in three stages.

- First, it makes the user select the state in which the area is.
- Then, take the other values mentioned above from the user and finally go to the database and take missing data needed for performing an operation.
- After data is received, a statistical message is displayed.
- There are three buttons in total, two are Go Back and Exit while the third is Get stats, which vanishes after being pressed.
- Other than that there are six Labels and one list.

The statistical message displayed is:

- Approximately 'x' Patients Have Recovered
- This is 'y'% of Total Cases
- At Present 'z'% People Are Affected and Detected
- While 'a'% People May Be Affected
- 'b'% Population is at Risk of Being Affected
- Please Avoid Visiting Any Area If Not Important

The variables x, y, z, a and b will be filled in with the values obtained from the model output.

The output of the corona calculator is:

15.9 Future Scope

The app can be grown in two directions from where we leave the project.

As mentioned above, this app is purely pattern analysis based. This can be changed by adding a way to consider user inputs in the form of surveys.

There needs to be a method to authenticate the survey inputs as they could disturb the model output if they are wrong.

The app also does not take inputs actively from government websites but depends on the developer to update its database.

This was done because there is no one place from where we scrapped the data.

Though if all the data could be brought to one place or instead a method exits to take data from multiple locations and feed it to one database accurately, then it can be applied.

Other than these two minor changes like using a real database instead of a csv can be done.

A csv file was used since we were constantly changing the data, but that will not be a concern for future applications.

Perhaps, there could also be a machine learning model, which gives better results, which we failed to test and that can be used as a future implementation.

15.10 Conclusion

The corona statistics app is far from perfect, taking into consideration the wide variety of data that could be used to train the ML model.

This project is barely the first step of the potentials of this app. Despite the fact that we feed very little data to it, the app gives surprisingly accurate results in some cases.

If received collaboration from the government and active and a variety of sources of data, the app could become the one app everyone needs to carry in order to be sure whether to visit a location or not.

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Analysis and Validation of Risk Prediction by Stochastic Gradient Boosting Along with Recursive Feature Elimination for COVID-19

16

Kamakhya Narain Singh, Jibendu Kumar Mantri, V. Kakulapati, Suraj Sharma, Sudhanshu Sekhar Patra, Chinmay Misra, and Nitesh Kumar

Abstract

Nowadays, in India the COVID-19 epidemic has reached the peak and is spreading exponentially due to which commercial, health services, businesses, and small industries are suffering, and all human beings' lives are at stake. In this scenario, government and government personnel are working day and night to handle the situations. The police and healthcare providers are giving their best to save the lives of people. Researchers and scientists are working towards innovation and useful ideas to help healthcare workers: doctors, nurses, technicians, and paramedic staff. Today, machine learning becomes a successful tool in disease diagnosis by analysing the massive amount of data and has proved efficiently in decision-making. Developing this type of model consumes more time and resources. In this chapter, a model significant in recognizing the features that add further in identifying diseases is proposed. This work aims to predict the stage of heart disease of a patient by employing machine learning algorithms. The

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stochastic gradient boosting algorithm along with Recursive Feature Elimination (RFE) for selecting the best features in the data and predicting the risk level of COVID-19 has been implemented.

Keywords

COVID-19 · Stochastic · Gradient · Machine learning · Recursive · Features · Prediction

16.1 Introduction

Coronaviruses (COVID-19) are from a diverse family of viruses causing a range of diseases in birds and mammals, e.g. chicken, bat, pigs, and humans. The aggressive virulence of this microorganism in respiratory symptoms makes this potentially lethal for human respiratory infection. One of the common and lethal CoVs was first identified and diagnosed in Southern China in 2002 causing severe acute respiratory syndrome (SARS) named as CoV (Du et al. 2009). As SARS-CoV spread throughout the world, a new strain of coronavirus named Middle East respiratory syndrome (MERS-CoV) has emerged, infecting and killing people with a high mortality rate of nearly 50% in the Middle East in 2012. The World Health Organization (WHO) counted 1651 overall cases, including at least 590 deaths (with mortality rate 36%) from MERS till March 2016 (Omrani et al. 2015).

Since SARS-CoV 2, the novel coronavirus that causes coronavirus disease 2019 (COVID-19), was first detected in December 2019 in Wuhan Province (Lai and Cavanagh 1997), approximately 16,323,409 cases have been reported globally where 9,984,438 cases (94%) recovered and 650,386 (6%) have been dead. Currently, there are 5,688,585 active infected patients, of which 5,622,427 (99%) have mild symptoms and 65,158 (1%) are serious or critical (Omrani et al. 2015); in this 1,435,213 cases are from India (Indian Council of Medical Research n.d.). The number of death caused by COVID-19 is 650,385 worldwide with the number of deaths in India standing approximately around 33,000. The USA has the highest number (4,341,491) of confirmed cases in the world, in which 2,072,518 (48%) patients are recovered and 149,601 (3.5%) are dead.

The number of cases varies across the globe with the United Kingdom having a death rate as high as 15.3% (Worldometer n.d.-a) to Singapore as low as 0.1% (Worldmeter n.d.-b). A recent report in science news suggested that the mortality is largely due to co-morbidities in the patient (Wadman et al. 2020). A higher percentage of mortality has been reported in the patient of age group 65 and above, which explain why Italy has the highest number of deaths in the world, as Italy has almost 21% of population above the age of 65 (Statista n.d.). Reports from across the globe in scientific journal suggest that obesity is one of the key features of all COVID-19 positive patients admitted to the hospital.

A recent weekly report published by CDC suggests that among the 1482 patients admitted in the US hospitals from 1 to 30 March, 78.3% were aged >50 and among them 48.3% were obese (Garg 2020). Similar findings were reported from South Korea that around 17.9% of cases in the study were obese (Kim et al. 2020).

As the understanding about COVID-19 is still in its infancy, rigorous scientific studies need to be performed to understand the various aspects of mortality as well as increase in the number of COVID-19 patient across India as well as the globe. COVID-19 patients fight the virus based on how strong their immunity is, and it is well known through scientific research that immune cells have proven to have an important role in the physiological dysfunction associated with obesity. Obesity is the final outcome when there is a disruption of energy balance, which results in gain of weight as well as metabolic disturbances that lead to tissue stress and dysfunction. These metabolic disturbances lead to immune activation in tissues such as adipose tissue, liver, pancreas, and the vasculature, and individuals often present with elevated plasma markers of chronic low-grade inflammation (Guilherme et al. 2008). Additionally, immune cells play a role in the perpetuation of chronic disease; scientific evidence has established a negative correlation of obesity with immunity which is supported by the evidence of higher rates of vaccine failure and complications from infection (Sheridan et al. 2012).

The cause of a variety of diseases is through infection of viruses in human beings and their household animals, and the primary cause of these contagions is the use of replication mechanism of host. Numerous proteins are involved in the replication mechanism. Although the role varies from each variety of viruses, the known mechanisms are very poorly defined. The genome organization of viruses and the structure and function of the proteins involved in the replication, transcription, or translational mechanisms are now rapidly constructed and understood by using molecular modelling methods. Due to the virulence of COVID-19, there is enormous pressure on clinicians and the Food and Drug Administration (FDA) to act rapidly to make medications available to patients.

There is no effective cure available to date for the COVID-19 epidemic. The treatment and diagnosis of COVID-19 patients are not predefined. In Indian, different states are working individually and along with the central government.

In the context of rare diseases like COVID-19, the main hurdle is to gather data from patients of specialized care centres, due to diversification and scattering of the centres, higher disease incidence, and insufficient availability of the resources, and a large proportion of rare-disease patients were hard to analyse. It endorses AI's role in medical practice. It eases the method and predicts with higher accuracy by processing gigantic datasets (big data) using numerous mathematical models (algorithms). Scientists improvise the models through correcting errors in the algorithm, thus making the AI predictive model more authentic.

Nowadays, in India the COVID-19 epidemic has reached the peak and is spreading exponentially, due to that economic, health services, businesses, and small industries are suffering, and all human being's lives are at stake. In this scenario, the government and government personnel are working day and night to handle the situations. The police and healthcare providers are giving their best to save the lives. Researchers and scientists are working towards innovation and useful ideas to help healthcare workers: doctors, nurses, technician, and paramedic staff. In this chapter, we propose to develop a model which helps to analyse symptoms of COVID-19, patient age (range), patient gender, confirmed case, number of death and recovery cases, patient route (travelling info), region, and weather.

The proposed model is significant to recognize the features that add further in identifying cases. This work aims to predict the stage of heart disease of a patient by employing machine learning algorithms and developing a model which helps to analyse symptoms of COVID-19 patient, confirmed case, and number of death and recovery. For this we implement the stochastic gradient boosting algorithm along with Recursive Feature Elimination (RFE) for selecting the best features in the data and predicting the risk level of COVID-19.

The following sections are structured as follows: Section 16.2 presents the related work; the proposed methodology are present in Sect. 16.3. In Sect. 16.4, we discuss the implementation. Section 16.5 contains conclusion, and in the last section, future scope of the work is proposed.

16.2 Related Work

Today, machine learning becomes a successful tool in disease diagnosis by analysing the massive amount of data and has proved efficiently in decision-making. Developing this type of model consumes more time and resources. In the literature, many related studies are discussed, which aim to predict COVID-19 cases and help to analyse confirmed, death, recovery, and active cases. Many machine learning algorithms are discussed which deal with various diseases to recognize the features that add further in identifying and monitoring COVID-19 novel coronavirus. Coronavirus causes a pandemic in the world and it is believed to have spread from China in 2019. Mostly those affected by COVID-19 present with flu like symptoms like fever, cold, cough, difficulty in breathing, muscle pain, and diarrhoea, and it is spreading rapidly from human to human.

J. H. Ng et al. (2020) measured the number of deaths of COVID-19 patients in hospital and patients on ventilator and days of stay with end-stage kidney disease (ESKD) and without ESKD. They observe the outcome of 10,482 patients; among 10,482 coronavirus infected patients 419 had ESKD. Thus ESKD with COVID-19 has higher fatality rate with 31.7% than without ESKD with 25.4%. More number of days or those more than 7 days on ventilator are without ESKD. Subsequently, measured primary outcome (in-hospital death), and secondary outcomes (length of stay on ventilation), of 10,482 patients with COVID-19,419 had ESKD.

Mazza et al. (2020) have done a comprehensive study for stress in coronavirus-positive survivors and observed the role of inflammatory and clinical predictors in this pandemic due to the novel coronavirus. They examined the psychiatric symptoms for 1 month post COVID-19 treatment in 402 COVID-19 survivors, of which 265 were male and 137 female with the average age of 58. Self-prepared questionnaires were asked to screen issues related to stress, modern life style, and obsessive symptomatology. Subsequently, they followed up oxygen saturation levels and collected sociodemographic information such as baseline inflammatory markers and clinical data. Martínez-García et al. (2020) conducted a prospective observational study on coronavirus-positive patients through remote monitoring and prescribing telemedicine at home in a proactive manner. This study was carried out in the Lugo healthcare area for 1 month over the 345,000 residents. Subsequently, they evaluated the efficiency of telemedicine through telemonitoring in detecting different cases of COVID-19 among patients while they are in isolation at their residence.

Sufian et al. (2020) have conducted a survey on deep learning techniques for mitigating the COVID-19 pandemic. They have used edge computing architecture to improve the efficiency. Considering the blood count and without using symptoms or patient history a methodology is presented by A. Banerjee et al. (2020) to test SARS-CoV-2 positive cases using ANN technique and simple statistical test with 94% AUC. A Generative Adversarial Network (GAN) model using deep learning technique is proposed by M. Loey et al. (2020) to predict COVID-19 from an X-ray report. The proposed framework takes less memory and time. A BCNN known as Bayesian Convolutional Neural Network uses deep learning model which is proposed by B. Ghoshal and A. Tucker (2020) to detect COVID-19 and improve diagnostic performance for X-ray. Using clustering methods a novel system is presented by M. Nilashi et al. (2017) to predict diseases. Furthermore, to improve the prediction to detect COVID-19 patients regression and fuzzy-based rules are implemented. Zhang et al. (2018) adopted Privacy-Preserving Disease Prediction using patient's medical history report data. They outsourced and encrypted medical history reports of patients and trained them for prediction. A framework is designed by Weng et al. (2016) to compare the performance of various classifiers with the individual classifier with respect to ensemble classifier.

Thakur and Jain (2020) study the emotional impact of COVID-19 warriors and patients and their family members. They also analysed the suicide cases due to COVID-19 across the globe. Messner et al. (2020) discussed plasma proteomics and its utility for recovering COVID-19 patients. They offer a low-cost workflow that manages daily up to 180 samples, reduces effects for large scale, and enables high precision quantification. Bulman et al. (2020) presented a telehealth model using a rule based on single-centre experience for the patient staying outside or in self-isolation or in home quarantine during the pandemic. Subsequently, the interventional radiology clinic has been transitioned to telehealth in this pandemic situation. A model is proposed by Zheng et al. (2020) to identify hospitalization priority and severe coronavirus-positive cases with 84.6% sensitivity, 84.6% specificity, and 100% accuracy. They used four easily accessible biomarkers for assessment and XGBoost technique to find out the risk of COVID-19. Furthermore, they implement a program for rapidly processing the evaluation. A disease prediction model is proposed by Koppu et al. (2020). They used a modified Dragonfly algorithm named as F-DA to minimize the error among the actual and predicted outcome. Satpathy et al. (2021) predicted mortality rate and associated risk for COVID-19 patients using deep learning applications.

16.3 Proposed Model of Assessment

Data has been collected from different online resources such as twitter, Facebook, mobile phones, and Google forms. The collected data is stored in a clinical database or dataset in the form of CSV, and some data like discharge summaries are in the form of text. Dataset is pre-processed for removing unnecessary comments, tags, noise elements, duplicates, etc. The dataset ready for analysing is electronic health records. These data can contain symptoms, discharge summaries, patient history, readmit information, etc.; if disease name is known, it can classify as the data of different disease stages (initial, advance, and fatal) using machine learning ensemble technique.

Models such as support vector machine, Bayesian ridge, and linear regression for predicting of confirmed cases are used. Regarding the attributes, the dataset attributes are "Date, Time, State/UnionTerritory, ConfirmedIndianNational, ConfirmedForeignNational, Cured, Deaths, Confirmed" to predict confirm, death, recover, and active COVID-19 cases in various regions. Calculate mean absolute error and mean squared error of test data and confirmed cases to measure the accuracy of each model. For disease diagnosis, analysis of the massive amount of data is used efficiently in decision making. Developing this type of model consumes more time and resources. In this section, we propose a model significant to recognize the features that add further in identifying diseases. This work aims to predict the stage of heart disease of a patient by employing machine learning algorithms. For this, we implement the stochastic gradient boosting algorithm along with Recursive Feature Elimination (RFE) for selecting the best features in the data and predicting the risk level of COVID 19.

Graphing the number of confirmed cases, active cases, deaths, recoveries, mortality rate (CFR), and recovery rate of moving average for 7 days as well as daily basis of global novel coronavirus cases since 22nd January 2020 using size of 30 to 10th August 2020 (Fig. 16.1).

16.4 Experiment Analysis

The dataset is taken from Kaggle and the data is pre-processed for removing unnecessary elements such as missing values, noise elements, and inconsistent data from the dataset. The dataset attributes are "Date, Time, State/UnionTerritory, ConfirmedIndianNational, ConfirmedForeignNational, Cured, Deaths, Confirmed" (Table 16.1).

We predicted confirmed cases using three prediction models such as Support Vector Machine, Polynomial Regression Predictions Model, and Bayesian Ridge Polynomial Predictions Model and found that SVM model prediction is more accurate. In Figs. 16.2, 16.3, and 16.4 the *X*-axis shows the number of cases and *Y*-axis shows the prediction.

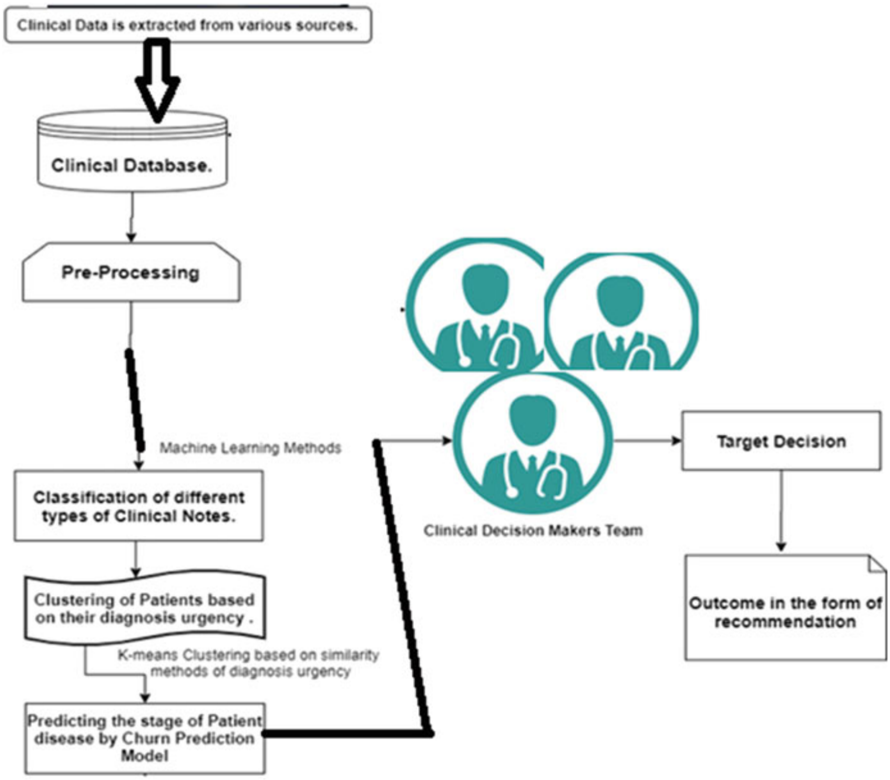

Fig. 16.1 The proposed framework for prediction of risk level of COVID-19 patients

Table 16.1 The example of attributes of the dataset

Sno	Date	Time	State/UnionTerritory	ConfirmedIndianNational	ConfirmedForeignNational	Cured	Deaths	Confirmed
1	2020-01-30	6:00 PM	Kerala	1	0	0	0	1
2	2020-01-31	6:00 PM	Kerala	1	0	0	0	1
3	2020-01-02	6:00 PM	Kerala	2	0	0	0	2
4	2020-02-02	6:00 PM	Kerala	3	0	0	0	3
5	2020-03-02	6:00 PM	Kerala	3	0	0	0	3

We analysed the number of confirmed cases, active cases, deaths, recoveries, mortality rate (CFR), and recovery rate of moving average of 7 days as well as daily basis using graphs. In Figs. 16.5, 16.6, 16.7, 16.8, 16.9, 16.10, and 16.11 the *X*-axis shows the number of days and *Y*-axis shows the number of cases.

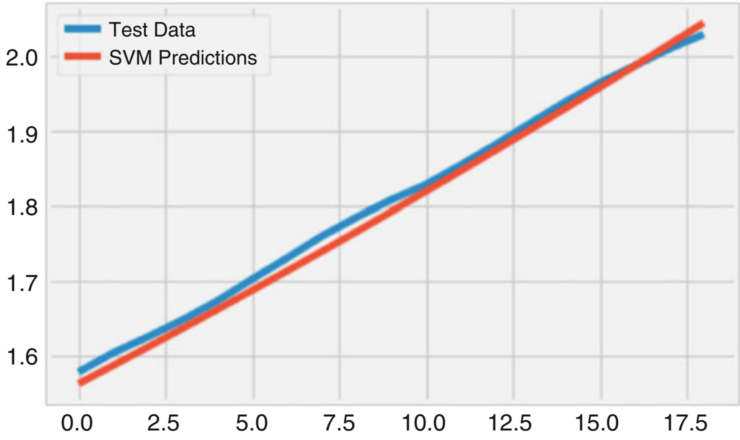

Fig. 16.2 Support vector machine prediction model

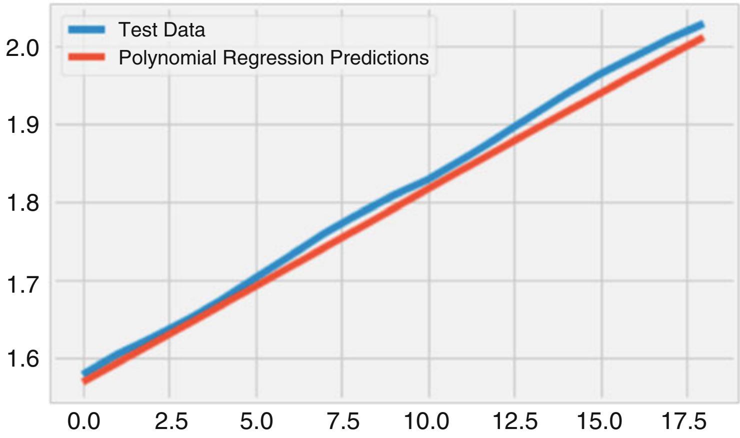

Fig. 16.3 Polynomial regression prediction model

We applied decision tree regressor and linear regressor to validate the proposed model and achieved with 98.25% accuracy of decision tree and 97.77% accuracy of linear regression. Figures 16.12 and 16.13 are plotted graph which shows the accuracy of validation of the model.

We applied the stochastic Gradient Boosting algorithm along with Recursive Feature Elimination (RFE) for selecting the best features on this dataset and predicting the risk level of COVID-19. It is achieved with 98% accuracy. Figure 16.14 shows the accuracy of Gradient Boosting Descent graph.

Stochastic Gradient Descent Classification Report:

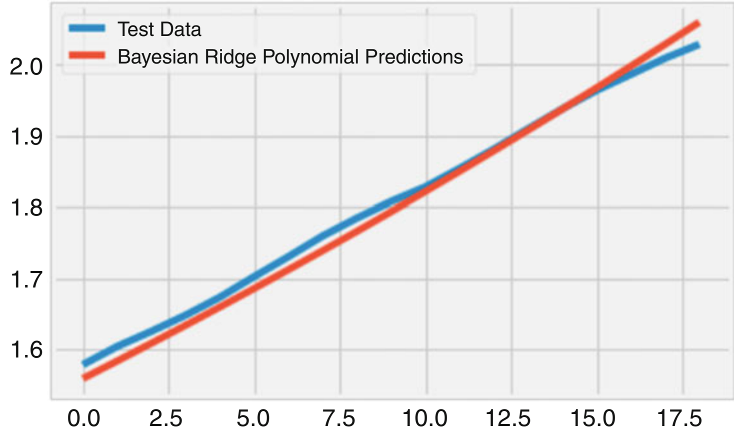

Fig. 16.4 Bayesian ridge polynomial predictions model

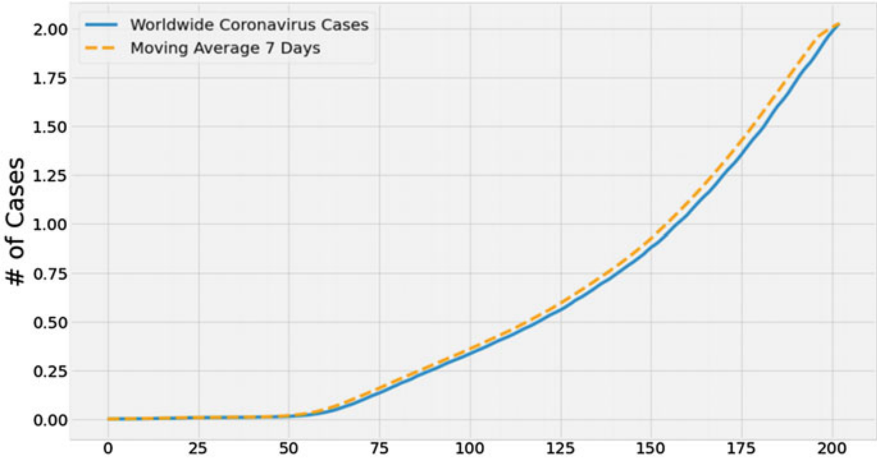

Fig. 16.5 Novel coronavirus cases over time throughout the world

```
Stochastic Gradient Descent Report (Training Set) :

Accuracy Score:  0.981 %
     Precision:  0.045 %
        Recall:  0.048 %
      F1 score:  0.045 %
```

From the classification report of gradient boosting algorithm with RFE, we can see it performs much better with 98% accuracy. In this metric, we chose the F1 score, which balances precision and recall. Since there are fewer positive cases than negative ones, we included recall as part of our metric, but included accuracy to avoid over-classification.

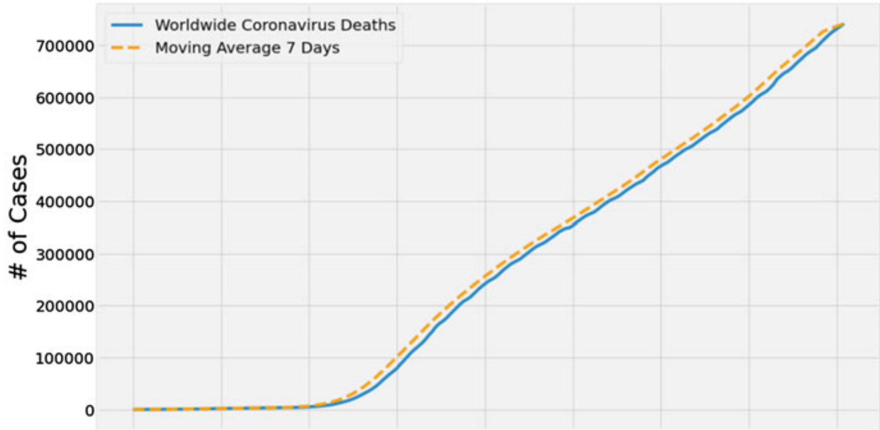

Fig. 16.6 Death cases over time throughout the world due to COVID-19

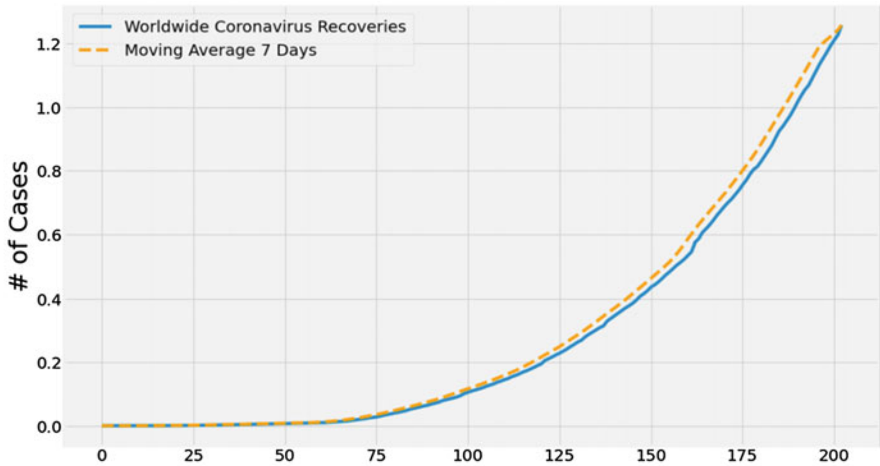

Fig. 16.7 Recovery cases over time throughout the world from COVID-19

We have taken data of all cases from 22nd January 2020 to 10th August 2020. Figure 16.2 represents the predicted confirmed cases. We applied the Support Vector Machine on this dataset to predict confirmed cases and calculated mean absolute error 11.81% and mean squared error 16.56% metrics on corresponding test data and confirmed cases of measuring accuracy for the continuous variable.

Figure 16.3 also represents confirmed cases. Here, we applied the Polynomial Regression Predictions Model on this dataset for prediction. Mean absolute error and mean squared error are 15.23 and 26.32, respectively. Here, mean absolute error and mean squared error of this model are greater than mean absolute error and mean

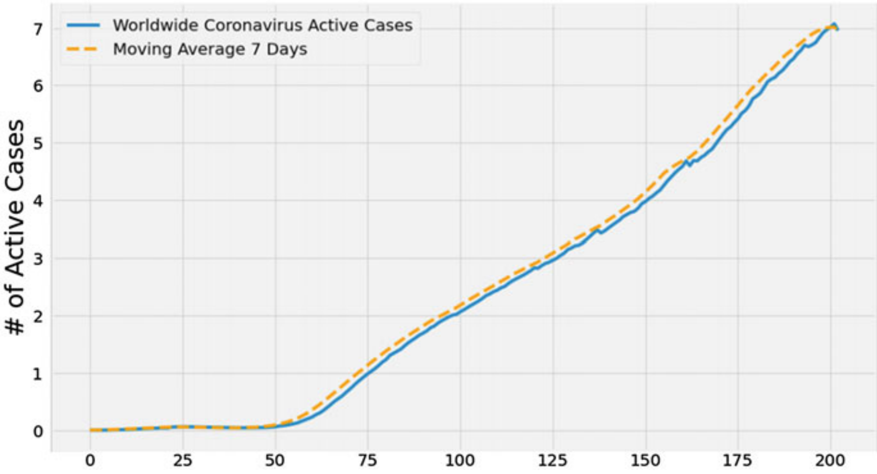

Fig. 16.8 Active cases over time throughout the world from COVID-19

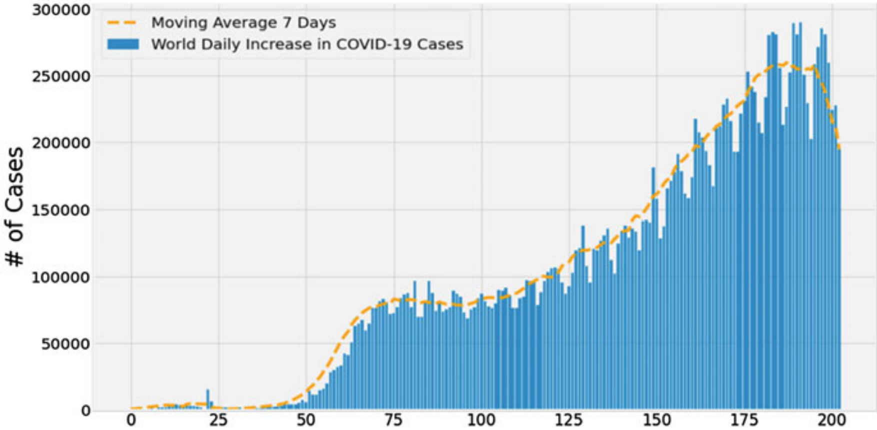

Fig. 16.9 World daily increase in confirmed cases

squared error of the SVM model. We can observe that these results are not better than the SVM model.

Figure 16.4 represents confirmed cases using the Bayesian Ridge Polynomial Prediction Model. Mean absolute error and mean squared error are 13.33 and 24.25, respectively. Here, the mean absolute error and mean squared error are greater than mean absolute error and mean squared error of the SVM model and smaller than the Polynomial Regression Predictions Model. We can observe that these results are not better than the Polynomial Regression Predictions Model. So the SVM model is better.

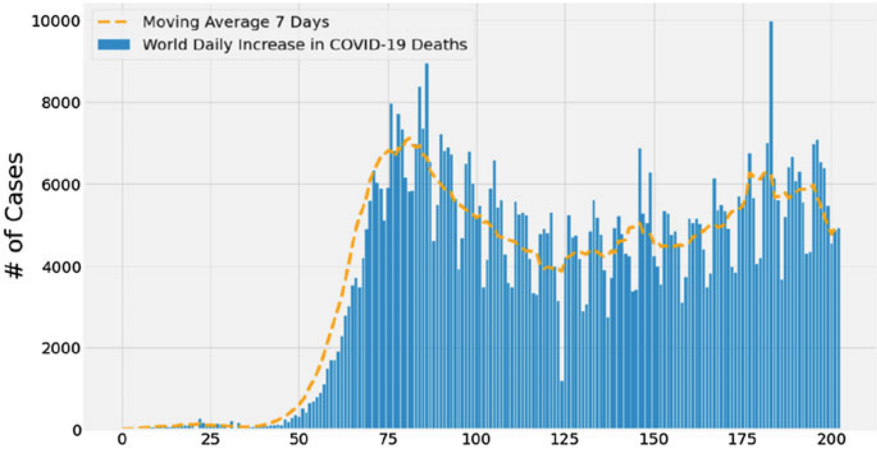

Fig. 16.10 World daily increase in deaths due to COVID-19

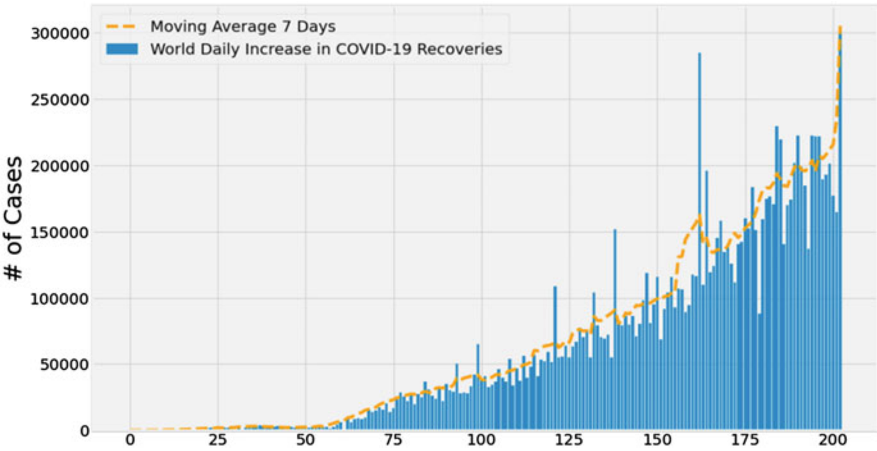

Fig. 16.11 World daily increase in recoveries

Figure 16.5 represents positive cases due to worldwide novel coronavirus of moving average for 7 days. Figure 16.6 represents deaths due to worldwide novel coronavirus of moving average for 7 days. Figure 16.7 represents recoveries from worldwide novel coronavirus of moving average for 7 days.

Figure 16.8 represents active cases from worldwide novel coronavirus of moving average for 7 days. Figure 16.9 represents increase in confirmed case on a daily basis throughout the globe due to the novel coronavirus. Figure 16.10 represents daily increase in deaths on a daily basis across the globe due to COVID-19. Figure 16.11 represents increase in recovery cases on a daily basis throughout the globe from COVID-19.

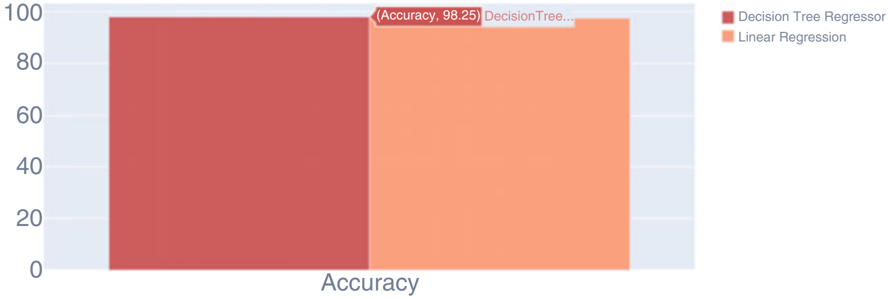

Fig. 16.12 Decision Tree Regressor

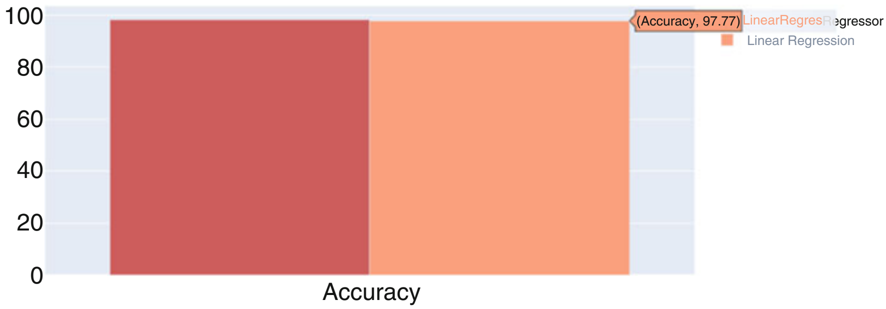

Fig. 16.13 Linear Regression

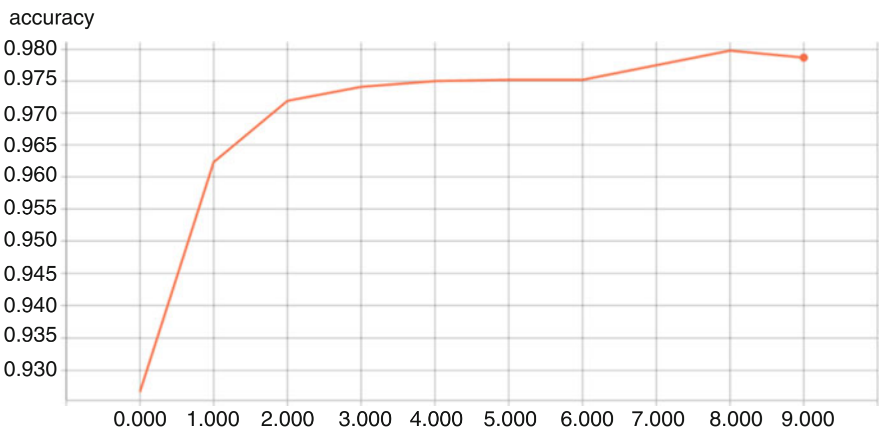

Fig. 16.14 Gradient boosting descent graph

Figure 16.12 represents validation of the model using decision tree regressor. Figure 16.13 represents also validation of the model; here we applied linear regressor to validate this model. Figure 16.14 represents the Gradient Boost Descent graph which is used to select the best features to predict the risk level of COVID-19 patients.

16.5 Discussions

Nowadays in India, the COVID-19 epidemic has reached the peak and is spreading exponentially, due to that economic, health services, business, and small industries are suffering, and all human being's lives are at stake. In this scenario, government and government personnel are working day and night to handle the situation. The police and healthcare providers are giving their best to save the lives. Researchers and scientists are working towards innovation and useful ideas to help healthcare workers: doctors, nurses, technician, and paramedic staff. In this work, we propose to develop a model which helps to analyse symptoms of COVID 19 patients, patient age (Range), patient gender, confirmed case, death case, recovery case, patient route (travelling info), region, and weather.

Our proposed model is significant to recognize the features that add further in identifying cases. This work aims to predict the stage of heart disease of a patient by employing machine learning algorithms and developing a model which helps to analyse symptoms of COVID 19 patient, confirmed case, death case, and recovery case. We implement the stochastic gradient boosting algorithm along with Recursive Feature Elimination (RFE) for selecting the best features in the data and predicting the risk level of COVID 19.

16.6 Conclusion

In this chapter, we propose a model that is significant to recognize the features that add further in identifying diseases. This work aims to predict the stage of heart disease of a patient by employing machine learning algorithms. Our proposed model helps to analyse symptoms of COVID 19 patient and confirmed, death, recovery, and active cases. We have represented confirmed, active, death, and recovery cases on moving 7 days average from 22nd January 2020 to 10th August 2020 through the respective graphs.

In this work, we utilize the machine learning technique, support vector machine, Bayesian ridge, and linear regression for predicting the confirmed cases. We implemented the stochastic gradient boosting algorithm along with Recursive Feature Elimination (RFE) with 98.1% accuracy for selecting the best features in the data and predicting the risk level of COVID 19. We validated the model using decision tree regressor with 98.25% accuracy and linear regressor with 97.77% accuracy.

16.7 Future Scope of the Work

In the future, the proposed model Risk Prediction by Stochastic Gradient Boosting along with Recursive Feature Elimination in data and predicting the risk level for COVID-19 patient in real health care environment will be implemented. To implement and validate the proposed methodologies in real life. Proposed methods can be improved to discover more deceases by taling large sample.

16.8 Executive Summary

The authors propose a model which collects data online using various ways and is significant to recognize the features that add further in identifying cases. This work aims to analyse the cases and predict the stage of heart disease of a patient by employing stochastic gradient boosting algorithm along with Recursive Feature Elimination (RFE). This helps to select the best features on this dataset and predicting the risk level of COVID 19 patients. It is achieved with 98.1% accuracy.

Our proposed model help to analyse symptoms of COVID 19 patient and confirmed, death, recovery, and active cases. We applied support vector machine, Bayesian ridge, and linear regression to analyse the confirmed, death, and active cases of COVID-19 for next moving 7 days. We validated the model using decision tree regressor with 98.25% accuracy and linear regression with 97.77% accuracy.

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Conflict of Interest Nil.

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Part IV

COVID 19 and Its Consequential Effects

Artificial Intelligence in Mental Healthcare During COVID-19 Pandemic

17

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Abstract

There is an emergence of several mental health issues in the community during this COVID-19 pandemic. Rising mental health concerns put mental health professionals under tremendous pressure. As mental health services are scarce worldwide and more so in the low- and middle-income countries, the mental health resources available will soon be depleted. During this mental health crisis, the use of technologies like artificial intelligence holds some promise. This chapter addresses the problems of mental health during this COVID-19 pandemic and the potential role of artificial intelligence in addressing mental health issues.

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Keywords

Mental health · Psychiatric disorders · COVID-19 · Artificial intelligence · Machine learning · Deep learning

17.1 Introduction

Over the past few decades, a new technology called artificial intelligence (AI) has caught researchers' attention. The development of this technology has made the task of understanding and predicting human behavior and responses much easier (Graham et al. 2019). The current conventional practice of mental health assessment mostly relies on the clients' responses in the clinical interviews, sometimes on certain psychological assessments and rarely on sophisticated investigations. Mental health assessment is the most time consuming, and interpretations are mostly subjective. Considering the paucity of clinician time and expertise, a lot of information may not get due consideration in the clinical decision-making process (Lovejoy 2019), for example, the tone, modulation, pauses, selection of words, etc. in the client's voice recordings in combination with neuroimaging and neurophysiological tests like electroencephalogram. Using various techniques of AI (machine learning, deep learning), researchers analyzed the neuroimaging findings in various neurological and psychiatric disorders (Vieira et al. 2017). These techniques allow minor alterations that are not visible to the naked eye, and often ignored, to be taken into consideration, which helps to describe the construct of interest with greater precision (Vieira et al. 2017). AI also helps in identifying potential biomarkers of illnesses (Vieira et al. 2017). Scientific data in mental health disciplines are highly different from other medical disciplines, and many a time, the interpretations are subjective. Due to this, there is a likelihood of variations in data interpretation. The machine learning technology of AI applies various computational models to generate several hypotheses at various levels for precise prediction (Rutledge et al. 2019).

However, if similar relevant information is documented in specific conditions, and AI is used for interpretation and prediction, clinical decision-making will probably be more precise. At the same time, the process will be easier and quicker. AI will certainly limit biases related to subjective interpretation (Lovejoy 2019; Shatte et al. 2019).

17.2 Artificial Intelligence in Healthcare

17.2.1 Concept

AI can be defined as "a system's ability to interpret external data correctly, to learn from such data, and to use these learnings to achieve specific goals and tasks through flexible adaptation." While the definition of AI has been debated for all these years, developments in AI have made our life in today's world much simpler. The question which arose with the development of the concept of AI, i.e., "whether machines can actually think like humans or rather be indistinguishable from humans," is yet to be answered. The origin of AI cannot be exactly pinpointed; however, it can be said that the idea arose in the 1940s when an American writer Isaac Asimov gave to the world a short story, which said the story of "a robot" built by engineers. His work has since then inspired many scientists. Around the same time, the world's first working electromechanical computer, "The Bombe," was developed by an English mathematician Alan Turing; this made it possible to break German army codes during World War II. The word "Artificial Intelligence" was officially coined in 1956 at Dartmouth College, New Hampshire, where a workshop was held by computer scientists Marvin Minsky and John McCarthy: the objective of the workshop was to unite researchers in different fields and to work toward developing machines with the ability to simulate human intelligence. The initial years following the development of AI were met with criticism by various governments. However, today following the rise of "big data" and advancements in ciphering, AI has become part of various fields and has even entered normal conversations in day to day life (Haenlein and Kaplan 2019).

Artificial intelligence has become a routine part of our lives, from displaying favorite songs in one's Spotify playlists, suggestions popping up for your dream trip, and voice recognition to self-driving cars. It is only natural that one will be fascinated to know how this works. Even though AI's concept brings into the mind the image of futuristic droids, it is based on the basic concept of application of certain "Algorithms." An algorithm is a set of step-by-step instructions that can be easily followed even by a computer. An AI system just follows a pipeline of algorithms. A system takes in data regarding a particular domain, performs a chain of calculations as per algorithm, and gives an output in the form of predictions or decisions. The AI explosion is taking place right now because of an amalgam of four things—faster computers, availability of expansive data sets, cloud computing, and, most important, all innovative ideas (Polson and Scott 2018).

It is expected that as AI becomes smarter than before, its uses will evolve and grow. There are three levels of AI based on the capabilities; these include:

Artificial Narrow Intelligence—It is the most common and currently available AI; examples include speech recognition, face recognition, etc. It is designed for one specific task and cannot perform beyond its fields. Hence it is also referred to as weak AI.

Artificial General Intelligence—It is the AI which can perform any intellectual task with efficiency like a human being. Currently, no such systems are available.

Artificial Super Intelligence—It is the level of systems intelligence at which machines with the complexity of human cognitive abilities could surpass human intelligence. It is the final aim of AI (javaTpoint 2020).

Based on the functionality of Artificial Intelligence, it can be divided into four types:

1. Reactive Machines: These are the most simple forms of Artificial Intelligence and will not preserve memories for future use. They can focus only on the task at hand. Examples include IBM's Deep Blue, Google's Alpha Go.
2. Limited Memory: These machines can store such data for a limited period of time and can adjust the answer to the output. Examples include self-driving cars.
3. Theory of Mind: These types are not yet developed, and these are machines that can understand human emotions, beliefs, and act like humans in a social environment.
4. Self-awareness: These types of machines are the future of AI. It is a hypothetical concept regarding machines that can be self-aware, i.e., have a mind of their own, which will be smarter than humans (javaTpoint 2020).

17.2.2 Healthcare Relevance of Artificial Intelligence

The term artificial intelligence refers to a set of approaches that mimic human cognitive functions. Several AI applications may have relevance for healthcare but differ in their processes and the specific tasks they support (Fig. 17.1). Below, we describe some of the AI applications that have particular relevance for healthcare.

17.2.2.1 Machine Learning: Neural Networks

The term machine learning (ML) refers to a type of AI approach that employs algorithmic models to assist machines in solving problems in the absence of specific computer programming (Jiang et al. 2017; Ngiam and Khor 2019). Already quite prevalent in a business discipline and several aspects of daily life, their disruptive potential to support various aspects of healthcare and healthcare delivery is increasingly being recognized and tapped.

The increasing penetration of technology such as smartphones, devices with wearable sensors such as smartwatches, and cloud computing has engendered unprecedented opportunities to collect large scale or "big" data; machine learning approaches such as "neural networks" can be progressively trained to recognize patterns within this big data provided they are mapped and processed appropriately. The term "neural networks" is used because this ML approach deconstructs problems in terms of input, output, and the weights of specific parameters or features that the system has been trained to use for associating inputs with outputs, similar to how human neurons behave and process signals (Davenport and Kalakota 2019).

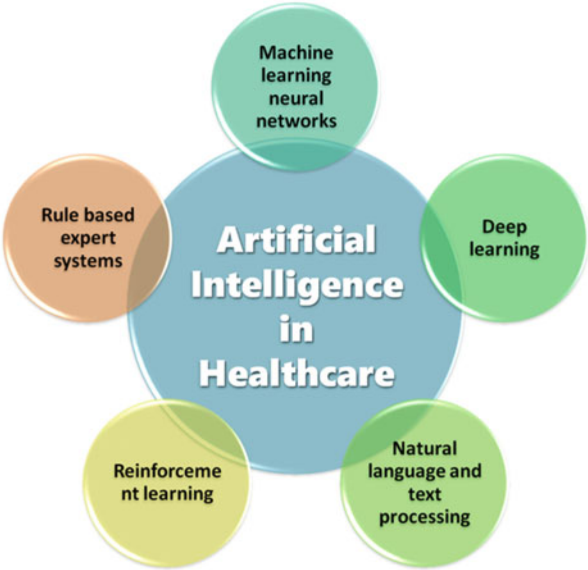

Fig. 17.1 Artificial intelligence in healthcare

Perhaps, the most important application for ML approaches in healthcare is to assist the practice of precision medicine—predicting which treatments are likely to work. In this context, the most popular approaches build relationships between patient traits (such as age, gender, or selected biological parameters) and medical outcomes of interest and use it for predictive modeling—referred to as supervised learning approaches. Other approaches are unsupervised learning (best used for feature extraction) and a recent hybrid variety called semi-supervised learning (Jiang et al. 2017).

17.2.2.2 Deep Learning

Deep learning represents an advanced form of machine learning that involves iterative representation learning—in which raw data is fed in, and the artificial neural network builds its representations that help in recognition of patterns. Thus, the data representation is refined with numerous levels of abstraction and therefore, the computational models designed are composed of many layers of the processing; in effect, this means that human engineering expertise is not required to design feature extractors that are an integral feature of traditional ML systems (Davenport and Kalakota 2019). Deep learning algorithms are increasingly drawing attention for their significant predictive validity.

One of the promising applications of deep learning in biomedicine involves using computational models to generate biomarkers as disease phenotype signatures; these can then be used to assess outcomes of clinical trials and identify disease subtypes, and monitor response to treatment, particularly for diseases like cancer. The utility of computational biology may span a wide range of data involving fields of genomics, transcriptomics, and proteomics (Mittal and Hasija 2020).

Medical imaging, or image processing, is another field where deep learning methods, such as convoluted neural networks (CNN), have shown promising results in dermatology, ophthalmology, radiology, and pathology diagnostic tasks (Davenport and Kalakota 2019).

Other applications of deep learning in biomedicine are studying, understanding, and predicting genetic splicing and using neural network-based computational models to predict drug toxicity, a crucial aspect of drug design and discovery (Esteva et al. 2019; Mittal and Hasija 2020).

17.2.2.3 Natural Language and Text Processing

Natural language processing (NLP) involves using deep learning algorithms such as recurrent neural networks (RNNs) to analyze vast quantities of text, voice, and time-series data to extract meaning from words. Notable applications of NLP techniques in biomedicine involve information and pattern extraction from text, information retrieval from scientific literature, text generation from large, structured databases such as laboratory data, and machine translations involving translating text from a source language to a target language. Examples of the latter could include translating consent forms to reach a wider audience for a study and translating medical instructions to assist patients from different linguistic backgrounds. In healthcare settings, NLP techniques also drive applications used in Electronic Health Records, which are now an important source of big data (Davenport and Kalakota 2019; Friedman and Johnson 2006).

17.2.2.4 Reinforcement Learning

The term reinforcement learning (RL) refers to approaches that train computational agents, such as robots, to iteratively interact with their environment and, through a feedback loop of reward and consequence, achieve intended goals (Neftci and Averbeck 2019). Learning in RL approaches can happen through supervising an expert's actions (imitative learning) or inferring the expert's intentions (inverse RL).

Reinforcement learning can have applications in biomedical domains such as robotic-assisted surgeries (Mittal and Hasija 2020) where RL techniques can be used to learn and infer a surgeon's maneuvers and perceive operating environments such as the contours of an open wound from its image data; such techniques have relevance for minimally invasive surgeries, which are rapidly becoming popular and may pave the way for surgeries fully performed by autonomous robots.

17.2.2.5 Rules-Based Expert Systems

Expert systems (ES) are probably one of the oldest modes of artificial intelligence use in healthcare. These expert systems are based on a set of rules constructed by human domain experts and engineers and are designed to permit replication of the decision-making process of a subject expert; for instance, the selection of a medication based on input data about patient demographics, medical comorbidities, symptoms, cost, and so on.

The most easily understood example of ES in healthcare and one that has probably been around for long is the clinical decision support system (CDSS)

(Sloane and Silva 2020), designed to provide clinicians and healthcare providers assistance with clinical decision-making tasks. As in the previous example, CDSSs will verify the prescribed drug against existing patient allergies and, if necessary, suggest safer alternatives. Expert systems continue to power domains within Electronic Health Records (EHR) even today and allow treatment protocols to be formulated based on patient data available in the EHR. However, due to their many limitations, ESs are being supplanted by more robust machine learning algorithms.

17.3 Mental Health Issues During COVID-19 Pandemic

The COVID-19 pandemic has devastatingly affected every aspect of our health and life. Mental health issues get less attention compared to physical health in almost every country of the world, irrespective of economic status. Moreover, the burden of mental health issues is yet to emerge fully as it takes time to come out as well as to evaluate the issue. Fundamentally, the lower-income, resource-strapped countries are expected to be less prepared for it.

17.3.1 Mental Health Issues in COVID-19 Positive Persons

Although COVID-19 started in December 2019, the spread of it varies widely from country to country. The rate and number of cases are also varied. Studies assessing the burden of mental health issues are coming out day-by-day that also varies in their methods and outcomes. Further studies and time are warranted to measure it precisely. Specification of diagnoses also needs a longer time duration as per the diagnostic guidelines. Demography, social context, health system status, and personality traits could affect the state; such multiple confounding variables make assessment challenging (Kar et al. 2020).

A recent systematic review and meta-analysis revealed disturbances in cognition, mood, behavior, and perception (Rogers et al. 2020). It found depressive symptoms (42%), anxiety symptoms (21%), memory problems (44%), and sleep disturbances (54%) (Rogers et al. 2020). Persons with confirmed COVID-19 positive cases naturally experience fear about their fatality and health of close family members and friends (Kar et al. 2020; Li et al. 2020; Wang et al. 2020). They experience boredom, loneliness, anger, depressive symptoms, anxiety symptoms, denial, despair, sleep disturbances, and may develop addictive behaviors, self-harm, and suicidality (Kar et al. 2020; Li et al. 2020; Vindegaard and Benros 2020; Wang et al. 2020; Yi et al. 2020).

In addition, physical symptoms of COVID-19 and side effects of prescription pharmaceutical products such as corticosteroids may produce more anxiety, mood elation, and mental distress (Kar et al. 2020; Wang et al. 2020). A survey of 1210 respondents found that 53.8% had moderate to serious psychological disorders, 31.3% had some form of depressive symptoms, 36.4% had some kind of anxiety symptoms and 32.4% had some stress symptoms (J. J. Liu et al. 2020a). The psychological effect was inversely associated with the self-assessed state of health (J. J. Liu et al. 2020a). Another systematic review showed that patients with COVID-19 had a high degree of post-traumatic stress symptoms (96.2%) and substantially higher depression (Vindegaard and Benros 2020). Positive COVID-19 tests with pre-existing psychiatric comorbidity reported aggravation of psychiatric disorders (Vindegaard and Benros 2020). Several risk factors for developing psychological symptoms have been identified, including female gender, poor self-related health, and closeness to COVID-19 patients (Vindegaard and Benros 2020).

After recovery from COVID-19 infection, the risk of developing a wide range of psychiatric disorders such as depression, anxiety, and PTSD is higher (Kar et al. 2020). Individuals can also develop obsessive-compulsive disorder (OCD) as a continuation of protection behaviors (Li et al. 2020). A recent systematic review and meta-analysis revealed that after COVID-19 disease, depression, sleep disorders, anxiety, irritability, memory problems, and fatigue were often documented (Rogers et al. 2020). The meta-analysis reported point prevalence of PTSD was 32.2%, depressive disorders were 14.9%, and anxiety disorders were 14.8% (Rogers et al. 2020). There are chances to have reinfection by COVID-19, causing anxiety, depression, stress, and adjustment issues with the new normal.

17.3.2 Mental Health Issues in COVID-19 Suspected Persons

COVID-19 suspected persons may develop psychological issues as these are persons who are supposed to be isolated and quarantined. Suspected isolated persons may develop anxiety due to uncertain COVID-19 status, OCD in the form of repeated checking and cleaning, and PTSD, which have been found positively associated with quarantine duration (Dubey et al. 2020). Reports available from previous pandemic outbreaks revealed various forms of the psychological impact of the quarantine such as irritability, fear of contagiousness, anger, frustration, loneliness, denial, anxiety, depression, sleep problems, and even suicide (Dubey et al. 2020).

17.3.3 Mental Health Issues in COVID-19 Among General Population

A recent systematic review found that when the comparison was made before COVID-19, the general population reported lower psychological well-being and increased ratings of anxiety and depression (Vindegaard and Benros 2020). Insufficient awareness of infection, transmission path, treatment, and safety measures may contribute to increased fear and anxiety (Ho et al. 2020; Kar et al. 2020; Li et al. 2020). The government implemented mass home quarantine and nationwide lock-down strategies that could result in mass hysteria, anxiety, and distress as a result of factors such as loss of control over the environment that can produce unwanted social behaviors such as panic buying (S. M. Y. Arafat et al. 2020a; Dubey et al. 2020; Li et al. 2020). These problems can be compounded if family members need separation, insufficient supply of basic goods, financial losses, increased perception of scarcity and danger, inadequate media knowledge, poor management of public health, social structure, and culture (S. M. Y. Arafat et al. 2020a; S. Y. Arafat et al. 2020b; Dubey et al. 2020; Sim et al. 2020). The lockdown state gives rise to uncertainty about the future and current income, which can lead to monotony, dissatisfaction, and irritability for the homebound people (Ho et al. 2020; Kar et al. 2020; Li et al. 2020). The pandemic can spur new psychiatric disorders and/or worsen the previous physical and psychiatric comorbidities (Kar et al. 2020). There can be a broad variety of psychiatric illnesses, such as depression, anxiety, panic disorder, somatic symptoms, self-blame, hopelessness, shame, PTSD, delirium, psychotic disorders, and eventually suicide (Kar et al. 2020; Yi et al. 2020).

The family members and the close contacts of COVID-19 positive cases are supposed to have some sort of psychological impacts because of their isolation or quarantine resulting in anxious and guilty situations as a possibility of contagion (Kar et al. 2020; Wang et al. 2020). The person who lost their family member due to COVID-19 may develop anger, resentment, guilt or stigma, depressive disorders, and PTSD (Kar et al. 2020). Isolated and quarantined children have a higher chance of developing acute stress disorder, adjustment disorder, PTSD, mood disorder, psychotic disorders, and suicidal behavior (Kar et al. 2020; Shah et al. 2020).

17.3.4 Mental Health Issues in COVID-19 Among Special Population

Healthcare professionals, persons dealing with the dead bodies of COVID-19, media personals, law enforcement members, public health members, persons with pre-existing physical and/or mental comorbidities, old age persons, homeless people, and peoples living in the old age homes and/or nursing care are supposed to have special consideration and have a higher propensity to develop mental health issues (Kar et al. 2020). The pandemic imposed an extra demand on the healthcare services and personnel across the globe, and healthcare personnel have to cope with this extra demand along with a perceived threat to their own life which caused physical exhaustion, fear, emotional disturbance, and insomnia (Ho et al. 2020; Kar et al. 2020). A study of 1563 health professionals revealed that more than half (50.7%) of the respondents had depression, 44.7% anxiety, and 36.1% insomnia (Ho et al. 2020). The frontline healthcare providers, including physicians, may develop psychiatric disorders like depression, anxiety, and PTSD (Li et al. 2020).

The COVID-19 pandemic has affected almost every sphere of life where mental health is not an exception (Fig. 17.2). There are wide variations in the distribution and presentation of mental health aspects in response to COVID-19. Further robust studies are warranted to generalize the impact of the COVID-19 pandemic on mental health.

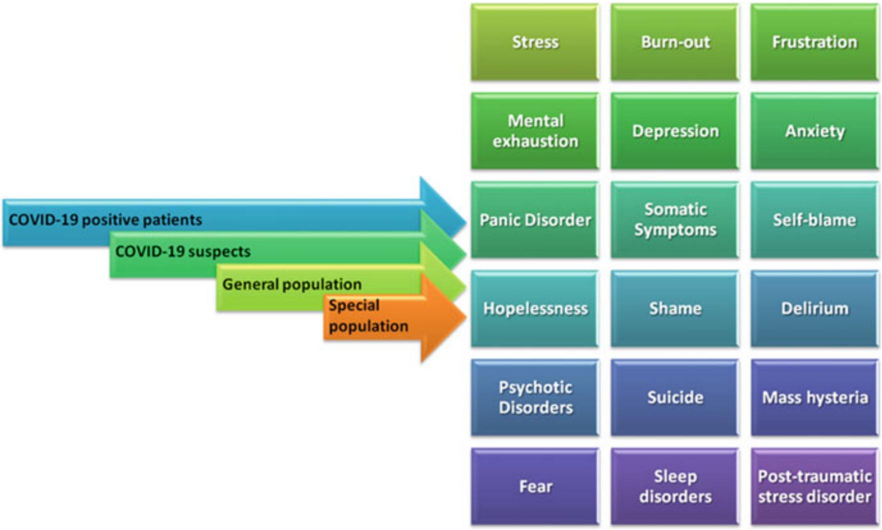

Fig. 17.2 Common mental health issues during COVID-19 pandemic

17.4 Mental Health Implications of Artificial Intelligence

Over the past several decades, artificial intelligence (AI) evolved significantly, and its application in mental healthcare has been increased (Graham et al. 2019). Artificial intelligence is being used to understand and analyze data related to several mental illnesses to guide treatment and predict outcomes with relatively better accuracy (Dwyer et al. 2018). Existing studies used data from patient's clinical records, investigation findings (neuroimaging, electroencephalogram, blood parameters, etc.), thought contents, facial emotions, various social media posts, messages, videos, online searches, and different psychological constructs for accurate interpretations (Graham et al. 2019). AI technologies have been used for the assessment and facilitate the delivery of mental healthcare. Gradually, technology is taking over the role of mental health professionals and accurately dealing with the issues in a limited time frame (Luxton 2014). AI also takes care of self-assessment, self-care, and even certain aspects of self-monitoring and management (Luxton 2016).

Considering several relevant characteristics, AI can be useful in predicting the course and the outcome of mental health issues. AI may help in the early detection of various psychiatric disorders. Early intervention may guide to effective prevention of the disorder (Lovejoy 2019). Recent studies indicate that AI guides the clinician about disease progression as well as predicting the initiation of disease (Fakhoury 2019; X. Liu et al. 2018). Recent research used multimodality neuroimaging along with AI to predict the progression and prognosis of early stages of Alzheimer's disease (i.e., mild cognitive impairment to dementia) (X. Liu et al. 2018).

Fig. 17.3 The utility of artificial intelligence in mental healthcare

A recent scoping review highlights that most of the current research in AI application in mental illnesses focuses on disorders like Alzheimer's disease, schizophrenia, and depression (Shatte et al. 2019). The common domains of application of AI in mental health research are (Fig. 17.3) research, identification, diagnosis, management, outcome, and public health significance (Shatte et al. 2019).

AI may also play a pivotal role in tailoring psychotherapy intervention. In the current scenario, most of the psychotherapy techniques (whether online or offline) are moderated by the therapist. The use of AI may limit the therapist's biases and guide the selection and delivery of a technique of intervention more accurately (D'Alfonso et al. 2017). As telepsychiatry is rapidly evolving globally, internet and mobile-based interventions are frequently being used to provide consultation to patients with psychiatric disorders. These modalities of intervention are more friendly with machine learning and AI techniques; hence, it opens up a potential ground for mental health research using AI (Ebert et al. 2019).

AI has potential implications in mental health researches. Biases (e.g., in interpretation, quantification of psychopathology) are one of the major limiting factors in mental health research, to overcome which various complex modifications (e.g., Blinding) are often done in the study designs. These limitations can be overcome through the use of AI (Lovejoy 2019). AI has been used more frequently in mental health research. AI uses various complex models to analyze huge data sets related to mental health. The difficult analyses to be interpreted through the application of conventional statistical procedures are now easier due to AI (Luxton 2016). As AI helps in tailoring mental healthcare more precisely, it will facilitate person-centered care for mental illnesses (Bzdok and Meyer-Lindenberg 2018).

17.5 The Relevance of Artificial Intelligence in Mental Healthcare During COVID-19 Pandemic

World communities have been paying careful attention to infectious diseases for decades, and noncommunicable diseases have received less publicity (Mohammad et al. 2019). This COVID-19 pandemic has infected a vast population worldwide and will undoubtedly have a significant effect on mental health (Kar et al. 2020). A total of 792 million people worldwide are dealing with mental health issues and the number of mental health cases is growing due to the pandemic, when millions of people in so many countries around the world are driven into loneliness, poverty, and anxiety (United Nation 2020). There are not sufficient mental healthcare professionals to look after these people (Allen 2020). Due to the lack of healthcare professionals, it is impossible to establish the intervention team that will support people with mental health needs (Duan and Zhu 2020). The increasing demand for mental healthcare services during the pandemic period on overburdened mental healthcare settings may create global public mental health crises and will bring frustration and suffering for mental health patients, their families, and healthcare providers (Ćosić et al. 2020).

Artificial intelligence aims to perform tasks that require intelligence, such as reasoning, learning, planning, problem-solving, and perception of machines (Luxton 2016). AI-based methods have been used in the field of mental health for several decades (Kalanderian and Nasrallah 2019) by analyzing health records, behavioral data, social media content, and outcomes of data on mental health (Su et al. 2020).

Using AI in mental health services will enable healthcare professionals to deal with complex problems and ever-expanding streams of information that stiffen the limits of human ability (Bennett and Doub 2016). AI-based mobile applications are useful when individual patients can be customized to meet their personal care goals and needs, and peer support availability (Torous et al. 2020). The use of big data by AI is useful in determining the particular trend for effective diagnosis and treatment of mental health problems. Including components of mental health in AI-based mobile applications can be exciting, available, affordable, and feasible to provide community support and recovery services for mental health problems (Ransing et al. 2020).

AI-based interventions can be designed, targeted, and adapted according to the severity of the individual's mental health, geographical location, and a group of people (Ransing et al. 2020). Liu et al. (2020a, b) reported that the rapid human-to-human transmission of the virus hampers the implementation of mental health services face to face. A recent study has shown that mobile contact tracing software technology is effective in combating the spread of COVID-19 infection (Jalabneh et al. 2020). AI has helped enable preparedness, track people with infection, and control the infection in many countries (Whitelaw et al. 2020). AI-based telepsychiatry provided high-quality care to patients with mental health needs because of its cost-effectiveness and increased patient observation (Deslich et al. 2013). AI can provide treatment decisions and forecast the outcomes of continued mental support, which will help the mental health practitioners investigate complex mental health problems and provide care.

During the lockdown situation, people stay at their homes with an anxious mind, feeling helpless and blaming others, slowly leading to a mental breakdown. Due to the popularization of internet services and smartphones, mental health professionals could provide mental healthcare support to patients during the pandemic in China (S. Liu et al. 2020b). Corruble (2020) realized that telepsychiatry and teleworking are well accepted by the healthcare staff and patients during the pandemic (Corruble 2020).

AI and language technology can track improvements in mental health based on the language and data that we create from our daily lives (Liakata 2020). AI-based software, along with telepsychiatry, can be a realistic solution to mental health problems. This is expected to reduce the treatment gap for mental health services during a pandemic (Ransing et al. 2020). In China, Wechat, *Weibo*, and *TikTok* have been widely used by the medical staff and patients for providing mental health education through a communication program (S. Liu et al. 2020b). Countries severely hit by the infection can adopt an AI-based approach to focus on prevention and not only guided but also self-guided interventions (Wind et al. 2020). There are AI support programs that were developed during the pandemic to support people's mental health. For example, AI program *Tree Holes Rescue* will identify individuals at risk of suicide by monitoring and analyzing messages posted on *Weibo* (S. Liu et al. 2020b). Wind et al. (2020) provided a solution for ongoing mental health support for individuals with mental health needs by video conferencing, and the virus seems to be working as a catalyst for the implementation of online therapy in routine practice (Wind et al. 2020). This kind of telehealth services can be used for isolated regions and reach across borders. Watkins (2020) proposed using a chatbot to deal with postpartum depression (S. C. Watkins 2020).

In many cases, especially women who suffer from postpartum depression will not reach out for any support. However, the chatbot is a cost-effective and low-barrier intervention to support mothers who suffer from postpartum mood and anxiety disorders. AI-based applications require less training to use such as mental health surveillance systems that can be developed, or healthcare settings can be equipped with AI to offer support to the general population during the pandemic (Ransing et al. 2020). AI-based smartphones are an extension of telemedicine; these days, smartphones are equipped with features like cameras, video recording and conferencing, navigation systems, e-mail systems, and web searching. Hence smartphone technology can be utilized for mental health advice and counseling (Iyengar et al. 2020). For homeless people, charging the phone or laptop can be a considerable barrier, and some people do not use smartphones. In these circumstances, the street psychiatry workforce can be developed to reach the vulnerable population. The street psychiatry workforce will provide street psychiatry and outreach work in addition to carrying chargers and portable hotspots (Torous et al. 2020).

17.6 Executive Summary

- Artificial intelligence is emerging as a technique to detect, predict, guide, and monitor mental health parameters more precisely.
- Artificial intelligence techniques may be useful in identifying biomarkers of various psychiatric disorders.
- Artificial intelligence has a potential role to play in reducing biases in mental health research and in managing of data, perfectly.
- The emerging mental health problems can be dealt effectively during the COVID-19 pandemic by using artificial intelligence technology.

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18 Effect of COVID-19 on Autism Spectrum Disorder: Prognosis, Diagnosis, and Therapeutics Based on AI

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Abstract

The outbreak of coronavirus disease 2019 (COVID-19) continues to spread globally throughout. With the present ongoing research, some vital information related to neurological manifestation and symptoms associated with COVID-19 is collected. The manifestation is associated with the injury in the central nervous system (CNS) and pathophysiology of autism spectrum disorder (ASD). The COVID-19 patients show symptoms with mild, moderate, or acute illness which can result in developing respiratory distress syndrome (RDS), cardiovascular diseases, liver dysfunction, and increased level of inflammatory cytokines affecting the immune system. The neuro manifestation covers seizures, encephalitis, acute necrotizing encephalitis, transverse myelitis, and acute flaccid myelitis, which are linked with viral respiratory infections. Research still continues on about a state of neuroinflammation in the CNS when the coronavirus makes its way via the olfactory nerve and a similar condition is spotted in ASD patients. The functional change which occurs with an individual having ASD involves increase in inflammatory cytokine and unusual immune system. Further, investigation also focuses on inflammatory illness during pregnancy and the concept of Insulin-like growth factor-1 (IGF-1) in ASD. The fact is well supported that one of the primary causes of autism is the deficiency of IGF-1 in the newborn infant which results in activation of COVID-19 cytokine, Interleukin-6 (IL6). IL6 reduces immunity particularly in older patients in comparison to younger ones.

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ASD is a neurodevelopmental disorder that affects an average portion of world's population but still there is an urge to analyze the pathophysiology of ASD under COVID-19. The risk factors such as comorbidities or biomarkers are to be identified which may incline an individual with COVID-19 to neurological manifestations including severity of CNS. Along with the multiple mechanism of neurological injury, this chapter also discusses the requirement of additional support towards the ASD individuals and their families during the COVID-19 outbreak. Moreover, it also focuses on the prognosis and diagnosis of ASD using AI techniques. Further, a glimpse of the therapeutics for ASD based on AI techniques is provided.

Keywords

COVID-19 · NeuroCOVID research · Central nervous system · Autism spectrum disorder · Cytokine · Risk factor

18.1 Introduction

The outbreak of COVID-19 continues to spread worldwide over 200 countries affecting millions of individuals. The individuals affected by the coronavirus SARS-COV-2 are accompanied with mild, moderate, or acute illness influencing multi-organ mechanism (Lima et al. 2020). Over the past 20 years, the human population has been affected with respiratory infections by some common viral pathogens such as coronavirus, influenza, human metapneumovirus (hMPV), respiratory syncytial virus (RSV), and enterovirus (Robinson and Busl 2020). In addition to mild upper respiratory symptoms, more severe manifestations including bronchitis, pneumonia, and acute respiratory distress syndrome (ARDS) are believed to occur. While respiratory illness is the consequence of coronavirus, it is well analyzed that there are a lot of beta-coronaviruses which affect the nervous system (Leonardi et al. 2020). The neurologic manifestation is related to the injury in CNS. SARS-COV-2 results in a state of neurotropism in the context of neuroinflammation via invasion of the virus through olfactory nerve further producing suppression of central cardiorespiratory drive. A similar condition is noted in the individuals with ASD. ASD is a neurodevelopmental disorder with repeated behaviors and disablement in social interaction (Del Barrio 2016). Along with viral respiratory ailment and neurologic injury, patients with COVID-19 also present themselves with cardiovascular diseases, liver dysfunction, cytokine storm with inflammation, and abnormal immunology. Studies correlate ASD with abnormal functioning of the immune system, cytokine dysregulation followed by inflammation and existence of autoantibodies, and report the presence of anti-brain immunoglobulins in ASD individuals. As a result of abnormal immune functioning in ASD, Natural Killer (NK) cells have high resting and reduced stimulated cytolytic activity leading to impaired response (Meltzer and Van de Water 2017). In accordance with the study of immunology in ASD individuals, it is found that ASD is associated with some of the alleles of human leukocyte antigen (HLA). Among the ASD children, excessive level of HLA-DRB1 *03 and HLA-DRB1 *11 is found which provides an autoimmune disorder towards autism (Mostafa et al. 2013). The conception of inflammation in the CNS among ASD patients has an adverse outcome in the form of rapid reproduction of glial cells and release of pro-inflammatory cytokines leading to disturbed neural signaling as well as cognitive functioning (Matta et al. 2019). Due to COVID-19, an elevation in cytokine profile of IL-1 beta and IL-4 has been found in prenatal stage while increase in inflammatory cytokines such as IL-1, IL-5, IL-6, IL-8, IL-12, IL-13, IL-17, IL-23, and TNF-alfa is found in postnatal state of the ASD patient. Therefore, autistic individuals are always at the highest risk of getting affected by a cytokine storm due to heavily elevated level of inflammatory cytokines (Ormstad et al. 2018). As per the dominant theories, one of the reasons for the cause of autism is the deficiency of IGF-1 in the newborn as a result of inherited polymorphism (Steinman and Mankuta 2018, 2019). The normal level of IGF-1 falls gradually from puberty onwards, thereby activating the inflammatory cytokine, IL-6, which approaches frailty with increased possibility of some diseases in older people (Chen et al. 2018). In the beginning of the twentieth century, it was studied that the developing fetus though isolated from the placenta and membranes could be infected by diseases in gravida. Increased amount of IL-6 in the placental environment during maternal immunologic activation decreases the placental synthesis of IGF-1. This would lead the fetus to be characterized with a reduced capability for myelinating its developing nervous system resulting in autistic brain dysconnectivity (Patterson 2011). Presently it is revealed that the risk of postpartum autism in infant doubles up with the maternal infection with fever during pregnancy (Hellström et al. 2016). In accordance with the recent report from China, IL-6 can be utilized as a biomarker in monitoring COVID-19 since increased level of IL-6 is found to be related with the acute seriousness of COVID-19 (Liu et al. 2020). Adequate quantity of IGF-1 is found in breast milk; a study regarding this reported minimization of autism in children who were breastfed for the entire first postpartum year (Tseng et al. 2019). Apart from breast feeding, oral consumption of bio-encapsulated lettuce cells and rice seeds also enhanced the level of IGF-1 (Xie et al. 2008; Park et al. 2020).

In the medical field, there is an urgent need for early diagnosis of ASD. Because of significant healthcare cost and time-consuming cum cost-effective diagnostic procedures, effective ASD screening and detection methods are needed. The hardest research is continuing on for classifying and detecting the ASD in all categories of individuals including adults, adolescents, children, and toddlers. In particular, machine learning and somehow deep learning are implemented for such classification and detection. The research area of machine learning incorporates mathematics, artificial intelligence, and other search methods for data processing. Data processing aims at deriving accurate predictive models from datasets. Machine learning tools need minimal human involvement at the time of data processing which includes neural network, decision tree, support vector machine together with rule-based classifiers (Thabtah 2019a). Machine learning methods are embedded in software packages. Examples of some software packages are Scikit Learn (Pedregosa et al. 2011), R (R RDCT 2013), WEKA (Hall et al. 2009), and others. During ASD

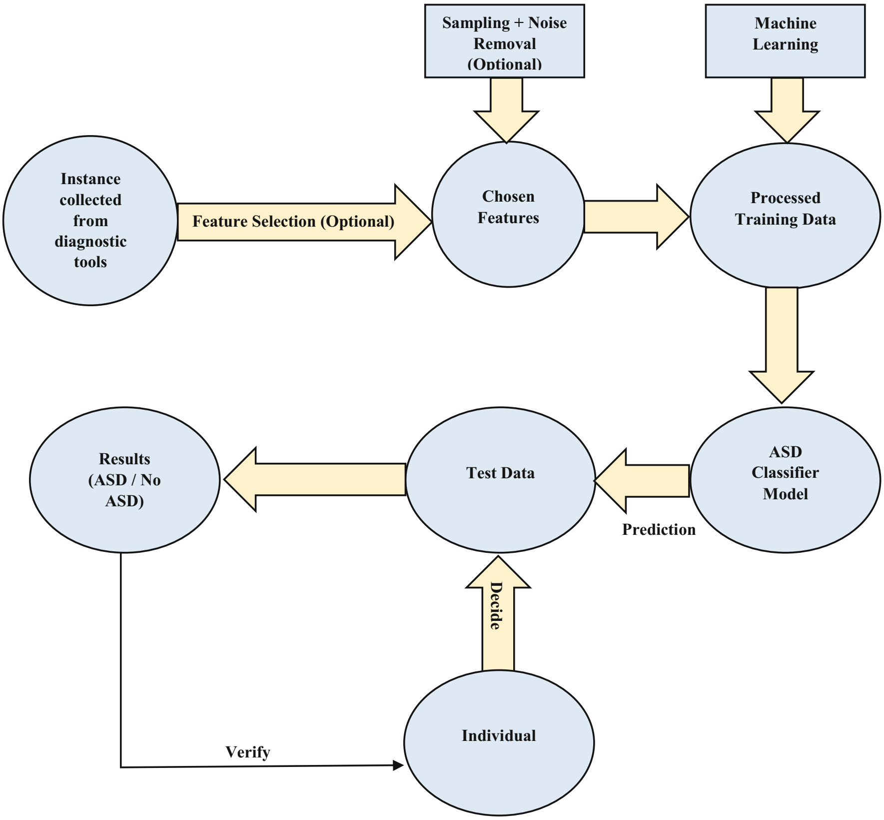

Fig. 18.1 Framework for ASD classification

diagnosis process, an automated classifier model is built using machine learning to discriminate between ASD and no ASD class. The classifier model is formulated from training data or former cases with and without ASD and gets evaluated on testing data or new cases. Present research on ASD classification focuses on:

(a) Evolution of new and latest machine learning methods to classify ASD.
(b) Reducing the number of features, thereby turning down the ASD diagnosis time.
(c) Improving the classification performance parameters.

The classification task in ASD diagnosis process is shown in Fig. 18.1.

The instances collected from the diagnostic tool form the diagnosed training dataset. After the training dataset is being identified, an optional feature selection step is applied with an aim to reduce data dimensionality, simplify problem, choose the best ASD feature, and reduce the ASD diagnosis time. The next optional step is noise removal and sampling. Noise is in the form of duplicate records, missing values, data balancing, etc. and employing sampling process to improve and rectify data issues. The processed data is then employed with ready-to-use software packages such as R and WEKA machine learning algorithm. The outcome in the form of ASD classifier model applied on test dataset evaluates the potential of the chosen machine learning algorithm. The evaluation performance parameters are accuracy, error, sensitivity, specificity, Area under Curve (AUC), positive predictive value (PPV), negative predictive value (NPV), etc. Thus, in order to carry out the ASD diagnosis, we need:

(a) Input training dataset of instances.
(b) Machine learning embedded with the processed data to construct an ASD classifier prediction model.
(c) The predictive model diagnosing the type of data.
(d) A licensed expert to confirm the outcome of predictive model.
(e) Optional feature selection method.
(f) Optional noise reduction as well as sampling to improve data issue.

The confusion matrix is shown below for ASD screening problem:

Actual class type	Predicted class type	
	ASD	No ASD
ASD	True positive (TP)	False negative (FN)
No ASD	False positive (FP)	True negative (TN)

(a) True Positive (TP): Actual data is positive and predicted data is positive.
(b) False Positive (FP): Actual data is negative and predicted data is positive.
(c) False Negative (FN): Actual data is positive and predicted data is negative.
(d) True Negative (TN): Actual data is negative and predicted data is negative.

The different performance parameters implemented for evaluating the performance of classifying and predicting ASD class are enumerated below:

$$\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{TN} + \text{FP} + \text{FN}} \tag{18.1}$$

$$\text{Sensitivity/Recall} = \frac{\text{TP}}{\text{TP} + \text{FN}} \tag{18.2}$$

$$\text{Specificity} = \frac{\text{TN}}{\text{TN} + \text{FP}} \tag{18.3}$$

$$\text{PPV/Precision} = \frac{\text{TP}}{\text{TP} + \text{FP}} \tag{18.4}$$

$$\text{NPV} = \frac{\text{TN}}{\text{TN} + \text{FN}} \tag{18.5}$$

$$\text{Error} = 1 - \text{Accuracy} \tag{18.6}$$

$$\text{AUC} = \frac{1 + \frac{\text{TP}}{\text{TP+FN}} - \frac{\text{FP}}{\text{FP+TN}}}{2} \tag{18.7}$$

$$F\text{-measure} = 2 * \frac{\text{precision} * \text{recall}}{\text{precision} + \text{recall}} \tag{18.8}$$

$$\text{Logloss} = \frac{-\sum_{y=1}^{j}\sum_{x=1}^{n} f(x,y)\log\left(p\ (x,y)\right)}{n}, \tag{18.9}$$

where x and y are training instances.

$$\text{Kappa Statistics} = 1 - \frac{1 - p_o}{1 - p_e} \tag{18.10}$$

where p_o and p_e are observed and expected accuracy respectively.

In addition to the mentioned parameters, Receiver Operating Characteristic (ROC) is another evaluation parameter in machine learning classifier models. ROC analyzes FPs in X-axis and TPs in Y-axis of the graphically derived classifier models. The performance of ROC graph is high for an FP of 0 and a TP of 1 and it is poor when FP becomes equal to TP.

To examine the effectiveness of machine learning predictive models, a testing method termed as cross validation is implemented (Abdelhamid and Thabtah 2014). First the input training dataset is divided into N number of partitions where N in general is adjusted to a number of 10. The classifier model gets trained upon $(N - 1)$ number of partitions and tested upon the remaining partitions, thereby followed by N time repetition of the procedure by randomly partitioning the training dataset. During the cross validation, stratification takes place where throughout the data splitting, random shuffling is done to make sure the availability of each class in each partition.

18.2 Literature Survey

The author in (Thabtah 2019b) proposed a mobile-based and time-efficient ASD screening tool termed as ASDTests. It was designed for testing distinct set of individuals including adults, adolescents, children, and toddlers in 11 different languages. Over 1400 cases have been collected by the ASDTest app. The participants were not directly accessed at the time of data collection as clear information was provided by the ASDTest app to the participants regarding their participation. The efficiency and accuracy of screening process was improved by the feature and predictive analysis. In addition, the performance parameters accuracy, specificity, and sensitivity rates were calculated via machine learning classifiers. The Test app was designed based on two versions of Qualitative Checklist for Autism in Toddlers (Q-CHAT) and Autism Spectrum Quotient (AQ) screening method each containing 10 numbers of questions. The questions were formulated for toddler (up to 36 months), child (4–11 years), adolescent (12–16 years), and adult (beyond 17 years). Previously CHAT method was developed as a screening tool for toddler but later the authors in (Robins et al. 2001) suggested the modified CHAT (M-CHAT), thereby enhancing the sensitivity of CHAT method. The screening method consisted of 20 questions which somehow consumed a bit longer duration. The authors in (Allison et al. 2012) reduced the number of questions to 10 with an aim to reduce the screening time by clinicians. Originally the AQ test developed for screening adults comprised of 50 numbers of questions as per five related areas: communication skill, imagination, social skills, and attention to detail and attention to switching. Later the authors in (Baron-Cohen et al. 2006; Auyeung et al. 2008) modified the AQ test to 10 questions which covered screening category for child and adolescent. There are four possible alternatives which characterize each question: definitely agree, slightly agree, slightly disagree, and definitely disagree, and alternative to each question scores a point. The author in (Allison et al. 2012) further proposed the AQ-10 to cover adult with the similar alternatives to each question followed by scoring. Under the AQ test, the screening method allots a point per question. If the individual scores more than 6, then ASD diagnostic assessment is referred for the individual.

In case of adult, for question numbers 1, 7, 8, and 10, if the answer is either "slightly agree" or "definitely agree," a point is assigned and for remaining questions, a point is assigned for the answer to be either "slightly disagree" or "definitely disagree." In case of adolescent, for question numbers 1, 5, 8, and 10, if the answer is either "slightly agree" or "definitely agree," a point is assigned and for remaining questions, a point is achieved for the answer to be either "slightly disagree" or "definitely disagree." For child, towards question numbers 1, 5, 7, and 10 if response is "slightly agree" or "definitely agree," then a point is assigned and for rest of the questions, a point is assigned for the answer to be "slightly disagree" or "definitely disagree." Table 18.1 below shows the AQ questionnaires for adult, adolescent, and child (https://www.autismresearchcentre.com/).

In case of a toddler, for question numbers 1–9, if the option in column C, D, or E is encircled then 1 point is scored per question. For question number 10, encircling the option in column A, B, or C scores a point. All the points are added. If the score is more than 3, then ASD diagnostic assessment is referred for the toddler. Table 18.2 below shows the questionnaires in Q-CHAT for toddler.

The author in (Thabtah 2019b) collected 1452 instances throughout an interval of 4 months by utilizing the ASDTest application which covered all the 4 categories of individuals. The screening was based on Q-CHAT 10 and all AQ-10 methods. But the investigator dropped the toddler instances from the entire data as vast majority of the toddler cases who underwent the Q-CHAT 10 test have found to be not associated with ASD which made the entire data unbalanced. The left 1100 instances belonged to child, adolescent, and adult. The data size of adult consists of 704 instances, that of adolescent contains 104 cases, and the child dataset comprises 292 cases. Some missing values got spotted in two features: "ethnicity" and "who_is_taking_the_test." Some of the features were extracted using wrapping

Table 18.1 AQ questionnaires for adult, adolescent, and child

Q. No.	AQ-10 adult questionnaire	AQ-10 adolescent questionnaire	AQ-10 child questionnaire	Definitely agree	Slightly agree	Slightly disagree	Definitely disagree
1	I mostly notice small sounds when others do not	He/she notices patterns in things every time	He/she mostly notices small sounds when others do not				
2	I generally focus on the entire picture, rather than small details	He/she generally focuses more on the entire picture, rather than small details	He/she generally focuses more on the entire picture, rather than small details				
3	I realize it to be easy for doing more than one thing at a time	In social group, he/she can easily keep track of different people's conversations	In social group, he/she can easily keep track of different people's conversations				
4	During an interruption, I can switch back very quickly to what I was doing	During an interruption, he/she can switch back very quickly to what he/she was doing	He/she realizes it to be easy for going back and forth in between different activities				
5	I realize it to be easy for reading between the lines while talking to someone	He/she frequently finds about not knowing to keep a conversation going	He/she has no idea of how to continue with a conversation with his/her peers				
6	I realize to inform whether someone hearing me is getting bored or not	He/she is fine with social chit-chat	He/she is fine with social chit-chat				
7	When I am through a story, it is hard for me to work out the characters' intentions	When he/she was younger, he/she enjoyed playing games with children which involved pretending	When he/she is through a story, it is hard for him/her to work out the characters' intention				
8	I like collecting information about group of things (e.g., types of bird car, plant, train, etc.)	He/she realizes it to be tough visualizing how would it be to be someone else	During his/her stay in preschool, he/she enjoyed playing games with children which involved pretending				

9	I feel easy to work upon what someone thinks or feels just by looking at his/her face	He/she realizes social situations to be easy	He/she feels easy to work upon what someone thinks or feels just by looking at his/her face				
10	I face difficulty in working out people's intentions	He/she realizes it to be hard in making new friends	He/she realizes it to be hard in making new friends				

Table 18.2 Q-CHAT questionnaires for toddler

		A	B	C	D	E
1	Does your child gaze at you when his/her name is called by you?	“Always”	“Usually”	“Sometimes”	“Rarely”	“Never”
2	How far is it easy for you to come in eye contact with your child?	“Very use”	“Quite easy”	“Quite difficult”	“Very difficult”	“Impossible”
3	Does your child point for indicating that he/she wants something? (e.g., pointing a toy which is out of reach from him/her)	“Many times a day”	“A few times a day”	“A few times a week”	“Less than once a week”	“Never”
4	Does your child point for sharing interest with you? (e.g., pointing towards an captivating sight)	“Many times a day”	“A few times a day”	“A few times a week”	“Less than once a week”	“Never”
5	Does your child pretend? (e.g., caring for dolls, talking on a toy phone)	“Many times a day”	“A few times a day”	“A few times a week”	“Less than once a week”	“Never”
6	Does your child follow your sight?	“Many times a day”	“A few times a day”	“A few times a week”	“Less than once a week”	“Never”
7	Does your child show signs of comforting you or someone else in the family when you or someone else is upset? (e.g., stroking your or their hair, hugging you or them)	“Always”	“Usually”	“Sometimes”	“Rarely”	“Never”
8	You would describe your child’s first words as:	“Very typical”	“Quite typical”	“Slightly unusual”	“Very unusual”	“My child doesn’t speak”

(continued)

Table 18.2 (continued)

		A	B	C	D	E
9	Does your child use basic gestures? (e.g., waving good bye)	"Many times a day"	"A few times a day"	"A few times a week"	"Less than once a week"	"Never"
10	Does your child gaze at nothing without any purpose?	"Many times a day"	"A few times a day"	"A few times a week"	"Less than once a week"	"Never"

filtering method in which all combination of feature class got tested and the set of features was selected that maximized the predictive parameters of classification. With an aim to get the most influential features out of entire features, the wrapping method also reduced the screening process of ASD. From the adult dataset, 12 influential features out of all features got filtered: AQ-10 adult questionnaire bearing items 1–10, "gender" and "used the app before." In case of adolescent category, 8 features out of 21 features got selected: AQ-10 adolescent questionnaire bearing items 2, 5, 9, and 10, "gender," "born with jaundice or not," and "used the app before." In continuation with the child dataset, 4 effective features got selected from 21 features: AQ-10 child questionnaire bearing items 1, 4, 8, and 10. Two machine learning classifiers, Logistic Regression (LR) and Naïve Bayes (NB), were implemented for classifying the ASD data. The performance parameters accuracy, sensitivity, and specificity were found for the child, adolescent, and adult dataset. Adult dataset gained higher rates in comparison to adolescent and child datasets as it has more number of instances than the other two datasets. Among the two, LR proved to be superior in comparison to the NB classifiers. In adult dataset, LR outperformed NB by 4.12, 4.2, and 3.01% in terms of accuracy, sensitivity, and specificity.

With an intension to improve the efficiency of screening classification system, the author in (Al-diabat 2018) evaluated fuzzy rule-based data mining techniques over child dataset for detecting individuals with autism. The proposed model analyzed If-Then rules upon different variables associated with behavior. The dataset collected from UCI data repository covered a period from September 2017 to February 2018 containing 509 instances with a division of 252 with NO ASD and 257 with ASD trait and hence the issue of data imbalance got suppressed. The dataset was formulated by the AQ-10 child screening questionnaire by a mobile ASDTest app developed by the author in (Thabtah 2019b). A total of 24 features are present in the actual dataset out of which some of the items based upon their influence on classifying cases are discarded including "case_ID," "Country_of_Residence," "Language," "Screening_Type," and "Used_App_Before." The fuzzy data mining classification algorithms FURIA, JRIP, RIDOR (Cohen 1995), and PRISM (Cendrowska 1987) have been used to analyze the overall performance. PRISM is an algorithm which emphasizes the rules having 100% expected accuracy. It utilizes the expected accuracy to decide about adding a feature in the dataset to the rule body. RIDOR is based on evaluating the importance of a feature in dataset as per the rule's predictive power before using it in the rule body. In comparison to PRISM, JRIP algorithm is more advanced. It develops an optimization approach which uses two subsets of data and lessens the number of generated rules during the learning phase. FURIA is a recent extension of RIPPER algorithm. Instead of conventional rules and rule list, it learns fuzzy rules and unordered rule sets. It also makes the excellent utilization of Rule Stretching method. According to the result, in case of accuracy rates, the classification model of FURIA suppressed JRIP, PRISM, and RIDOR models by 3.14%, 7.66%, and 0.98%, respectively. In terms of sensitivity, again FURIA outperformed JRIP, RIDOR, and PRISM by 3.2%, 1.0%, and 3.0%, respectively. But surprisingly, PRISM suppressed rest of the models in terms of specificity rate. So the FURIA data mining model showed higher performance in predicting accuracy and sensitivity but lower performance in predicting specificity in comparison to other models. The investigation was limited only to child dataset.

The authors in (Vaishali Ravindranath 2018) stated the importance of implementing machine learning algorithms to develop ASD prediction models where the quality of prediction completely depends upon the improved performance parameters computed from the prediction model. It was proposed by the authors in (Wang et al. 2007; Unler et al. 2011) about the swarm intelligence-based feature selection wrappers to be better approaches for feature subset evaluation by avoiding inter-feature correlation with correlation bias with minimum iterations. The authors in (Vaishali Ravindranath 2018) with an aim to reduce noise from the dataset and for dimensionality reduction via feature selection used swarm intelligence-based binary firefly feature selection wrapping method. The experimentation was done on the child dataset comprising 292 instances with 21 features obtained from UCI machine learning repository. The dataset is established on the AQ-10 child screening ASDTest developed by the author in (Thabtah 2019b). Out of 292 instances, there are 151 cases with ASD class type and remaining 141 cases with no ASD class type proving the dataset to be clean from the problem of class imbalance. The swarm intelligence-based feature selection method filtered 10 features out of 21 as "A1_Score," "A2_Score," "A3_Score," "A4_Score," "A5_Score," "A7_Score," "A8_Score," "A9_Score," "A10_Scor"e and relation to classify ASD and no ASD patients. Hence the optimum feature subset is 10. Followed by dimensionality reduction, to classify ASD and no ASD type, machine learning classifier models are used as NB (Langley and Langley 1995), J48 Decision tree (Quinlan 1993), Surface Vector Machine (SVM) (Keerthi et al. 2001), K Nearest Neighbors (KNN) (Aha et al. 1991), and Multilayer Perceptron (MLP) (Pal and Mitra 1992). The objective of the experimentation focused on minimum features and maximum accuracy. The parameters set in the feature selection analysis involves R and WEKA software platform tools, evaluation algorithm as KNN wrapper with $K = 5$, Euclidean distance, 30 particles, 100 iterations, and objective function as single weighted fuzzy fitness. The evaluation parameters constitute accuracy, TP rate, Root Means Square Error (RMSE), and ROC. All the machine learning classifiers got evaluated with an observation of improved accuracy after feature selection by 3 out of 5 classifier models. The range of accuracy rate lies between 92 and 98% after feature selection. NB, J48, and KNN showed improved accuracy rate by 2.4%, 1.02%, and 6.17% respectively. But somehow SVM and MLP showed decreased accuracy. The deterioration of the two classifier models is due to the presence of 15% of the missing values in selected features. Next to accuracy, the range of TP rate after feature selection ranges between 92 and 98% with 3 out of 5 classifiers resulting in improved TP rate. NB, J48, and KNN showed improved TP rate by 3%, 1%, and 5% respectively. For SVM and MLP, the TP rate fell but still remained close to the rate in the original model. MLP showed maximum ROC of 100% both before and after feature selection method. Finally, both SVM and MLP resulted in the minimum RMSE of 0.06 and 0.052 respectively before feature selection and after the optimal method 0.14 each. With the optimum feature subset selection and training the classification models with minimum behavior sets, the performance of classification models is validated.

The authors in (Akyol et al. 2018) laid their investigation upon child category for detecting ASD. They paid emphasis on the importance of attributes and the prediction models for detecting ASD. The dataset was collected through the UCI Machine Learning Repository, 2018, consisting of 292 instances with 21 attributes. The outcome variable is a class of ASD. Firstly, the dataset was preprocessed and shuffled. The raw data consists of 292 instances but after preprocessing the number of instances dropped to 247 as some instances including the missing values for ethnicity and relation attributes were removed. Then the categorical information like Yes/No and m/f were converted into 1/0 categorical values. The categorical transformation for "Ethnicity" attribute which includes categories like Middle Eastern, White-European, and Black and "country_of_residence" attribute including categories like Jordan and United States is carried out, too. The authors used LR based on feature selection method for investigating the significance of questions being asked to patients and ASD attributes. The approach calculated the probability of an event to occur as well as not occur and that is why each independent attribute was explained in terms of odds ratio (Hosmer and Lemeshow 2000). In particular, the odds ratio is a score indicating the effect of each independent variable on the outcome ASD class. From the odds ratio, it was found that the attributes "age," "ethnicity," "country_of_residence," "relation," and "result," and questions 4 and 10 in AQ-10 child questionnaire set held much weightage. Two datasets were considered: firstly, the preprocessed dataset and secondly, the dataset of the best attributes. The investigators then divided both the datasets into training and testing dataset with a ratio of 70:30 with 172 instances in training dataset and that of 75 in testing dataset. The training dataset was set as the input to the Fuzzy Rule algorithm (Roubos 2003). The test data was fed to the predictive models for the testing. Two predictive models were implemented by the author for testing: only fuzzy rule model (FR) and the combination of Logistic Regression and fuzzy rule (LR-FR). The performance parameters taken into account, accuracy and sensitivity, were evaluated. It was found that LR-FR model yielded better result in comparison with only FR model on best attribute dataset. The accuracy achieved was 97.33% and that sensitivity was 97.06%.

The authors in (Thabtah et al. 2018) with an intension to have effective screening identified more fewer and influential features in ASD screening process. The analysis covered 1452 instances belonging to different group of individuals such as toddler, child, adolescent, and adult was collected by Q-CHAT-10 and AQ-10 screening approaches respectively by an ASDTest App developed by the author himself in (Thabtah 2019b). The toddler sub-dataset was dropped off from the entire dataset as the author found majority of the toddler instances with a "no ASD" class type, thus resulting in a imbalanced dataset. The remaining 1100 cases belonged to child, adult, and adolescent category of individual. More number of male cases occurred in comparison to females as 625 and 475 respectively. Further in the overall dataset, there are 707 and 393 instances present with ASD and no ASD class type. The authors proposed a computational intelligence method termed as Variable Analysis (VA) which considers feature to class correlation and decreases feature to feature correlation. VA is embedded with machine learning tool, WEKA version 3.9.1, and used in Java programming language (Hall et al. 2009). The result of VA was compared against other filtration methods: CHI-SQ (Hall 1999), IG (Liu and Setiono 1995), Correlation Feature Set (CFS) (Witten et al. 2016), and Correlation Attribute Evaluation analysis (Ross Quinlan 1986). VA analysis was able to choose less number of items as 6, 8, and 8 out of 21 from AQ-10 adult, AQ-10 adolescent, and AQ-10 child dataset respectively. The result of the VA got verified by two machine learning algorithms, Repeated Incremental Pruning to produce Error Reduction (RIPPER) and C4.5 (Decision Tree) with automated classification system in terms of adequate level of specificity, sensitivity, PPV, NPV, and accuracy. As per the study, both the algorithms hold good in machine learning and data mining area (Thabtah and Kamalov 2017; Abdelhamid et al. 2017; McCluskey et al. 2014). Tenfold cross validation was also used to train the dataset where arbitrarily the dataset is divided into ten parts. The learning algorithm, RIPPER or C4.5 trained nine parts and developed a classifier model to test on the remaining parts to achieve evaluation metrics (error rate). The procedure was repeated for ten times on the dataset, thereby splitting the dataset into ten parts to obtain an error rate. Finally, the average of all the error rates is calculated to produce one global error rate of the classifier. VA reduced the features in child dataset by 27.3%, 46.7%, 38.5%, and 20.0% in comparison to CHI, IG, Correlation, and CFS filtering methods respectively. In case of adolescent dataset, VA minimized the features by 11.1%, 38.5%, 50.0%, and 0% in comparison to CHI, IG, Correlation, and CFS filtering methods respectively. Finally, it showed the reduction by 53.8%, 62.5%, 60.0%, and 45.5% than CHI, IG, Correlation, and CFS methods respectively. The result of VA features is compared with the features of IG, CHI, correlation, CFS and original 21 features by RIPPER and C4.5 algorithms. For adolescent case in particular, the accuracy of VA scaled good with IG, CHI, correlation as well as CFS. The result marked a slight fall in the accuracy rate for child and adult dataset. To be specific, for adult dataset, the C4.5 classifier model formulated from VA features produces reduced accuracy by less than 2.8% in comparison to IG, CHI, correlation, and CFS. In adolescent dataset, when compared with original number of features, the RIPPER and C4.5 classifier models derived from VA features showed higher accuracy by 10% and 6%

respectively. Despite the reduction in accuracy, still the features derived by VA maintained an acceptable range of accuracy, thereby reducing the number of features to a large extent. The specificity rate is the highest in adult dataset found from the VA features but were 2.8%, 1.9%, 1.4%, 3.6%, and 3.0% less in comparison with the features of no feature selection, IG, CHI, Correlation as well as CFS respectively. The sensitivity rates found by the RIPPER classifier is the highest for VA features in adolescent dataset. It is found to be 87.30%. For the same adolescent dataset, the C4.5 classifier produced the sensitivity rate to be approximately 91% but it was lesser than the sensitivity rate for CFS features. For adult dataset, RIPPER classifier resulted in a sensitivity rate of 82.54% and C4.5 classifier produced a sensitivity rate of 80.95% from VA features. The reason behind the lower sensitivity is the misclassification of ASD type. In case of adolescent dataset, the RIPPER algorithm derived by VA features proved to be more sophisticated in terms of PPV as well as NPV than other feature sets. But the VA feature classifiers resulted in lesser PPV and NPV rates upon the child as well as adult dataset though maintaining acceptable rate. All the found performance parameters concluded that VA is able to select much limited number of features from the three datasets in comparison to the other filtering methods taken into consideration. The minimal selected items when processed by the classifier models yielded acceptable rate of accuracy, sensitivity, specificity, PPV, and NPV rates.

ASD detection is absolutely based upon the automated classifiers constructed by Machine Learning which involves determining performance parameters. In addition, to establish a better performance, the authors in (Thabtah and Peebles 2020) proposed a new Rule-based Machine Learning (RML) which apart from detecting autistic cases also offered rules which can be used to analyze the reasons behind classification. Except toddlers, the research covered datasets associated with child, adolescent, and adult category. With an intension to evaluate the performance, the result of RML was further compared with the other eight algorithms: RIPPER, RIDOR, Nnge, Bagging, Boosting, CART, C4.5, and PRISM (Cohen 1995; Gaines and Compton 1995; Salzberg 1994). For processing the dataset, various learning schemes are required which are provided by the mentioned algorithms. In C4.5 and CART, pessimistic error estimation was used for constructing decision tree classifiers which convert into rule sets. RIPPER implements optimization procedures to evaluate the worthiness of feature in dataset before using them in the rule body. As per the rule's predictive power, RIPPER either accepts or ignores the feature and generates the rule. The classifier models employed by Bagging and Boosting are merged to form rules. The operation is done by deriving N number of classifiers for predicting the class type of test data instances using a voting mechanism finally resembling the class type belonging to majority classifiers gets allotted to the test instance. The data upon which the experimentation was done were collected using the ASDTest app developed by the author himself. There was no direct access for the individual in ASDTest app. The data size of adult, adolescent, and child is 704, 104, and 292 cases respectively. There were some missing values found in some features like "ethnicity" and "who_is_taking_the_test." Throughout the dataset, the most popular ethnicities belong to white, Asian, and Middle Eastern. In case of adult dataset, RML classifier achieved error rates of 4.41%, 2.7%, 0.15%, 2.14%, 3.7%, 3.27%, 1.57%, and 1.83% lesser than PRISM, CART, AdaBoost, Bagging, Nnge, RIDOR, C4.5, and RIPPER algorithms respectively. In case of child dataset, RML classifier resulted in error rate of 5.82%, 4.11%, 0.69%, 2.4%, 1.03%, 5.82%, and 2.4% lesser than PRISM, CART, AdaBoost, Bagging, Nnge, RIDOR, and RIPPER algorithms respectively. But C4.5 classifier resulted in less error rate than RML classifier by 0.34%. In adolescent dataset, RML classifier produced 7.69% lesser error rate than C4.5 algorithm. Not only C4.5, it also outperformed RIPER, Nnge, Bagging, Cart, and PRISM algorithm with lesser error rates, almost same error rate with RIDOR algorithm but slightly higher error rate from Ada Boost algorithm. The result analysis on error rate somehow proved that RML not only performs effectively on datasets (adult) having large number of instances but also with datasets (child and adolescent) having limited number of instances. In general, the acceptance rate of sensitivity and specificity for ASD classification is 80%. In adult dataset, RML classifier derived sensitivity rates of 1.9%, 3.3%, 2.0%, 2.8%, 3.2%, 1.7%, 0.2%, and 1.7% higher than RIPPER, RIDOR, Nnge, Bagging, CART, PRISM, AdaBoost, and C4.5 algorithms, respectively. Continuing with the same dataset, it achieved specificity rates of 2.52%, 3.49%, 1.55%, 2.72%, 2.72%, 1.94%, 5.02%, and 2.72% higher than RIPPER, RIDOR, Nnge, Bagging, CART, PRISM, AdaBoost, and C4.5 algorithms, respectively. In case of child dataset, the sensitivity rate of RML classifier was 2.4%, 5.9%, 1.1%, 2.4%, 4.2%, 0.78%, and 0.7% higher than RIPPER, RIDOR, Nnge, Bagging, CART, PRISM, and AdaBoost algorithms, respectively. The sensitivity rate of C4.5 was slightly higher than RML by 0.3%. Though the adolescent dataset is a small one with less number of instances in comparison to adult and child dataset, still RML showed elevated sensitivity rate in comparison to RIPPER, Bagging, Nnge, AdaBoost, CART, and C4.5 algorithms by 20.2%, 5.8%, 2.9%, 0.6%, 13.5%, and 7.7% respectively. Now, to be exact with specificity, RML achieved higher specificity rates by 19.8%, 6.0%, 2.7%, 0.4%, 13.2%, and 7.5% in comparison to RIPPER, Bagging, Nnge, PRISM, CART, and C4.5 algorithms respectively. It got outperformed by RIDOR and AdaBoost algorithms by 0.2% and 0.8% respectively. In terms of accuracy, the classifier generated by RML outperformed all the other Machine Learning algorithms in adult and child dataset. But in case of adolescent dataset, the AdaBoost algorithm slightly suppressed RML. Overall, the performance of RML was satisfactory in comparison to the considered Machine Learning algorithms. The only limitation of the research is not including the toddler instances due to their rare availability.

The authors in (Erkan and Thanh 2020) focused on early detection of ASD based on supervised learning. The data was collected from UCI repository from the ASDTest screening app developed by the author in (Thabtah 2019b). The dataset comprises three categories of individuals: child, adolescent, and adult, with 21 attributes excluding the case number. There also exist some missing values in the attributes mainly "ethnicity," "who is taking the test," and "age." The adult dataset has 704 instances followed by neglecting the missing data due to which the instances dropped to 609. Similarly, after exiting the missing data, the number of instances fell from 104 to 98 in adolescent sub-dataset followed by child sub-dataset where the cases dropped from 292 to 249. To enhance the attribute selection and extraction, the numeric translation rule was implemented during the preprocessing phase of the data. Excluding the attributes of screening questions which are already set to either 0 or 1, upon the four string features such as “gender,” “ethnicity,” “country of residence,” and “who is completing the test” and three binary features such as “born with jaundice,” “family member with PDD,” and “used the screening app before,” the translation concept was put in. Numbers 1 and 0 were used upon “gender” attribute (male and female respectively). For the feature “ethnicity,” mathematical numbers 1–14 were applied and in case of missing ethnicity value, the number 15 was used. In case of the feature “country of residence,” as per data gathered from 89 countries, integers 1–89 were allocated in alphabetical order for each country. Upon the attribute “who is completing the test,” integers 1–6 were allocated where 6 was for missing attribute value. Any change in the data structure may result in erroneous result and thus to avoid such change, in case of missing value, a number other than the known value was used. Followed by the preprocessing, the authors performed the classification on the datasets by utilizing KNN, SVM, and Random Forest (RF) classifier (Breiman 2001). The preprocessed data was divided into two sections: the first was training data expressed in $\alpha\%$ within the range of 50–90%. The training data trains the classification models. The second section was the testing data expressed as $(100 - \alpha)\%$ which was used as the ground truth for measuring and comparing the classifier performance parameters. The ground truth resembled the attribute “class name” to evaluate the performance parameters. To analyze the performance of classification models, the following performance parameters were employed: F-measure, sensitivity, accuracy, and AUC. Five experiments were performed with $\alpha = 50$–90% followed by random selection of training as well as testing data 100 times in each experiment. The average values of performance parameters were calculated from all the 100 cases in each experiment. For each ASD data sub set, two cases were considered for the entire experimentation: complete as well as missing data cases. The result showed that, in case of adult dataset, the RF and SVM classifier model showed 100% performance on both complete and missing data test cases. For adolescent dataset, the performance of RF classifier was 100% on both complete and missing data test cases but SVM classifier scored 100% for $\alpha = 60$–90% in complete data and showed the same performance for $\alpha = 80$–90% in missing data. The performance of RF classifier in child dataset is somehow reduced slightly. It showed 100% performance for $\alpha = 60$–90% in missing data and $\alpha = 80$–90% in complete data. The SVM classifier resulted in performance of more than 90% in all cases of child dataset. The slightly reduced performance of classifiers in child dataset is due to a smaller number of instances present in that dataset (only 104). The KNN classifier model resulted in the lowest performance. The authors concluded that the RF classifier model proved to be at its maximum performance level for early classification of ASD class and it can be also implemented as clinical decision support systems.

The authors in (Akter et al. 2019) with an intension for early detection of ASD collected ASD datasets related to adult, adolescent, child, and toddler. Along with rest of the datasets, much emphasis was paid towards the toddler dataset. A total of

2009 instances were collected from UCI ML repository and Kaggle. Out of the total number of instances, the number of adult cases is 609, that of adolescent is 98, 248 cases for children, and the highest which is 1054 cases for toddlers. In all categories, the male population dominated the female group which can be analyzed by the fact that adult dataset consists of 321 males and 288 females, the adolescent dataset contains 49 individuals in both gender cases followed by child dataset comprising 174 males and 74 females, and finally the toddler dataset characterized by 735 males and 319 females. There are 21 attributes excluding the case number with some missing, unwanted, and noisy records. Prior to the classification methods, three feature transformation methods including log, *Z*-score, and sine functions were applied to the datasets followed by application of 250 machine learning classifiers upon the feature transformed datasets. Out of them, only nine classifiers which showed accuracy of more than 70% got selected as Adaboost (Mease et al. 2007), Flexible Discriminant Analysis (FDA) (Zhao et al. 2019), C5.0, Boosted Generalized Linear Model (Glmboost) (Hofner et al. 2014), LDA (Arabameri and Pourghasemi 2019), Mixture Discriminant Analysis (MDA) (Hastie and Tibshirani 1966), Penalized Discriminant Analysis (PDA) (Hastie et al. 1995), SVM, and CART. Statistical features like mean, median, and maximum were used to produce experimental results. In addition, performance parameters including Accuracy, Kappa Statistics, AUROC, Sensitivity, Specificity, and Logloss were calculated to justify the experimental results. In terms of accuracy, the SVM classifier predicted ASD with 98.77%, Adaboost resulted in 97.20%, Glmboost produced 93.89%, and Adaboost yielded 98.36% in toddler, child, adolescent, and adult dataset respectively. In terms of kappa statistics, the SVM classifier predicted ASD with 97.10%, Adaboost resulted in 94.41%, Glmboost produced 86.37%, and Adaboost yielded 96.02% in toddler, child, adolescent, and adult dataset respectively. In case of AUROC, the SVM classifier predicted ASD with 99.98%, Glmboost produced 99.87%, Glmboost yielded 98.61%, and Adaboost resulted in 99.95% in toddler, child, adolescent, and adult dataset respectively. For sensitivity, the SVM classifier classified ASD with 99.39%, Adaboost produced 98.40%, SVM classifier resulted in 97.50%, and Adaboost predicted with 99.30% in toddler, child, adolescent, and adult dataset respectively. In terms of specificity, Adaboost yielded 99.59%, PDA resulted in 98.46%, Glmboost produced 98.33%, and Adaboost yielded 96.11% in toddler, child, adolescent, and adult dataset respectively. Lastly, for logless, SVM classifier produced 3.01%, Adaboost yielded 9.62%, Adaboost gave 15.81%, and the same Adaboost resulted in 5.64% in toddler, child, adolescent, and adult dataset respectively. The author analyzed that SVM classifier showed maximum performance for toddler dataset, Adaboost classifier showed the best performance for child dataset, while Glmboost model performed the best for adolescent dataset and Adaboost once again proved to be the best classifier for adult dataset. On the other hand, the feature transformation which resulted in the best classification for toddler dataset was the sine function and for child, adolescent, and adult dataset, it was *Z*-score. With appropriate optimization, machine learning classifiers can be the best platform for early prediction and detection of ASD status.

The authors in (Alwidian et al. 2020) examined the Association Classification (AC) as data mining technique in predicting ASD. The ASD adult dataset was obtained from UCI repository which got collected via screening in ASDTest app developed by the author in (Thabtah 2019b). It consists of 21 attributes excluding case number and covers 704 instances, out of which 515 cases are under "no ASD" class type and remaining 189 under "ASD" class type. There were certain number of values assigned to each attribute in the dataset. All the ASD screening questions and in addition "gender," "Born with jaundice," "Family member with PDD," "used app before," and "class name" were being assigned with 2 number of values, "age" and "screening score" were allotted with 4 number of values, "ethnicity" and "country of residence" were allotted with 11 and 67 number of values respectively. The author implemented seven algorithms: Classification based on Association Rules (CBA), Multiple Class-Association Rules (CMAR), Multi-Class classification based on Association Rules (MCAR), Fast Associative Classification Algorithm (FACA), Fast CBA (FCBA), Enhanced CBA (ECBA), and Weighted CBA (WCBA) to analyze the performance of AC technique by identifying correlation between features for classifying ASD classes. CBA algorithm generates the item set by using Apriori algorithm and satisfies the rule estimation measures. The efficiency of the algorithm is not much satisfied in the case when there exist multiple passes against the dataset during rule generation (Liu et al. 1998). The CMAR algorithm focuses on mining large datasets, thereby building a class distribution-associated FP-tree. To preserve the mined association rules and later with an aim to retrieve the rules as well as adopt other pruning measure rules, a CR-tree is adopted. The algorithm is able to solve the issue of multiple pass up to far extent (Li et al. 2001). In the MCAR algorithm, same procedure as that in CBA algorithm is used to generate single item set. In order to generate the next item set, extra scanning of the dataset is done followed by storing the occurrence position for each attribute. It works on rule ranking method while selection between multiple rules to minimize the randomization decision (Thabtah et al. 2005). FACA supports and sorts the generated rules with an intension to improve the speed of model building. The algorithm allows selecting the class type with a high number of rules, thereby splitting the matched set of rules into clusters. It improves the accuracy of the algorithm (Hadi et al. 2016). The authors in (Alwidian et al. 2016a) proposed FCBA algorithm with an aim to optimize the time for building the model and in addition to also optimize the classification accuracy rate of CBA algorithm. The FCBA algorithm adopted a new ranking method which enhanced the speed of Apriori algorithm by introducing a new pruning mechanism for rule generation. The authors in (Alwidian et al. 2016b) proposed the ECBA algorithm which proved to be better than the mentioned algorithms in terms of accuracy, scalability, and the time required to build the model. The authors implemented optimizing Apriori algorithm with some statistical measures to improve the performance. The authors in (Alwidian et al. 2018) introduced WCBA algorithm which was meant for rule evaluation and prioritization through an efficient weighted association classification technique. In addition, for prediction and pruning techniques, statistical measures were also implemented. As per the experimentation, the WCBA algorithm proved to have improved performance than other algorithms upon two breast cancer datasets. The evaluation metrics used to determine the performance of classification included accuracy, precision, F-measure, and Recall. The experimentation was repeated thrice with distinct values of minimum support value and minimum confidence value. In experiment 1, minimum support value and minimum confidence value were 0.1 and 0.5 respectively; in experiment 2 the values were respectively 0.1 and 0.6 followed by the values to be respectively 0.2 and 0.4 in experiment 3. The experiment 1 result revealed that FACA and WBCA outperformed other AC algorithms with an accuracy of 85.2% each. In terms of F-measure, the FACA algorithm held the first position with 87.4% followed by WBCA with 84.5%. Highest precision of 85.5% was achieved by ECBA followed by FACA with a precision of 84.6%. Finally, FCBA was ranked first in Recall with a value of 96.6% followed by WCBA with a Recall value of 96.3%. In experiment 2, with the increase in minimum confidence value from 0.5 to 0.6, the WCBA outperformed all other algorithms in terms of accuracy, F-measure, and Recall as 87.84%, 88.6%, and 97.2% respectively. But it was ranked in second position for a precision of 81.4% where the highest precision of 83.2% was acquired by MCAR algorithm. Lastly in experiment 3, with the increase in minimum support value from 0.1 to 0.2, WCBA and FCBA showed the highest accuracy of 84.36%, FCBA ranked first in *F*-measure of 87.4%, ECBA outperformed other algorithms with a precision of 85.7% followed by WCBA with a precision of 85.0%. Finally, FCBA achieved the highest Recall value of 90.5%. The average accuracy of each algorithm was found which indicated the highest average accuracy rate was achieved by WCBA followed by FACA and MCAR with an average accuracy rate of 83% and the CMAR resulted in the least accuracy rate of 77%.

With an intension to implement deep learning concept, the authors in (Raj and Masood 2020) predicted the possibility of ASD in child, adolescent, and adult by employing four machine learning algorithms: NB, LR, SVM, and KNN. Apart from the machine learning algorithms, Artificial Neural Network (ANN) (Pal and Mitra 1992) and Convolution Neural Network (CNN) (Masood et al. 2018a, b) were also used to predict ASD. The datasets were collected from the UCI Repository which are stored in the online research site by the ASDTest app developed by the author in (Thabtah 2019b). There are 292 instances in the child dataset, 104 cases in adolescent category, and finally adult dataset comprises higher number of instances in comparison to child and adolescent category, i.e., 704 instances. Each of the datasets contains 21 attributes. In the research, the author preprocessed the raw data into an understandable and desirable format. The raw data in general was incomplete and inconsistent in terms of large number of attributes, errors, missing values, data discretization, etc. In majority cases, the author found some missing values in the datasets and handled by imputation method. Following preprocessing, the processed dataset was divided in the ratio of 80:20 as training and testing dataset respectively. Further the training dataset was divided into training and validation dataset in the ratio of 80:20 respectively for cross validation. All the 21 features without any dimensionality reduction are used to predict ASD. Gaussian NB is used in NB algorithm, for SVM, RBF kernel with a gamma value of 0.1 is used, in case of

KNN, $N = 5$ is set. The Adam Optimizer with a learning rate of 0.01 and 100 epoch is employed in case of ANN followed by the use of Relu activation function, binary cross-entropy loss function, Adam Optimizer, 16 & 32 filters, and 0.5 dropouts in addition with 150 epochs for CNN. In case of adult dataset, the CNN outperformed rest of the classifier models with an accuracy rate of 99.53%, sensitivity rate of 99.39%, and a specificity rate of 100%. For adolescent dataset, CNN again resulted in the highest accuracy and sensitivity rate of 96.88% and 93.35% respectively. But the specificity rate yielded to be 100% by all classifiers except for NB. Finally, for the child dataset, the highest accuracy rate of 98.30% is achieved by CNN, ANN, LG, and SVM; highest specificity rate of 100% by CNN, LG, and SVM. But in terms of sensitivity rate, the SVM outperformed CNN merely by only 0.01%. The analysis concluded that the CNN-based classifier model resulted as a better option for predicting and classifying ASD in all category of individuals. Though in terms of specificity CNN got down by SVM, it is only by a small rate which possibly cannot put up uncertainty regarding the performance of CNN. The research dropped the category of toddlers among the dataset. One of the reasons for not considering the toddler dataset is that majority of toddler cases through the Q-CHAT 10 test have been found not associated with ASD which made the entire data unbalanced.

In the present scenario, along with the technical advancement in ASD prediction, the rightful promotion of physical health risks of COVID-19 has served as a platform for discussing its effect on children with mental disabilities. In general, mentally disabled persons need to maintain an intact routine. But due to social distancing and work from home measures because of COVID-19, there has been lacuna in maintaining the structured routine of those disabled children (Patel 2020). According to the authors in (Bartlett et al. 2020), disruption in the routine as a result of closure of day care centers, schools, social distancing, and isolation can lead to a great struggle for physically and mentally challenged children. As per the investigation in (UNICEF 2020), since April 2020 in 189 countries, all schools have been suspended and the entire education system is being shifted to online mode. The online mode of education is quite favorable to most of the children but at the same time, children with disabilities suffer. Research in (Hills 2020) reveals that the online education platforms have proved themselves not compatible not only for children with physical and mental disabilities but also for children with visual impairment. The disabled children feel frustrated towards the lack of recreational activities in online learning. Children with ASD are have difficulty in maintaining social interaction and developing social skills because they are not allowed for any outdoor activity as a result of social distancing. So, they feel more anxious and restless with unpleasant feelings. The author in (Tandon 2020) explained briefly about the relationship between psychiatry and COVID-19. Due to disruption in routine, mentally disabled children experience negative emotions, change in the pattern of their daily work like eating, sleeping, etc., and change in moods followed by mood swings. All these circumstances put them on the verge of relapse of mental illness. The trauma caused by COVID-19 has initiated to deteriorate the mental health of the ASD patients (Patel et al. 2020). As per the information provided by the authors in (Bull et al. 2017), overall 20% of the individuals with ASD are diagnosed with anxiety and 11%

are affected by depressive disorders. The additional stress caused by the COVID-19 pandemic is likely to worsen more the mental health of individuals with ASD, and in addition those with ASD who did not experience anxiety and depression are likely to experience them.

Table 18.3 shows the analysis of ASD classification in behavioral science.

18.3 Methodology

The author in (Thabtah 2019b) proposed a mobile-based time-efficient ASD screening tool called as ASDTests. Via screening, he was able to collect 1452 instances covering a period of 4 months utilizing the ASDTest application which covered all the four categories of individuals. The screening was based on Q-CHAT 10 and all AQ-10 methods. But the toddler instances were dropped from the investigation by the investigator as it was found that the toddler dataset made the entire data unbalanced. The left 1100 instances belonged to child, adolescent, and adult. The data size of adults comprises 704 instances, that of adolescents contains 104 cases, and the child dataset comprises 292 cases. The analysis spotted some missing values in two features: "ethnicity" and "who_is_taking_the_test." Some of the features got extracted by wrapping filtering method in which all combination of feature class got tested and the set of features was selected that maximized the predictive parameters of classification. With an aim to get the most influential features out of entire features, the wrapping method also reduced the screening process of ASD. From the adult dataset, 12 influential features out of all features got filtered: items 1–10 in the AQ-10 Adult questionnaire, "gender" and "used the app before." In case of adolescent category, 8 features out of 21 features got selected: item 2, 5, 9 together with 10 from the AQ-10 Adolescent questionnaire, "gender," "born with jaundice or not," and "used the app before." In continuation with the child dataset, 4 effective features got selected from 21 features: item 1, 4, 8, and 10 AQ-10 Child questionnaires. Two machine learning algorithms, LR and NB, were implemented for classifying the ASD data. The performance parameters were found for all datasets in terms of accuracy, sensitivity, and specificity.

To improve the efficiency of screening classification system, the author in (Al-diabat 2018) implemented fuzzy rule-based data mining techniques over child dataset for detecting ASD. If-Then rules were analyzed by the proposed model upon distinct variables associated with behavior. The dataset was collected from UCI data repository which covered a period from September 2017 to February 2018 with 509 instances with a categorization of 252 with NO ASD and 257 with ASD class followed by no issue of data imbalance. The dataset was formulated based upon the AQ-10 Child screening questionnaire by ASDTest app developed by the author in (Thabtah 2019b). Out of 24 features present in the actual dataset, some of the items based upon their influence on classifying cases are discarded including "case_ID," "Country_of_Residence," "Language," "Screening_Type," and "Used_App_Before." The fuzzy data mining classification algorithms FURIA, JRIP, RIDOR, and PRISM were used to analyze the overall performance. The author

Table 18.3 Sample of analysis on ASD classification in behavioral science

Author in	Year of research	Source of data collected	Category of individuals	Classifiers used	Number of features extracted	Performance parameters
23	2018	ASD screening Test App.	Adult, adolescent, child	LR, NB	12, 8, 4	Accuracy, sensitivity, specificity
29	2018	UCI repository	Child	FURIA, PRISM, JRIP, RIDOR	16	Accuracy, sensitivity, specificity
32	2018	UCI repository	Child	NB, J48 (DT), SVM, KNN, MLP	10	Accuracy, TP rate, ROC area, RMSE
40	2018	UCI repository	Child	FR, LR-FR	6	Accuracy, sensitivity
43	2018	ASD screening Test App.	Adult, adolescent, child	RIPPER, C4.5 (DT)	6, 8, 8	Accuracy, sensitivity, specificity, PPV rate, NPV rate
51	2019	ASD screening Test App.	Adult, adolescent, child	RML, PRISM, CART, Adaboost, bagging, Nnge, RIDOR, C4.5 (DT), RIPPER	19	Error rate, sensitivity, specificity, harmonic mean (F1), accuracy
54	2019	UCI repository	Adult, adolescent, child	KNN, SVM, RF	No feature extracted	Accuracy, sensitivity, F-measure, AUC
56	2019	UCI repository, Kaggle	Adult, adolescent, child, toddler	Adaboost, FDA, C5.0, Glmboost, LDA, MDA, PDA, SVM, CART	No feature extracted	Accuracy, kappa statistics, AUROC, sensitivity, specificity, logloss
63	2020	UCI repository	Adult	CBA, CMAR, MCAR, FACA, FCBA, ECBA, WCBA	No feature extracted	Accuracy, precision, F-measure, recall

(continued)

Table 18.3 (continued)

Author in	Year of research	Source of data collected	Category of individuals	Classifiers used	Number of features extracted	Performance parameters
71	2020	UCI repository	Adult, adolescent, child	LR, NB, SVM, KNN, ANN, CNN	No feature extracted	Accuracy, sensitivity, specificity

Note: Data gathered by ASDTest App. are stored in UCI repository for experimental purpose

performed all experiments on data mining algorithms on a machine learning platform, WEKA. The process of tenfold cross validation was implemented for training the data. The mentioned data mining algorithms were used for classification of ASD class. A personal computer having 8 GB RAM of memory with 2.3 GHz processor was used to conduct the investigation.

The authors in (Vaishali Ravindranath 2018) in order to reduce noise from the dataset and reduce dimension via feature selection used binary firefly feature selection wrapping method based on swarm intelligence. The experimentation covered the child dataset having 292 instances comprising 21 features obtained from UCI repository. The dataset is based on the AQ-10 child screening ASDTest app developed by the investigator in (Thabtah 2019b). Out of 292 instances, there are 151 cases with ASD class type and 141 cases with no ASD class type proving the dataset to be class balanced. Firstly, the author implemented swarm intelligence-based feature selection method which filtered ten features out of 21 as "A1_Score," "A2_Score," "A3_Score," "A4_Score," "A5_Score," "A7_Score," "A8_Score," "A9_Score," "A10_Score," and "relation" to differentiate between ASD and no ASD patients. Hence the optimum feature subset was 10. Next to dimensionality reduction, to classify ASD and no ASD class type, machine learning classifier models were used as NB, J48 DT, SVM, KNN, and MLP. The software platform tools such as R and WEKA were involved for setting parameters in the feature selection method, evaluation algorithm as KNN wrapper with $K = 5$, Euclidean distance, 30 particles, 100 iterations, and single weighted fuzzy fitness objective function. The evaluation parameters were accuracy, TP rate, RMSE, and ROC. All the machine learning classifiers were evaluated with an improved accuracy after feature selection by 3 out of 5 classifier models.

Paying importance on the child dataset, the authors in (Akyol et al. 2018) did his investigation again upon child category for predicting ASD. The dataset was fetched from the same UCI Repository, 2018 consisting of 292 instances with 21 attributes with the outcome variable as ASD class type. Firstly, the author preprocessed the dataset and then shuffled. The raw data had 292 instances but after preprocessing the number of instances reduced to 247 as some of the missing values for ethnicity and relation attributes were removed. Following the preprocessing, the categorical information like Yes/No and m/f were converted into binary values of 1/0. The categorical transformation for "Ethnicity" attribute and "country_of_residence" attribute was carried out, too. For investigating the significance of questions being asked to patients and to maintain the importance of ASD attributes, the author used LR based on feature selection method. Each independent feature was explained by means of odds ratio which calculated the probability of an event to occur and not occur. From the odds ratio, it was found that the attributes "age," "ethnicity," "country_of_residence," "relation," "result" and questions 4 and 10 in AQ-10 child questionnaire set held much weightage. Followed by the attribute selection, two datasets were considered: firstly, the preprocessed one and secondly, one of the best attributes. Then investigators divided both the datasets into training and testing ones with a percentage of 70 and 30% and 172 instances in training dataset and that of 75 in testing dataset. The training dataset was set as the input to the Fuzzy Rule algorithm. The test data was fed to the predictive models for the testing. Two predictive models were implemented by the author for testing: FR model and LR-FR. The performance parameters taken into account, accuracy and sensitivity, were evaluated.

The authors in (Thabtah et al. 2018) aimed at selecting fewer and prominent features in ASD screening method. The analysis took into account 1452 instances covering distinct category of individuals: adult, adolescent, child, and toddler. The data got collected by AQ-10 and Q-CHAT-10 screening approaches respectively by an ASDTest App developed by the author himself in (Thabtah 2019b). Due to data imbalance, the author dropped the toddler dataset from the investigation. The remaining 1100 cases belonged to child, adult, and adolescent category of individual. The number of male and female cases in the entire dataset is 625 and 475 respectively. Further in the overall dataset, there are 707 and 393 instances present under ASD and no ASD class type. The author presented a computational intelligence method, VA, that considers feature to class correlation and decreases feature to feature correlation. VA is embedded with WEKA version 3.9.1 and used in Java programming language. The result of VA was compared against other filtration methods: CHI-SQ, IG, CFS, and Correlation Attribute Evaluation analysis. VA analysis chose less number of attributes as 6, 8, and 8 out of 21 from adult, adolescent, and child dataset respectively. Followed by the attribute selection, the result of the VA analysis got verified by two machine learning classifiers, RIPPER and C4.5 (DT), with automated classification system in terms of adequate level of specificity, sensitivity, PPVs, NPVs, and accuracy. The investigators used tenfold cross validation for training the dataset where arbitrarily the dataset was divided into ten parts. RIPPER or C4.5 trained nine parts and developed a classifier model to test on the persisting parts to achieve evaluation metrics (error rate). The procedure was repeated for ten times on the dataset, thereby splitting the dataset into ten parts to obtain an error rate followed by the calculation of average of all error to yield a global error rate of the classifier. The result of VA features was compared with the features of IG, CHI, correlation, CFS, and original 21 features by RIPPER and C4.5 algorithms.

The authors in (Thabtah and Peebles 2020) paid attention on the reasons behind ASD classification and proposed a new RML algorithm for predicting ASD. Except toddlers, the research covered datasets associated with child, adolescent, and adult category. The data were collected using the ASDTest app developed by the author himself. As the investigator faced some data imbalance issue in toddler dataset, he dropped that category to be investigated. The data size of adult, adolescent, and child is 704, 104, and 292 cases respectively. There were some missing values in some features like "ethnicity" and "who_is_taking_the_test." On the obtained raw data, the author performed preprocessing operations including replacement of missing values and discretization of continuous attributes. Followed by the preprocessing, feature selection was implemented to avoid the redundant attributes. Two features "final score from screening method" and "scoring method type" were eliminated. Then a learning algorithm, RML, was applied on the preprocessed data which discovered rule sets to find the correlation between attributes in training dataset and ASD class. Further the datasets of all categories were evaluated to store only those rules which classified training instances. Upon testing the classifier model, different evaluation metrics were formulated for revealing the efficacy of rules in predicting cases. To evaluate the performance, the result of RML was further compared with the other eight algorithms: RIPPER, RIDOR, Bagging, Nnge, Boosting, CART, PRISM, and C4.5. In C4.5 and CART, pessimistic error estimation was used for constructing DT classifiers which convert into rule sets. RIPPER implemented optimization procedures to evaluate the worthiness of feature in dataset before using them in the rule body. As per the rule's predictive power, RIPPER either accepted or ignored the feature and generated the rule. The classifier models employed by Bagging and Boosting are merged to form rules. The process was carried out by deriving *N* number of classifiers for predicting the nature of class of test data instances utilizing a voting mechanism finally resembling the class type belonging to majority classifiers gets allotted to the test instance.

The authors in (Erkan and Thanh 2020) used supervised learning for early detection of ASD. The data was obtained from UCI repository based on ASDTest screening app developed by the author in (Thabtah 2019b). The dataset comprises three categories of individuals: child, adolescent, and adult with 21 attributes in each set excluding the case number. In addition, some missing values also exist in the attributes "ethnicity," "who is taking the test," and "age." The adult sub-dataset has 704 numbers of instances followed by exiting the missing data which dropped the number of instances to 609. Similarly, after exiting the missing data, the number of instances fell from 104 to 98 in adolescent sub-dataset and finally the child sub-dataset where the cases dropped from 292 to 249. For the attribute selection and extraction, the numeric translation rule was implemented during the preprocessing stage of the data. Excluding the attributes of screening questions which were already set to either 0 or 1, the translation rule was applied upon the four string attributes such as "gender," "ethnicity," "country of residence," and "who is completing the test" and three binary attributes such as "born with jaundice," "family member with PDD," and "used the screening app before." For the "gender" attribute, the numbers 0 and 1 were used (female and male respectively). For "ethnicity" attribute, the numbers from 1 to 14 were used and in case of missing ethnicity value, the number 15 was used. In case of the attribute "country of residence" having data from 89 countries, the numbers from 1 to 89 were allocated to each country in alphabetical order. For the attribute "who is completing the test," numbers from 1 to 6 were allocated where 6 was for missing attribute value. After the preprocessing, the authors performed the classification on the datasets by utilizing KNN, SVM, and RF classifier. The preprocessed data was divided into two sections: the first is training data expressed in $\alpha\%$ with a range of 50–90% to train the classification models. The second section was the testing data expressed as $(100 - \alpha)\%$ used as the ground truth for measuring and comparing the classifier performance parameters. To analyze the performance of classification models, the investigator used the following performance parameters: accuracy, sensitivity, F-measure, and AUC. Experiments were performed for five times with $\alpha = 50$–90%. In each experiment, the training as well as testing data were randomly selected 100 times. The average values of accuracy, sensitivity, F-measure, and AUC were calculated from all the 100 cases in each experiment. For each ASD data sub set, two cases are considered for the entire experimentation: complete data and missing data.

The authors in (Akter et al. 2019) collected ASD datasets related to adult, adolescent, child, and toddler. In the investigation, along with rest of the datasets, emphasis was also laid on the toddler dataset. A total of 2009 instances were collected from UCI ML repository and Kaggle. From the total number of cases, the number of adult cases is 609, that of adolescent is 98, 248 cases for children, and the highest which is 1054 number of cases for toddlers. In all category of individuals, the population of male dominated the female group as adult dataset consists of 321 males and 288 females, the adolescent dataset contains 49 individuals in both gender cases followed by child dataset comprising 174 males and 74 females, and finally the toddler dataset is characterized by 735 males and 319 females. The datasets are further characterized by 21 attributes excluding the case number with some missing, unwanted, and noisy records. Prior to the classification methods, three feature transformation methods, log, Z-score, and sine functions, were applied to the datasets followed by application of 250 machine learning classifiers upon the feature transformed datasets. Among them, only nine classifiers Adaboost, FDA, C5.0, Glmboost, LDA, MDA, PDA, SVM, and CART which showed accuracy of more than 70% were selected. Statistical features like mean, median, and maximum were used to produce experimental results. In addition, performance parameters including Accuracy, AUROC, Kappa Statistics, Specificity, Sensitivity, and Logloss were calculated to account for the experimental results.

The authors in (Alwidian et al. 2020) examined the AC as data mining technique in predicting ASD in individuals. The ASD adult dataset was obtained from UCI repository which was collected via screening in ASDTest app developed by the author in (Thabtah 2019b). The dataset got 21 attributes excluding case number with 704 instances out of which 515 cases are under "no ASD" class and remaining 189 under "ASD" class. A certain number of values were assigned to each attribute in the dataset like all the ASD screening questions and in addition "gender," "Born with jaundice," "Family member with PDD," "used app before," and "class name" were being assigned with 2 number of values, "age" and "screening score" were allotted with 4 number of values, and "ethnicity" and "country of residence" got 11 and 67 number of values respectively. The authors implemented seven algorithms

CBA, CMAR, MCAR, FACA, FCBA, ECBA, and WCBA to analyze the performance of AC technique by identifying correlation between features for classifying ASD classes. The evaluation metrics to determine the performance of classification were accuracy, precision, F-measure, and Recall. The experimentation was repeated thrice with distinct values of minimum support value as well as minimum confidence value. In experiment 1, minimum support value and minimum confidence value were 0.1 and 0.5 respectively; in experiment 2 the values were respectively 0.1 and 0.6 followed by the values to be respectively 0.2 and 0.4 in experiment 3. The result was analyzed as per the distinct experimentation with distinct minimum support and confidence values.

The author in (Raj and Masood 2020) predicted the possibility of ASD in child, adolescent, and adult by employing four machine learning algorithms: NB, LR, SVM, and KNN. Apart from the machine learning algorithms, ANN and CNN were also used to predict ASD. The datasets were collected from the UCI Repository which are stored in the online research site by the ASDTest app developed by the author in (Thabtah 2019b). There are 292 instances in the child dataset, 104 cases in adolescent category followed by adult dataset comprising higher number of instances in comparison to child and adolescent category, i.e., 704 instances. The datasets are also characterized by 21 attributes excluding the case number. In the research, the author preprocessed the raw data into a desirable format as the raw data was incomplete and inconsistent with a large number of attributes, errors, missing values, discretized data, etc. In majority cases, the author found some missing values in the datasets and handled by imputation method. Following preprocessing, the processed dataset was divided in the ratio of 80:20 as training as well as testing dataset respectively. Further the training dataset was divided into training and validation dataset in the ratio of 80:20 respectively for cross validation. Free from any sort of dimensionality reduction, all the 21 features were used to predict ASD. Gaussian NB was used in NB algorithm, for SVM, RBF kernel with a gamma value of 0.1 was used, and in case of KNN, $N = 5$ was set. With a learning rate of 0.01 and 100 epoch, The Adam Optimizer was employed in case of ANN followed by the use of binary cross-entropy loss function, Relu activation Function, Adam Optimizer, 16 & 32 filters, and 0.5 dropouts and with 150 epochs for CNN.

18.4 Result

The author in (Thabtah 2019b) investigated child, adolescent, and adult dataset being collected by himself through ASD screening Test App, consisting of 21 attributes excluding case number. The investigation yielded the result in favor of adult dataset in which dataset gained higher rates in comparison to adolescent and child datasets as it has more number of instances than the other two datasets. Among the two machine learning classifiers, LR proved to be superior in comparison to the NB classifiers. In adult dataset, LR outperformed NB by 4.12%, 4.2%, and 3.01% in terms of accuracy, sensitivity, as well as specificity. The best result from adult dataset is indicated in Table 18.5.

The author in (Al-diabat 2018) performed his investigation on child dataset being accumulated from the UCI repository. According to the result, in case of accuracy rates, the classification model of FURIA suppressed PRISM, JRIP, and RIDOR models by 7.66%, 3.14%, and 0.98% respectively. The accuracy rate of FURIA was found to be 91.5%. In terms of sensitivity, again FURIA outperformed JRIP, RIDOR, and PRISM by 3.2%, 1.0%, and 3.0% respectively. The sensitivity rate of FURIA came out to be 91.40%. But surprisingly, PRISM suppressed rest of the models in terms of specificity rate. So, the FURIA data mining model showed higher performance in predicting accuracy and sensitivity but lower performance in predicting specificity in comparison to other models. The specificity rate of FURIA was 88.09%. The best result is shown in Table 18.5.

The authors in (Vaishali Ravindranath 2018) investigated the child dataset. All the 5 machine learning classifiers were evaluated with an improved accuracy after feature selection by 3 out of 5 classifier models. The range of accuracy rate lies between 92 and 98% after feature selection. NB, J48, and KNN showed improved accuracy rate by 2.4%, 1.02%, and 6.17% respectively. But somehow SVM and MLP presented decreased accuracy. Due to 15% of the missing values in selected features, the deterioration of accuracy rate occurred in the two classifier models. Followed by accuracy, the range of TP rate after feature selection ranges between 92 and 98% with 3 out of 5 classifiers resulting in improved TP rate. NB, J48, and KNN showed improved TP rate by 3%, 1%, and 5% respectively. For SVM and MLP, the TP rate fell but still remained close to the rate in the original model. MLP showed maximum ROC of 100% both before and after feature selection method. Finally, both SVM and MLP resulted in the minimum RMSE of 0.06 and 0.052 respectively before feature selection and after the optimal method 0.14 each. With the optimum feature subset selection and training the classification models with minimum behavior sets, the performance of classification models is validated. The comparative analysis of result before (B) and after (A) the feature selection is given in Table 18.5.

The authors in (Akyol et al. 2018) also experimented on the child dataset with two predictive models for testing: FR and LR-FR. The performance parameters taken into account, accuracy and sensitivity, were evaluated. It was found that LR-FR model yielded better result in comparison with only FR model on the best selected attribute dataset. The accuracy achieved was 97.33% and that sensitivity was 97.06%. The comparative result is shown in Table 18.5.

The authors in (Thabtah et al. 2018) investigated the category of child, adolescent, and adult. The VA selected and extracted 8, 8, and 6 features from child, adolescent, and adult dataset respectively. VA result was compared against other filtration methods: CHI-SQ, IG, CFS, and Correlation Attribute Evaluation analysis. The comparative reduction of the features by VA in comparison to CHI-SQ, IG, Correlation, and CFS is mentioned in Table 18.4 below.

The result of the VA was verified by two machine learning algorithms, RIPPER and C4.5, in terms of adequate level of specificity, sensitivity, PPVs, NPVs, and accuracy. The accuracy of VA was good with CHI, IG, correlation, and CFS particularly in adolescent case. In adolescent dataset, when compared with original

Table 18.4 Reduction in features by VA

Dataset	VA/CHI	VA/IG	VA/Correlation	VA/CFS
Child	27.3	46.7	38.5	20
Adolescent	11.1	38.5	50	0
Adult	53.8	62.5	60	45.5

number of features, the RIPPER and C4.5 classifier models derived from VA features showed higher accuracy by 10% and 6% respectively. But the result marked a slight fall in the accuracy rate in case of child and adult dataset. Despite the reduction in accuracy, still the features derived by VA maintained an acceptable range of accuracy, thereby reducing the number of features to a large extent. Specificity rate was the highest in adult dataset for the VA features but still with a large value; the specificity rate was 2.8%, 1.4%, 1.9%, 3.6%, and 3.0% less in comparison with "no feature selection," CHI, IG, Correlation as well as CFS features. The sensitivity rates found by the RIPPER classifier was the highest for VA features in adolescent dataset. It was found to be 87.30%. For the same adolescent dataset, the C4.5 classifier produced the sensitivity rate to be approximately 91% but it was lesser than the sensitivity rate for CFS features. For adult dataset, RIPPER classifier resulted in a sensitivity rate of 82.54% and C4.5 classifier produced a sensitivity rate of 80.95% from VA features. The reason behind the lower sensitivity is the misclassification of ASD type. In case of adolescent dataset, the RIPPER algorithm derived by VA features proved to be superior in terms of PPV as well as NPV in comparison to other feature sets. But the VA feature classifiers resulted in lower PPV together with NPV rates upon the child as well as adult dataset but still conserved acceptable rates. All the performance parameter results concluded that VA is able to select much limited number of features from the three datasets in comparison to the other filtering methods taken into consideration.

The research in (Thabtah and Peebles 2020) covered datasets associated with child, adolescent, and adult category. The result of the proposed RML algorithm was compared with the other eight algorithms: RIPPER, RIDOR, Nnge, Bagging, Boosting, CART, C4.5, and PRISM. The performance parameters considered for the investigation included error rate, sensitivity, specificity, F1, and accuracy. In case of **adult** dataset, RML classifier achieved error rates of 4.41%, 2.7%, 0.15%, 2.14%, 3.7%, 3.27%, 1.57%, and 1.83% lesser than PRISM, CART, AdaBoost, Bagging, Nnge, RIDOR, C4.5, and RIPPER algorithms respectively. In general, the acceptance rate of sensitivity and specificity for ASD classification is 80%. RML classifier derived sensitivity rates of 1.9%, 3.3%, 2.0%, 2.8%, 3.2%, 1.7%, 0.2%, and 1.7% higher than RIPPER, RIDOR, Nnge, Bagging, CART, PRISM, AdaBoost, and C4.5 algorithms, respectively. In the same dataset, it achieved specificity rates of 2.52%, 3.49%, 1.55%, 2.72%, 2.72%, 1.94%, 5.02%, and 2.72% higher than RIPPER, RIDOR, Nnge, Bagging, CART, PRISM, AdaBoost, and C4.5 algorithms, respectively. In terms of F1, RML outperformed RIPPER, RIDOR, Nnge, Bagging, CART, PRISM, and C4.5 by 1.7%, 3.1%, 3.6%, 2.2%, 2.6%, 1.8%, and 1.6%, respectively but slightly outperformed by Adaboost. For **child** dataset, RML classifier resulted in error rate of 5.82%, 4.11%, 0.69%, 2.4%, 1.03%, 5.82%, and 2.4% lesser than PRISM, CART, AdaBoost, Bagging, Nnge, RIDOR, and RIPPER algorithms respectively. But C4.5 classifier resulted in less error rate than RML classifier by 0.34%. The sensitivity rate of RML classifier was 2.4%, 5.9%, 1.1%, 2.4%, 4.2%, 0.78%, and 0.7% higher than RIPPER, RIDOR, Nnge, Bagging, CART, PRISM, and AdaBoost algorithms, respectively. The sensitivity rate of C4.5 was slightly higher than RML by 0.3%. Further regarding specificity, RML achieved higher specificity rates by 19.8%, 2.7%, 6.0%, 13.2%, 0.4%, and 7.5% in comparison to RIPPER, Nnge, Bagging, CART, PRISM, and C4.5 algorithms, respectively. It was outperformed by RIDOR and AdaBoost algorithms by 0.2% and 0.8% respectively. In **adolescent** dataset, RML classifier produced 7.69% lesser error rate than C4.5 algorithm. Not only C4.5, it also outperformed RIPER, Nnge, Bagging, Cart, and PRISM algorithm with lesser error rates, almost same error rate with RIDOR algorithm but slightly higher error rate from AdaBoost algorithm. The result analysis on error rate proved that RML performs well on both the datasets having large and limited number of instances. Though the adolescent dataset is a small one with less number of instances in comparison to adult and child dataset, still RML showed higher sensitivity rate than RIPPER, Nnge, Bagging, CART, AdaBoost, and C4.5 algorithms by 20.2%, 2.9%, 5.8%, 13.5%, 0.6%, and 7.7% respectively. In terms of accuracy, the classifier generated by RML outperformed all the other Machine Learning algorithms in adult and child dataset. But in case of adolescent dataset, the AdaBoost algorithm slightly suppressed RML. Overall, the performance of RML was satisfactory in comparison to the considered Machine Learning algorithms. But the analysis revealed that the maximum level of RML performance was found in adult dataset in comparison to toddler, child, and adolescent category. The positive rate by which RML outperformed other classifiers in adult dataset is shown in Table 18.5.

The authors in (Erkan and Thanh 2020) focused on early detection of ASD based on supervised learning over child, adolescent, and adult dataset. After considering complete and missing value cases, next to preprocessing, the author classified the datasets by KNN, SVM, and RF classifier. To analyze the performance of classification models, the following performance parameters were used: *F*-measure, accuracy, AUC, and sensitivity. Five experiments were performed with $\alpha = 50–90\%$. The average values of F-measure, accuracy, AUC as well as sensitivity were calculated from all the 100 cases in each experiment. For each ASD data sub set, two cases are considered for the entire experimentation: complete data (C) and missing data (M). The result showed that, in case of adult dataset, the RF and SVM classifier model showed 100% performance upon all test cases on both complete together with missing data. For adolescent dataset, the performance of RF classifier is 100% upon all test cases on both complete together with missing data but SVM classifier scored 100% for $\alpha = 60–90\%$ in complete data and showed the same performance for $\alpha = 80–90\%$ in missing data. The performance of RF classifier in child data showed 100% performance for $\alpha = 60–90\%$ in missing data and $\alpha = 80–90\%$ in complete data. The SVM classifier resulted in performance of more than 90% in all cases of child dataset. The KNN classifier model resulted in the lowest performance.

Table 18.5 Result analysis

Author	Dataset	Classifier	Performance parameters: Accuracy rate		Sensitivity/recall rate		Specificity rate	TP rate		ROC area		RMSE		Error rate	*F*-measure		AUC		Kappa statistics	AUROC	Logloss	Precision rate
23	Adult	LR	99.85		99.9		99.7															
		NB	95.73		95.7		96.69															
29	Child	FURIA	91.35		91.4		88.09															
			B	A				B	A	B	A	B	A									
32	Child	NB	93.15	95.55				0.93	0.96	0.99	1	0.22	0.2									
		J48	91.1	92.12				0.91	0.92	0.89	0.9	0.3	0.28									
		SVM	99.66	97.95				1	0.98	1	0.98	0.06	0.14									
		KNN	87.67	93.84				0.88	0.93	0.97	0.97	0.3	0.23									
		MLP	99.66	97.6				1	0.98	1	1	0.052	0.14									
40	Child	FR	92		85.29																	
		LR-FR	97.33		97.06																	
51	Adult	RML-PRISM			1.7		1.94							4.41	1.8							
		RML-CART			3.2		2.72							2.7	2.6							
		RML-Adaboost			0.2		5.02							0.15	Negative value							
		RML-Bagging			2.8		2.72							2.14	2.2							
		RML-Nnge			2		1.55							3.7	3.6							
		RML-RIDOR			3.3		3.49							3.27	3.1							
		RML-C4.5			1.7		2.72							1.57	1.6							
		RML-RIPPER			1.9		2.52							1.83	1.72							
			C	M	C	M									C	M	C	M				

54	Adult	RF ($\alpha = 50$–90%)	100	100	100	100						100	100	100	100				
		SVM ($\alpha = 50$–90%)	100	100	100	100						100	100	100	100				
	Adolescent	RF ($\alpha = 50$–90%)	100	100	100	100						100	100	100	100				
		SVM ($\alpha = 60$–90%)	100		100							100		100					
		SVM ($\alpha = 80$–90%)		100		100							100		100				
	Child	RF ($\alpha = 80$–90%)	100		100							100		100					
		RF ($\alpha = 60$–90%)		100		100							100		100				
56	Toddler	SVM	98.77		99.39											97.1	99.98	3.01	
		Adaboost					99.59												
	Child	Adaboost	97.2		98.4											94.41		9.62	
		Glmboost															99.87		
		PDA					98.46												
	Adolescent	Glmboost	93.89				98.33									86.37	98.62		
		SVM			97.5														
		Adaboost																15.8	
	Adult	Adaboost	98.36		99.3		96.11									96.02	99.95	5.64	

(continued)

Table 18.5 (continued)

Author	Dataset	Classifier	Performance parameters												
			Accuracy rate	Sensitivity/ recall rate	Specificity rate	TP rate	ROC area	RMSE	Error rate	*F*-measure	AUC	Kappa statistics	AUROC	Logloss	Precision rate
63	Adult (Expt.1)	FACA, WBCA	85.2												
		FACA								87.4					85.5
		ECBA													
		FCBA		96.6											
	Adult (Expt.2)	WCBA	87.84	97.2						88.6					
		MCAR													83.2
	Adult (Expt.3)	WCBA, FCBA	84.36												
		FCBA		90.5						87.4					
		ECBA													85.7
71	Adult	CNN	99.53	99.39	100										
	Adolescent	CNN	96.88	93.55											
		LR, SVM, KNN, ANN, CNN			100										
	Child	CNN, ANN, LR, SVM	98.3												
		ANN		100											
		CNN, LR, SVM			100										

The author concluded that the RF classifier model proved to be at maximum level for early classification of ASD class. The result analysis is shown in Table 18.5.

The authors in (Akter et al. 2019) collected ASD datasets related to adult, adolescent, child, and toddler. Nine classifier models Adaboost, FDA, C5.0, Glmboost, LDA, MDA, PDA, SVM as well as CART were implemented for classification of ASD class. Statistical features like mean, median, and maximum were used to produce experimental results. In addition, performance parameters including Accuracy, AUROC, Kappa Statistics, Specificity, Sensitivity, and Logloss were calculated to account for the experimental results. For accuracy, the SVM classifier predicted ASD with 98.77%, Adaboost resulted in 97.20%, Glmboost produced 93.89%, and Adaboost yielded 98.36% in toddler, child, adolescent, and adult dataset respectively. In terms of kappa statistics, the SVM classifier predicted ASD with 97.10%, Adaboost resulted in 94.41%, Glmboost produced 86.37%, and Adaboost yielded 96.02% in toddler, child, adolescent, and adult dataset respectively. In case of AUROC, the SVM classifier predicted ASD with 99.98%, Glmboost produced 99.87%, Glmboost yielded 98.61%, and Adaboost resulted in 99.95% in toddler, child, adolescent as well as adult dataset respectively. For sensitivity, SVM classifier classified ASD with 99.39%, Adaboost produced 98.40%, SVM classifier resulted in 97.50%, and Adaboost predicted with 99.30% in toddler, child, adolescent, and adult dataset respectively. In terms of specificity, Adaboost yielded 99.59%, PDA resulted in 98.46%, Glmboost produced 98.33%, and Adaboost yielded 96.11% in toddler, child, adolescent, and adult dataset respectively. Lastly, for logless, SVM classifier produced 3.01%, Adaboost yielded 9.62%, Adaboost gave 15.81%, and the same Adaboost resulted in 5.64% in toddler, child, adolescent together with adult dataset respectively. According to the author's analysis, SVM classifier showed maximum performance for toddler dataset, Adaboost classifier showed the best performance for child dataset, while Glmboost model performed the best for adolescent dataset and Adaboost once again proved to be the best classifier for adult dataset. On the other hand, the feature transformation which resulted in the best classification for toddler dataset was the sine function and for child, adolescent, and adult dataset, it was *Z*-score. The maximum results are summarized in Table 18.5.

The authors in (Alwidian et al. 2020) examined the AC as data mining technique in predicting ASD over adult category. The performance parameters for determining the performance of classification were accuracy, precision, F-measure, and Recall. Three experiments with distinct values of minimum support value as well as minimum confidence value is performed. The result from experiment 1 revealed that FACA and WBCA outperformed other AC algorithms with an accuracy of 85.2% each. In terms of F-measure, the FACA algorithm led with 87.4% followed by WBCA with 84.5%. Highest precision of 85.5% was achieved by ECBA followed by FACA with a precision of 84.6%. Finally, FCBA led in case of Recall with a rate of 96.6% followed by WCBA with a Recall value of 96.3%. In experiment 2, with the increase in minimum confidence value from 0.5 to 0.6, the WCBA led in terms of accuracy, F-measure, and Recall as 87.84%, 88.6%, and 97.2% respectively. But it was ranked in second position for a precision of 81.4% where the highest precision of 83.2% was acquired by MCAR algorithm. Finally, in experiment 3, with the increase in minimum support value from 0.1 to 0.2, WCBA and FCBA resulted in the maximum accuracy of 84.36%, FCBA ranked first in *F*-measure of 87.4%, ECBA led with a precision of 85.7% followed by WCBA with a precision of 85.0%. Finally, FCBA achieved the highest Recall value of 90.5%. The average accuracy of each algorithm was found which indicated the highest average accuracy rate was achieved by WCBA followed by FACA and MCAR with an average accuracy rate of 83% and the CMAR resulted in the least accuracy rate of 77%. The best rates are summarized in Table 18.5.

The authors in (Raj and Masood 2020) predicted the possibility of ASD in child, adolescent, and adult by employing four machine learning algorithms: NB, LR, SVM, and KNN. Apart from the machine learning algorithms, ANN and CNN were also used to predict ASD. The performance parameters considered for the investigation were accuracy, sensitivity, and specificity. For adult dataset, the CNN outperformed rest of the classifier models with an accuracy rate of 99.53%, sensitivity rate of 99.39%, and a specificity rate of 100%. For adolescent dataset, CNN again resulted in the highest accuracy and sensitivity rate of 96.88% and 93.35% respectively. But the specificity rate yielded to be 100% by all classifiers except for NB. Finally, for the child dataset, the highest accuracy rate of 98.30% is achieved by CNN, ANN, LG, and SVM; highest specificity rate of 100% by CNN, LG, and SVM. But in terms of sensitivity rate, the SVM outperformed CNN merely by only 0.01%. The analysis concluded that the CNN-based classifier model resulted as a better option for predicting and classifying ASD in all category of individuals. Though in terms of specificity CNN got less scores than SVM, it is only by a small rate which possibly cannot put up uncertainty regarding the performance of CNN. The result is summarized in Table 18.5.

18.5 Discussion

There has been much emphasis laid on the technical investigation of ASD throughout. The investigation being carried out for the early detection of ASD in all types of individuals really helped and in addition supported a lot of families around us. As per the literature review and results of investigation, it can be confirmed that the technical analysis of ASD is almost undisturbed. But presently all the families are facing much difficulty due to increasing effect of COVID-19 pandemic and particularly those families with ASD individuals. Now apart from research on ASD detection which can be carried out smoothly using any software tool and online ASD data, there are so many challenges which are being faced by ASD individuals presently during the COVID-19 pandemic period. As ASD is characterized by repeated behavior, communication disorder, anxiety, and learning disabilities, these comorbidities add up additional challenges for ASD individuals and their caregivers to cope during this pandemic.

Firstly, the most common feature of ASD individuals is their obsession with routine which should be always intact and any disturbance in that routine results in behavioral and emotional changes. Due to the COVID-19 pandemic, many centers across the world providing special education and training programs to ASD individuals have been closed either voluntarily or due to mandates. Because of the closure of centers, individuals with ASD are receiving fewer therapies and lesser classroom time than they normally would receive. The result is disruption in their routine establishing behavioral changes in them.

Secondly, during this pandemic parents of ASD children are either facing loss of employment or engaged in work from home due to which they are unable to meet the necessities of their children in terms of daily support of therapists. Due to financial crisis and lack of time, parents are unable to maintain the daily routine of their ASD wards. This challenge can be overcome by the implementation of telehealth which will be an effective tool for providing teaching and all sorts of therapies including speech therapy, language therapy, and behavioral therapy to ASD individuals. It will be an effective tool to support the families.

Thirdly, if an ASD individual faces some health issue and needs to be at clinic or hospital for treatment, then it is very difficult for the parents and caregivers to make them understand about maintaining physical distancing for reducing the risk of corona infection. ASD individuals might not understand the need to wear a mask. They might not feel comfortable wearing a mask. So, there is indeed a requirement for home-based COVID-19 testing for ASD individuals. In addition, parents and caregivers with certain constraints and rules should be completely allowed to remain with their relatives with ASD during their health services. Presently in many hospitals, the number of visitors has been limited to zero.

Fourthly, improper staff knowledge about ASD details, lengthy waiting times, and insufficient engagement of parents to provide exact information about their ASD children to health experts are some of the further challenges in the pandemic. So, parents and caregivers should be provided with sufficient duration and chances of describing the conditions and symptoms of their relatives with ASD to the healthcare worker.

Finally, in critical situations in which if the parents or guardians of ASD individuals get infected by COVID-19, need hospitalization or unfortunately die. Then there arises the question regarding the responsibility bearer of those ASD children. For such unwanted situation, guardian services should enlist policies and plans to address the needs of ASD individuals with parents or guardians. Similar polices should be also enlisted by children's hospital, foster care systems, and social service systems.

18.6 Conclusion

Approximately before 2 years, ASD data was rarely available but with the rapid advancement in smart phone technology, ASDTest App was designed. The app collected individual's data via the test and the data related to ASD got stored in a vital data repository (UCI repository) which can be utilized by researchers and scientists for analysis. The questionnaires in the screening app are based upon the

Q-CHAT 10 and AQ-10 questionnaire for all categories of individuals. The app is still in use for early prediction of ASD in a simple and time-efficient way which is accessed by many users including parents, clinicians, caregivers, and healthcare professionals. The diagnostic tools for ASD demand time efficiency and increased accuracy without any compromise with the sensitivity and specificity of the test. Over the past few years, many scientists and scholars adopt intelligent machine learning methods to achieve the aforementioned goals. Machine learning aims at yielding promising results in predicting ASD by:

(a) New approaches to diagnose ASD cases.
(b) Shortening the duration of ASD diagnosis process.
(c) Identifying the most prior features which influence ASD.
(d) Extracting and reducing the features influencing ASD without disturbing accuracy, sensitivity, and specificity.

Machine learning approaches also face some issues in the dataset which include overlapped features, noise processing, feature selection and extraction, and imbalanced datasets. So for better investigation, researchers have been enhancing and validating implementation of machine learning in predicting ASD taking into account all the data issues. They almost overcome the challenges with their hardest research and laid machine learning applicability as one of the most effective predictive models in ASD research.

As the epidemic of COVID-19 increasingly spreads globally, there is a lot of evidence gathered regarding the existence of neurological manifestations as well as symptoms associated with it. The results emphasize the presence of CNS manifestation associated with coronavirus. The major impact of COVID-19 on ASD individuals is upon the CNS leading to the condition of neuroinflammation and immune system. It is observed that ASD patients are more prone to viral and bacterial infections with cough and common cold particularly in the first 3 years of their life. So basically, individuals with ASD are identified as a group at an extreme risk towards complications of COVID-19. The intact routine of ASD patients has been abruptly disturbed, parents and caregivers of ASD individuals are unable to provide sufficient attention towards their wards, it is very difficult to make ASD patients understand about the risk factors of COVID-19, and social isolation deteriorates their behavior. Hence it becomes very important to keep especially children with ASD not only physically safe but also to take care of their psychological and emotional feeling. During this pandemic, parents and caregivers of ASD individuals might feel anxious and frustrated. Shortage of time, heavy load of patient cases, and insufficient staff members to handle and train ASD patients make the scenario much heated and uncomfortable. In such an environment, productive measures are to be taken for immediate and long-term solutions against this pandemic. Parents and caregivers need to have patience and hope, and proper attention should be given to them without any discrimination. Because it is well known fact for all that the world believes and lives on hope.

18.7 Future Scope of the Work

The ASD detection using time series data for different age groups are successfully implemented by various researchers. The techniques involve the traditional classification process along with machine learning approaches involving AI. However, it may be synchronized with various imaging modalities of human brain imaging for more accurate analysis and therapeutics. Real-time monitoring of certain drug's effects on ASD can be observed with it.

18.8 Executive Summary

ASD and its effects on humans start from the early childhood and last throughout the life. So early diagnosis and therapeutics may be useful for decreasing the severity of the disease. In this chapter, an attempt is made for effective diagnosis of ASD using machine learning and AI techniques. The techniques involving AI process shorten the diagnosis procedure and identify the most prominent features influencing ASD, thereby providing accurate diagnosis values which can be used clinically for ASD detection.

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19 Use of Mobile Phone Apps for Contact Tracing to Control the COVID-19 Pandemic: A Literature Review

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Abstract

Background: Contact tracing is a widely adopted surveillance system that is used to identify, evaluate, and handle people who have been exposed to novel infectious diseases. The mobile phone apps using a digital technological system, called "proximity tracking," is used as a surveillance system to control the COVID-19 pandemic.

Objective: This aim of this review is to examine the use of mobile phone apps for contact tracing to control the COVID-19 pandemic worldwide.

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Method: A search of different electronic databases, such as PubMed, PubMed Central, Google Scholar, and Google, was carried out using search items "mobile app," "tracing," and "COVID-19." The search was conducted between 18 and 31 May 2020.

Findings: The search revealed that a total of 15 countries in the world developed and actively using 17 mobile apps for contact tracing to control the COVID-19 pandemic during the selected time frame. China and Malaysia were only using two apps. Out of 17 apps, three were protected by the country's data protection laws. The results indicate that the mobile apps were used to monitor self-isolated individuals, identify individuals not wearing masks, whether they had close contact with an infected person, provide exact time and place of the encounter, and possible risk of infection.

Conclusion: Contact tracing is found to be an essential public health approach to fight the spread of COVID-19 pandemic and other novel infectious diseases. However, caution is warranted to generalize the usability of apps, especially in the LMICs, and to address the concerns regarding data anonymization, data privacy and usage, and data rights.

Keywords

COVID-19 pandemic · Mobile phone apps · Contact tracing · Prevention · Data privacy

19.1 Introduction

The newly found zoonotic viral infection known as COVID-19 affects people globally by causing a major health crisis (Kar et al. 2020). With more than 5,550,000 cases globally and claiming the lives of more than 350,000 people worldwide, COVID-19 has spread overwhelmingly, affecting every part of the world directly or indirectly (WHO 2020). The practical options to control the spread of the infection are antiviral therapy and vaccination, but they are under research and development (Lai et al. 2020). In light of the pandemic, countries worldwide imposed strict public health and social measures such as border lockdown, a national advisory to stay-at-home, and many other orders with the sole aim of reducing the spread of the virus (WHO 2020). As countries gear up to ease the lockdown, vigorous surveillance techniques have to be kept in place to maintain the consistent decline of new positive cases of COVID-19 (WHO 2020). Moreover, some of the countries have already experienced the "second wave" of coronavirus cases. An alternative to the lockdown approach, scientists have thus proposed an app-based contact tracing to keep the epidemic in check (Abeler et al. 2020).

According to the World Health Organization (WHO) guidelines, member states are obligated to put a surveillance system in place and attain critical and evidence-based data for their COVID-19 response while keeping in check the unambiguousness and privacy concerns of the community (WHO 2020). Digital technologies, when combined with artificial intelligence, could prove to be an asset to public health workers in terms of rapid reporting, data collection, and analysis (WHO 2017; Wong et al. 2019). Contact tracing is a widely used surveillance system. It works by identifying, evaluating, and handling people who have been exposed to the disease or have been in contact with a person exposed to the disease. Early detection and reporting can prove to be useful in breaking the transmission chain of the virus (WHO 2020). A digital technological system called "proximity tracking" is gaining popularity worldwide and is now a widely used surveillance system for COVID-19 (Parker et al. 2020). Scientists have recommended using a mobile tracing app to control the epidemic. To reduce the spread of the infections, it is essential to find all the people who came in close contact with the COVID-19 diagnosed individual (Abeler et al. 2020). Proximity tracking calculates whether two devices (e.g., smartphones) near enabled the spread of the virus from an infected individual to an uninfected individual. A person is notified if exposed and necessary measures can be taken by the health officials (Crocker et al. 2020). Many countries have come up with their contact tracing apps and the devices have already become popular among users. In a recent study in the UK, 74% of respondents said they would definitely or probably download/install a contact tracing app (Parker et al. 2020). As a majority of the people are interested in using the app and even people in the low- and middle-income countries (LMICs) use a smartphone, proper use of an app could be a potential strategy to ensure contact tracing. However, the available apps have not been compared and contrasted regarding development, confidentiality, popularity, and user-friendliness. Therefore, we aimed to conduct this review to examine the use of mobile apps in different countries to trace and detect COVID-19 positive cases to control the pandemic. The apps can help managing the transmission in the countries where the epidemic is active and to prevent further waves in the countries where the pandemic has been controlled.

19.2 Method

Academic databases/search engines such as PubMed, PubMed Central, Google Scholar, and Google were used to gather information on the usage of a mobile application for tracing COVID-19. The following search terms are used alone or in combination: "mobile app," "tracing," and "COVID-19." The reference lists from retrieved articles were also examined manually for relevant evidence. The search was conducted until 31 May 2020.

19.3 Results and Discussion

The search revealed that a total of 15 countries in the world developed and actively using 17 mobile apps for contact tracing to control the COVID-19 pandemic during the selected time frame (Table 19.1). China and Malaysia were only using two apps. Out of 17 apps, three were protected by the country's data protection laws.

Table 19.1 Key characteristics of mobile app for COVID-19 tracing by different countries

Name of the app	Country	Method of data collection and type of data	Protected by data protection law	Storage policy
COVIDSafe	Australia	Name, mobile number, postcode, and age	Yes	All storage data will be deleted after the pandemic
BeAware	Bahrain	Self-isolated individuals locations are traced and monitored by electronic bracelets	Not available	Not available
Facial recognition technology	China	The surveillance system can detect fever with a 0.3 °C margin of accuracy and can identify individuals not wearing a face mask	Not available	Not available
Mobile payment systems (Ali Pay and We Chat)	China	Combine the users' data such as location, health, and also financial data and then generate a tailored personal infection risk status	No	Not available
The e-Rouŝka	Czech Republic	Only identifies the people a person has been in contact with by tracing the location	Yes	Data is only accessible for the epidemiological purpose
CoronApp	Columbia	Symptoms, receive preventive advice and locating individuals	Not available	Not available
GH COVID-19 Tracker App	Ghana	Can trace anyone who has come in contact with an infected person	Not available	Not available
VirusRadar	Hungary	If an individual is infected, the app user will be asked to share the information with the health authorities	Yes	Stored on the device for 14 days
Rakning C-19	Iceland	Tracks users' GPS data to collect information about the users' encounters		The data is stored only on the phone and is accessible only to the user. The information is stored for 14 days and then deleted

(continued)

Table 19.1 (continued)

Name of the app	Country	Method of data collection and type of data	Protected by data protection law	Storage policy
AarogayaSetu	India	Tracks location and Bluetooth contact but also assigns color-coded badges indicating infection risk	No	The information stored is deleted after 30 days in case a person wishes to opt out
HAMAGEN	Israel	Uses GPS location of the phone to notify the user if s/he happens to cross a COVID-19 positive person and provides the exact time and place of the encounter	Not available	Not available
MyTrace	Malaysia	A community-driven application that assists users to exchange proximity information between each other once the app detects another device with the installed app		
MySejahtera	Malaysia	Personal data such as name, ID number, postcode	No	
NZ Covid Tracer app	New Zealand	Personal data, a digital diary of different locations that have been visited		
Smittestopp	Norway	Collects data about the movement pattern of the users, and in case one of them has been in close contact with another user who is diagnosed with COVID-19		The users' data is anonymized and data older than 30 days are deleted continuously
Tatamman	Saudi Arabia	The app provides services to identified cases for follow-up and lab test results as well as users who were in contact with confirmed cases	Not available	

(continued)

Table 19.1 (continued)

Name of the app	Country	Method of data collection and type of data	Protected by data protection law	Storage policy
TraceTogether	Singapore	Allows exchange of short-distance Bluetooth signals; therefore, everyone can detect other TraceTogether users and alert whenever someone comes into contact with a COVID-19 patient to take precautions		The data are automatically deleted every 3 weeks if the user doesn't come into contact with a positive case during this period

19.4 COVIDSafe

Australia is one of the countries which is affected by the current COVID-19 pandemic, and the adverse effects of the crisis have spilled over different sectors in the country, such as healthcare, trading, energy, finance, and tourism (Chang et al. 2020) The current reported cases (30 June 2020) are 7834, as the majority of them are between 20 and 29 years of age. The total 104 death cases with the majority between 80 and 89 years of age and the country showed high promising recovery rates with 7037 cases (Department of Health, Australia Government 2020). Australian authorities developed COVIDSafe as a contact tracing app (Department of Health, Australia Government 2020), which is the only Government approved app (Australian Government 2020). This app started functioning from 26 April 2020 and gathered personal details like name, mobile number, postcode, and age range. A unique encrypted code is generated after creating a confirmatory text message. It is highly sophisticated and works by using Bluetooth signals to record encrypted data about close contacts with other users. Data-protection laws still protect this revolutionary app through the Privacy Amendment bill (Department of Health, Australia Government 2020). After the diagnosis of COVID-19, immediate communications are verbally recorded and then uploaded into the COVIDSafe app storage system. Health officials analyze the gathered information to trace and control the pandemic spread. As an element of data protection, the infected person's details will not be disclosed. The users are advised to delete the app and all stored information is destroyed only once the pandemic ends. The data on the patient and their contacts stored in the secured system will be removed only at the end of the pandemic, which unfortunately looks remote, and hence of serious security concern. However, the deletion of personal information from the storage system can be requested (Australian Government 2020).

19.5 BeAware

Bahrain is a developing country, which is not also immune to the pandemic like their neighboring countries in the Arabian peninsula (Ministry of Information Affairs 2020). The first two cases were reported on 24 February 2020 and the first death case on 16 March 2020. The curve kept increasing slowly and reported cases were low until 11 April, and afterward, it started growing massively, and the peak of the evidence was recorded on 13 June. To date (30 June 2020), Bahrain recorded 26,239 cases and 84 deaths (Ministry of Health Bahrain 2020; World Health Organization (WHO) 2020a). The Kingdom of Bahrain authorities developed BeAware app (Kingdom of Bahrain 2020). It tracks COVID-19 patients using wearable electronic bracelets and alerts the government about any suspicious activity, and tracks movement through Bluetooth with GPS. People in self-isolation are advised to set their location. For monitoring, the Ministry of Health requests pictures which have to show the users' face and bracelet. The monitoring center is alerted if the wearer moves 15 m away from their phone. Violations are punished with penalties and/or a jail term. Removing or tampering with the bracelet is considered a breach. The users are required to charge their devices and make sure that the location and internet connection is on.

19.6 Facial Recognition Technology

China is the first country to report COVID-19 cases, the pandemic that contributed to enormous adverse impacts globally. The first case in Wuhan was reported back in late December 2019 (Epidemiology Working Group for NCIP Epidemic Response, Chinese Center for Disease Control and Prevention 2020). Afterward, the number of cases started to increase until it peaked on 3 February 2020, whereas the death rate was rising since 11 January onward (World Health Organization (WHO) 2020b). The Chinese Government placed high measures of quarantine and social distancing on the affected areas (Epidemiology Working Group for NCIP Epidemic Response, Chinese Center for Disease Control and Prevention 2020), which resulted in a marked decrease in both confirmed and death cases, as after 17 April the total confirmed cases and deaths until 30 June is 85,227 and 4648, respectively (World Health Organization (WHO) 2020b).

China has repurposed the existing digital surveillance system to cover COVID-19 contact tracing. This system can detect fever with a 0.3 °C margin of accuracy and can identify individuals not wearing a face mask. The highly sophisticated facial recognition technology has been developed by Sense Time and Megvii, which are high-tech Chinese firms with expertise in this field. Sense Time has developed a temperature detection software. Enforcement of these gadgets to control the spread of COVID-19 has been promoted and supported by the Chinese Government (Huang et al. 2020). The Government considers this as an approach that would allow COVID-19 infected people to resume healthy lives with thorough monitoring (Ministry of Foreign Affairs of the Peoples Republic of China 2020). Mobile payment systems encompassing touchless money transfers and mobile wallets are popular digital payment apps in China; these apps combine the users' data such as location, health, and financial details and then generates a tailored personal infection risk status. This runs in collaboration with government agencies, which then decides the users' status of accessing transport, shops, and other public spaces (Ministry of Foreign Affairs of the Peoples Republic of China 2020). However, with private technology companies involved in data collection and reluctance to share information on a local level has hindered the government's ability to limit the spread of COVID-19 toward the earlier stages of the outbreak. Ant Financial is a sister concern of the technology giant, Alibaba. Ant Financial has leveraged the Alipay Health Code, which places the public in color-coded categories for risk of COVID-19, based on collected and self-reported data. This then dictates their freedom of movement, including the freedom to travel. The green band allows unrestricted travel, and yellow recommends a week of quarantine, and red imposes a 2-week quarantine (CGAP 2019).

19.7 e-Rouŝka

The first three cases of COVID-19 in the Czech Republic were reported on 1 March 2020; since then, the number of cases went up to 9226, with 319 reported deaths (Komenda et al. 2020). To slow the spread of the virus, a project was created within the COVID19CZ initiative (a joint venture of Czech technology companies and IT enthusiasts to fight COVID-19) and ran under the auspices of Ministry of Health of the Czech Republic. The project was named "The e-Rouŝka" (e-facemask) and aimed to help hygienists in recognizing the people at high risk of infection by easy and sufficient identification. The data stored is only accessible to the hygienists for epidemiological purposes (Ministry of Health of Czech Republic 2020). The app helps in separating the exposed from healthy individuals and identifying the people who were insignificant contact (longer than 15 min for a distance of fewer than 2 m) with the infected. It is believed to aid in the gradual release of the national quarantine and decrease the effects of the pandemic on the society and economy (Ministry of Health of Czech Republic 2020).

19.8 CoronApp

In Colombia, the pandemic followed an exponential trend since the first case was reported back on 6 March 2020, where the most affected age group is $\geq$60 years (Amariles et al. 2021). Currently (30 June), the total confirmed cases are 91,769, and deaths are 3106, and the peak of the pandemic is not yet recognized at the country's curve as the cases are nevertheless on the rise (World Health Organization (WHO) 2020c). The Government-approved CoronApp-Colombia app allows provisions for users to register friends and family and can report health information including symptoms, receive preventive advice, and updated information about the virus in addition to being able to locate where cases are located in the map (Columbia Government 2020). Authorities removed contact tracing feature after experiencing glitches and adopted Apple and Google's contact tracing technology (Columbia Government 2020).

19.9 GH COVID-19

Ghana reported its first COVID-19 case on 12 March and as of 28 May 2020, Ghana has 7768 positive cases with 35 deaths (Ghana Health Services 2020). On 12 April 2020, ministries of Communications and Health launched a mobile app for contact tracing known as "GH COVID-19 Tracker App." The app works by identifying suspected cases with testing and tracking contacts of confirmed positive cases of COVID-19. The app works through mobile network platforms and can trace the recent locations visited by the individual and notify if a person needs to self-quarantine following exposure. The collection and availability of data through the app have been a significant aid in Ghana's battle against COVID-19 (Ministry of Communications Ghana 2020).

19.10 Virus Radar

The first case of COVID-19 was reported on 4 March 2020 in Hungary. As of 29 May 2020, Hungary recorded 3841 confirmed cases of COVID-19, with 517 deaths (Statista Research Department 2020). The Ministry of Innovation and Technology announced an official COVID-19 tracker app called "VirusRadar" on 13 May (Nextsense 2020). Developed by Nextsense, the app used the company's contact tracing technology and was donated to authorities as support against the COVID-19 fight (Nextsense 2020). The app uses Bluetooth technology and exchanges encrypted, anonymized data with other app users, measuring the distance between the phones. The information collected is stored on the device for 2 weeks. If an individual is infected, the app user will be asked to share the information with the health authorities. The data collected is stored on a safe server managed by health authorities and neither the location is tracked nor personal information is disclosed (Nextsense 2020).

19.11 Rakning C-19

Iceland started its coronavirus fight from 28 February 2020 with its first reported case. As of 27 May, a total of 1315 COVID-19 positive cases and ten deaths have been reported (Statista 2020). Rakning C-19 was launched in early April and tracks users' GPS data to collect information about their encounters and allowing investigators to trace the exposed individuals (Johnson 2020; Director of Public Health and the Civil Protection Department 2020). With nearly 40% of citizens using the app, it has the most significant penetration rate of all contact trackers worldwide (Johnson 2020). The country has managed to flatten the curve, and the numbers have been stagnant for several weeks. The last COVID-19 case was recorded on April 19 and the country has not undertaken drastic social measures like the rest of the world. It is focused mostly on a mixture of social distancing, “bubble strategy” of dividing workplaces, and schools into isolated units with do not interact with each other. The success has been attributed to aggressive testing, tracing, and isolation by the government (Johnson 2020). Once installed, the app runs in the background and saves the location of the phone numerous times in an hour. The data is stored only on the phone and is accessible only to the user. The information is stored for 2 weeks and then deleted.

19.12 AarogayaSetu

As of 31 May 2020, India has 89,995 confirmed cases of COVID-19 and 5164 deaths (Government of India 2020). On 2 April 2020, India launched its mobile tracing app known as “AarogayaSetu” which is aimed at facilitating the efforts of limiting the spread of the virus in India (Ministry of Electronics and Information Technology 2020). As of 26 May, the app has over 114 million users, more than any other contact tracing app in the world and is available in 12 languages on Android, iOS, and KaiOS platforms (Ministry of Electronics and Information Technology 2020). AarogayaSetu, unlike other similar apps, is a massive all-in-one undertaking that not only tracks the location and Bluetooth contact but also assigns color-coded badges indicating infection risk.

India is the only democratic country in the world, making the coronavirus app mandatory for its citizens. However, the country lacks a national data privacy law, and thus there is ambiguity as to who can access the data from the app. There are concerns regarding blurring the line between voluntary and mandatory, and between preserving and overtaking the privacy (O’Neill 2020). The app pioneers new data-driven flattening of the curve using “syndromic mapping.” So far, the app has reached out to more than 900,000 users and is useful in advising quarantine, testing, or precaution. The overall COVID-19 positive rate is around 4.65% and among those who were instructed to get tested, 24% have been found positive for COVID-19 infection. The app has identified nearly 3500 hotspots across India using the “syndromic mapping” approach and these predicted hotspots were confirmed as real hotspots in 17–25 days (O’Neill 2020).

19.13 HAMAGEN

As of 30 May 2020, Israel has 16,809 confirmed COVID-19 cases with 281 deaths (WHO 2020). Developed by the Ministry of Health (MOH), the contact tracing app is named “HAMAGEN” which was launched on 22 March 2020 (Ministry of Health 2020). The app uses a phone GPS location to notify the user if he/she happens to cross a COVID-19 positive person and provides the exact time and encounter location. The user is then able to review, confirm, or reject the notification manually. The cross-referencing of the GPS history is done with the epidemiological data of the MOH and is stored only on the user's phone and is inaccessible to any third party. The app's control system is voluntary and provides sole discretion to the user (Ministry of Health 2020).

19.14 MySejahtera

*By the end of January 2020, the COVID-19 patient numbers have been growing exponentially in Malaysia. Consequently, Malaysia has the highest number of cases within Southeast Asia at that time (*Lip et al. 2020*). Three main tracking applications were developed* by different governmental entities *to control* the *spread of COVID-*19. The first one is MyTrace, which is a community-driven application that assists users to exchange proximity information between each other once the app detects another device with the installed app (Ministry of Science, Technology and Innovation (MOSTI) 2020). Therefore, MyTrace is enabled to identify users who were close to infected individuals. It was developed through internal collaboration between eight governmental agencies, the International Islamic University Malaysia, and Google. The second one is MySejahtera, which helps the users to perform a self-assessment and monitor progress, as well as allows the MOH to provide any immediate interventions when it is required (Ministry of Science, Technology and Innovation (MOSTI) 2020). The third one is Gerak Malaysia, which gives users access to get traveling permission during the moving control order (Malaysian Communications and Multimedia Commission 2020). Additionally, it allows the MOH in tracing the movement of the users and potential patients' contacts. However, this app collects a lot of personal data like name, ID number, and postcode, which raise concerns regarding data privacy and usage.

19.15 NZ Covid Tracer App

New Zealand is one of the countries that controlled the pandemic and is raising promising results so far. The country recorded the first COVID-19 case and death on 28 February and 29 March 2020, respectively (Ministry of Health New Zealand 2020). Since the new COVID-19 pandemic, contact tracing is a top priority with the purpose of identification and isolation of people who have been exposed to an infectious case, to prevent onward transmission from the contact to others (Verall 2020). The tracing chiefly was done by medical, health, and public health staff who are specialists in infectious disease control. Moreover, the MOH in New Zealand has launched the NZ Covid Tracer app on 19 May 2020 as part of their contact tracing strategy (Ministry Of Health 2020b). The app requires to set up an account that includes personal data (Ministry Of Health 2020b). Amid registration, the user needs to create a digital diary of different locations that have been visited. If the user were identified as close contact to a COVID-19 case, the National Close Contact Service would contact the user to provide the necessary advice and arrangement. Additionally, they will collect further information about the social circle of the users to identify whether anyone may also have exposure to the virus (Ministry Of Health 2020b).

19.16 Smittestopp

Since the first detected case of COVID-19 in Norway in February 2020, the public health authorities have provided advice on well-known infection control measures, such as hand hygiene, sneezing and coughing habits, isolation of individuals with COVID-19 symptoms, avoiding unnecessary travels, work from home if possible, and tracing of contacts of confirmed cases (Helsingen et al. 2020). To limit the transmission of coronavirus, the health authorities have developed the Smittestopp app, which is an app supported by Apple and Google Play stores (Helsingen et al. 2020). The Smittestopp app collects data about the movement pattern of the users, and in case one of them has been in close contact with another user who is diagnosed with COVID-19, the app will provide a piece of advice about how to limit the transmission. The users' data is anonymized and data older than a month are deleted continuously (Norwegian Institute of Public Health 2020).

19.17 Tatamman

In Saudi Arabia, the pandemic caused high rates of mortality until now; the first case was reported on 2 March 2020, and the earliest death on 24 March. Since these dates, the cases count is increasing, as the country is still going toward the peak, and the total recorded cases until 30 June 2020 is 186,436 and 1599 deaths (World Health Organization (WHO) 2020d). The MOH has launched an app called "Tatamman" as part of its qualitative initiatives to prevent COVID-19 spread (Ministry Of Health Saudi Arabia. MOH 2020). According to MOH, the app aims at providing protection to those who are self-isolating or in quarantine to prevent and enhance their recovery procedures, respectively. The app provides services to identified cases for follow-up and lab test results as well as users who were in contact with confirmed cases (Ministry Of Health 2020c). Moreover, all citizens returning from abroad need to wear bracelets that are linked to the same app (Ministry Of Health 2020c).

19.18 TraceTogether

Singapore's first COVID-19 cases were identified at the beginning of March 2020. Therefore the government starts to implement public health measures to control the spread and flatten the curve (Smart Nation Singapore 2020). The government launched the TraceTogether application on 20 March 2020 in their efforts to combat and mitigate the range of COVID-19 through community-driven contact tracing (Smart Nation Singapore 2020). This mobile app was developed by the Government Technology Agency, in collaboration with MOH (Smart Nation Singapore 2020). The application allows exchange of short-distance Bluetooth signals; therefore, everyone can detect other TraceTogether users and alert whenever someone comes into contact with a COVID-19 patient to take precautions. The application only requests a registered phone number, and no further information is collected. Additionally, the data are automatically deleted every 21 days if the user does not come into contact with a positive case during this period (Smart Nation Singapore 2020).

So many countries in the world so far have developed and launched applications with a purpose to control the spread of COVID-19. The main strength of these apps is their "novelty effect," which helps the health authorities to monitor and diagnose the infected individuals. According to Amnesty International, Bahrain's "BeAware Bahrain," Kuwait's "Shlonik," and Norway's "Smittestopp" apps are found to be "the most alarming mass surveillance tools" and compromise users' privacy as the apps "actively carrying out live or near-live tracking of users' locations by frequently uploading GPS coordinates to a central server." (Cho et al. 2020). This recent coronavirus infection has affected a large population globally, so a universal mobile application system can be developed that will incorporate all vital features to locate, monitor, and to send alerts and connectivity with the health authorities and government officials so they can take immediate measures to control the spread of infection. This is the first such kind of review to compare and contrast the available apps and their applicability in controlling the pandemic.

The applications mostly supported Apple and Google Play stores and were created in the spoken languages in the countries as well as English. However, this strategy has raised concerns regarding data anonymization, data privacy, and usage (Amnesty 2020), particularly with the involvement of Google and Apple who could have access to the database which implies the question whether data rights are safeguarded (Parker et al. 2020), as well as lacking policy that will give privacy considerations when designing contact tracing apps (Amnesty 2020). The use of a mobile app for tracing COVID-19 positive patients may produce inaccurate data and in some instances using the app can be troublesome. It should be noted that this form of the mobile app is not a substitute for treatment or necessary follow-up. Maintenance of this system can be difficult as it would require backup systems in case of problems with the transmission. It is unlikely that the users are at risk even in case of transmission issues as senders are usually notified. The systems require to meet data protection guidelines and also privacy and confidentiality requirements.

Moreover, the applications are installed voluntarily. Therefore it does not ensure full public engagement. To date, there is no scientific evidence that correlates the effectiveness of mobile applications and COVID-19 contact tracing. Moreover, there is no available data regarding the number or percentage of people who have installed the app and are using it regularly. Additionally, the mobile applications are a continuous work that is in progress and updated periodically. Therefore, the collected information may always change, which will affect data analysis. The search was not systematic. Not all databases have been searched. No previously tested or valid instrument was used to evaluate the apps.

19.19 Conclusion

The review reveals that the use of mobile technology is helping the health authorities to monitor and diagnose the infected individuals and thus controlling the spread of infection. The COVID-19 pandemic affected the health facilities' responses even in developed countries with proven and state–of-the-art modern healthcare systems (Pillai et al. 2020). With proper utilization of these mobile contact tracing apps, it would be possible to control, detect the clusters, and predict next waves of the COVID-19 pandemic and future disease outbreaks. However, strong caution is warranted to generalize the usability of apps, especially in the LMICs, and to address the concerns regarding data anonymizing, data privacy and usage, and data rights.

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Role of IoT and Social Networking in Mental Healthcare of Transgender Community During COVID-19 Pandemic

20

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Abstract

Years of social exclusion and economic boycott have left the transgender community with little opportunity to progress in a transphobic world. Begging, street entertaining, paid sex, and other minimal jobs fetch them their daily bread and butter. However, the situation of the COVID-19 pandemic is worse than just a viral infection for them. In this grave situation of social distancing and lockdown, the financial constraints, delay in sex reassignment surgery, lack of medical care for hormonal treatment, and the vacuum created due to the uncertainty amid the pandemic have gradually brought overwhelming levels of stress, helplessness, anxiety, depression, and suicidal risks among them. Fortunately, due to social networking through IoT, they can access information regarding the government schemes for food supply, telemedicine and online video consultations with their healthcare professional, get updated news about COVID-19 prevention, detection, and treatment goals, reduce the distance between their beloved ones through verbal communication and texting, accurate updates on transmission in their region, and information about closures and shutdowns. This brings mental stability among them by eliminating their ignorance about the uncertainty arising from the COVID-19 pandemic. A 20-item measure of the Center for Epidemiologic Studies-Depression Scale (CES-D) and ANOVA is used to quantify and measure the statistical significance of the findings in the research work. The pragmatic analysis of data in the study focuses on the role of IoT and social networking in uplifting mental healthcare among the transgender community by minimizing panic and anxiety in the pandemic situation.

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Keywords

IoT · Social networking · Transgender · Mental healthcare · COVID-19 · ANOVA · CES-D

20.1 Introduction

Every life is supposed to have equal value, but it is evident enough that it is not always the case with transgender lives. Time and time again, the transgender community has faced the repercussions of the gender biased society in the form of prejudices and poverty. However, the existence of community of transgender dates back to thirteen and fourteen centuries in India (Konduru and Hangsing 2018). The ancient Indian civilization portrayed a little evidence of violence toward them in comparison to the present scenario. However, in the twenty-first century, the stigma and gender incongruence against the transgender community is quite common. The gender identity of transgender individuals mismatches their sexual anatomy, and thus they remain ghettoized by the society. The attitude of Indian society toward transgender individuals is deceitful as they transgress the rigid concept of binary arrangement of social division of sexes (Priyadarshini and Swain 2020a). Consequently, the social ostracization has segregated this community from the mainstream, thereby limiting them to minimal remunerated alternatives for their livelihood such as begging, street entertaining, and paid sex. The unfair refusals in accessing housing, healthcare, educational, and employment opportunities reveal their hardship resulting from unacceptance and animosity of general public toward them. Further, the mental torment ranging from verbal abuses to physical violence makes their life treacherous. Thus, the socioeconomic status of the transgender community was always at nadir, and further the situation of the COVID-19 pandemic has degraded their situation from bad to worse. COVID-19, broadly known as coronavirus infection caused by novel coronavirus, has been declared as a pandemic, thereby claiming millions of lives globally (Khadidos et al. 2020). In India, approximately 906,752 cases were diagnosed with coronavirus infection, and 23,727 citizens lost their lives by 1 July 2020 (World Health Organization 2020). To curtail the widespread diffusion of coronavirus infection, the Indian Government declared social distancing, thereby completely shutting down the educational institutes and commercial establishments and prohibiting social, political, and religious gatherings since March 24, 2020 (Priyadarshini and Swain 2020b).

However, the situation of the COVID-19 pandemic is worse than just a viral infection for the community of transgender people. According to census 2011, the number of the transgender population is 4.88 lakhs in India, and a bulk of them are reliant on a form of livelihood which is based on social interactions such as begging and paid sex for their bread and butter. Majority of transgender people are predominantly dependent on community-oriented jobs and earn a meager income from their gig jobs. Owing to the persisting lockdown situation, the cancelation or postponement of engagements, weddings, or baby showers, shutting down of red light areas, restraints on begging or street entertaining due to social distancing, or travel restrictions, they are left penniless, thereby relying on their paltry savings. Consequently, the pandemic scenario has halted their incomes and left their lives unsettled. The idea of social distancing has proved to be effective in curtailing the viral infection but simultaneously has put the lives of the transgender community at risk due to their lost livelihoods. Most of the transgender people are not privileged enough to operate through online world and earn a living out of it, thereby making it difficult for them to make their ends meet. Lockdown has resulted in lost livelihood, leading to clogged income stream and food insecurity among the transgender community. In order to overcome the financial constraints and fulfill the daily needs, most of the transgender individuals prefer borrowing from multiple unorganized loaning sources. Due to ignorance and lack of necessary documents, they fail to access loans from banks. Consequently, due to high interest rate and inability to payback on time, they remain debt trapped (Priyadarshini and Swain 2020b). This dismal situation amid the COVID-19 pandemic has created uncertainty among transgender individuals regarding their life and livelihood. The panic-stricken transgender community have remained restricted to their home bunkers since lockdown. From struggling to make ends meet to deteriorating mental health due to isolation, the community of transgender are subjected to greater brunt of COVID-19 lockdown. The uncertainty about lockdown period, lost livelihood, clogged income stream, food insecurity, burden of debt, exhausting savings, and distance from their loved ones have created anxiety and imbued fretfulness among them. The void created in the lives of transgender people due to social distancing has adversely affected their mental health to a significant extent. On the baseline, the degradation in quality of lives and change in lifestyle pattern due to financial constraints have psychologically burned them. Additionally, they experience unique stressors related to their identity, which get combined with other stressors to impact their mental health. Further, the empty hands and minds revive memories of old traumas of their personal lives, which build depressive symptoms in them (Thomas 2020). However, Internet of things (IoT) and social networking have played a significant role in improving mental health by facilitating virtual social ties and maintaining mutual support amid the COVID-19 pandemic. Internet has always remained a podium for extending moral support to overcome the difficulties of everyday life related to their unique identity, dealing with loneliness, understanding transgenderism, finding emotional support and job opportunities, and providing advice regarding coming out for the transgender community (Cipolletta et al. 2017). During the critical situation of COVID-19 pandemic, IoT such as mobile phones or cellular phones and smart televisions has turned to be a versatile platform for providing information regarding the government schemes for food supply, telemedicine and online video consultations with their healthcare professional (Reback and Rünger 2020), getting updated news about COVID-19 prevention, detection, and treatment goals, reducing the distance between their beloved ones through verbal communication and texting, getting accurate updates on transmission in their region, and information about closures and shutdowns.

Transgender people like other all genders are social creatures who need the companionship of others to thrive their lives, and the strong connections through social platforms have a major impact on their mental health and happiness. However, social distancing and isolation have put a limit in their social engagement in real world, which exposes them to loneliness, anxiety, depression, stress, self-harm, suicidal thoughts, and uncertainty. Both anxiety and depressive disorders are found to be associated with substantial impairment (Ferrari et al. 2013) among the transgender community, developed mostly due to blank mind and empty hands (Hegland and Nelson 2002). Social networking sites such as Facebook, WhatsApp, Twitter, Instagram, Transgender Amino, Butterfly, Snapchat, and YouTube act as invaluable tools for connecting transgender individuals with friends, family, and wider world amid the pandemic. The communication through transgender YouTube channels, transgender support circles, and transgender forums is helpful in providing joy and comfort and preventing loneliness, which can stabilize their mental and emotional health. Although social media can never be a replacement for real-world human connection, social networking through online platforms has the potential to trigger their hormones that alleviate their stress, anxiety and depression, boost their self-worth, and make them happy and healthier (Smith 2020). However, literature on online support through social platforms and forums has grown enormously over the last decade, but very little attention has been provided on how social networking through IoT devices can boost their mental health during pandemic situations. This study has focused on the potential impact of social connectivity through IoT in maintaining the mental healthcare balance among the transgender community in the grim situation of COVID-19.

20.2 Materials and Methods

20.2.1 Study Design

This qualitative study was conducted from March 31, 2020, to July 1, 2020, which was based on content analysis. The opinion of transgender respondents regarding their lives in the pandemic situation in online platforms (blogs and articles in Facebook, Instagram, Twitter, and Snapchat) was analyzed. Both online and offline experiences of transgender respondents from different states of India were recorded because their online experiences are deeply entrenched in their offline lives (De Koster 2010).

20.2.2 Online Forums and Offline Data Collection

The online viewpoint and experiences of transgender respondents were selected by googling keywords like "Transgender lives in Covid-19," "Psychology of Transgender in Pandemic," "Mental health of Transgender in Lockdown," "Connecting transgender through social networking," and "IoT and transgender lives in

Pandemic." The same keywords were looked up in social networking sites (Trans Forum, Trans Chat, Facebook, Instagram, and Twitter), and their lives in the pandemic were recorded. The analysis of transgender respondents on online platforms was not sufficient to study and evaluate the in-depth understanding. Consecutively, primary survey was conducted through snowball sampling (Goodman 1961) by collecting the responses of transgender people on the role of IoT and Social Networking in Mental Healthcare of the Transgender Community in the Covid-19 Pandemic. Interview was conducted. The total number of recorded statements of transgender people on online forum was 25 and on offline world was 75. The age of transgender respondents ranged from 17 to 55 years. However, primary data is collected from 75 Bhubaneswar-based transgender respondents during their leisure time. The respondents were paid Rs 100 each for their valuable response. The research took approximately 3 months to collect and analyze the ground reality about the role of IoT and Social Networking in Mental Healthcare of the Transgender Community in the Covid-19 Pandemic.

20.2.3 Data Analysis

The experiences of transgender people recorded on online platform and interviews of transgender people collected from offline world were analyzed using grounded theory (Glaser and Strauss 1967). The collected data passes through three stages for building a grounded theory with the help of empirical materials and content analysis. In the first stage or open coding stage, responses of transgender respondents were recorded on the basis of keywords such as "Transgender," "Pandemic," "IoT," "Social networking," and "COVID-19." In the second stage or axial coding stage, those recorded responses were accumulated to create new and wider categories like "Transgender lives in Covid-19," "Psychology of Transgender in Pandemic," "Mental health of Transgender in Lockdown," "Connecting transgender through social networking," and "IoT and transgender lives in Pandemic." In the third stage or selective coding stage, the categories will be refined in order to identify the core category. The core category will comprise the main theme of research I, that is, the role of IoT and Social Networking in Mental Healthcare of the Transgender Community in the Covid-19 Pandemic (Strauss and Corbin 1998). The software used for the analysis of qualitative data was IBM SPSS STATISTICS 23. The reliability of qualitative analysis was tested through Cronbach's alpha statistic. Further, a comparative analysis of the level of depression between transgender people using smartphones and transgender people not using smartphones is measured through a 20-item measure of the Center for Epidemiologic Studies-Depression Scale (CES-D) (Radloff 1977, 1991).

20.3 Discussion

20.3.1 Adverse Impact of COVID-19 on Transgender Community

The stigmatized community of transgender people is suffering from deteriorated mental health amid nationwide lockdown. Lost livelihood has resulted in clogged income stream, thereby making it difficult for this community to make their ends meet. Zoya Thomas Lobo (25), a transgender woman, who is solely dependent on begging in women's compartment in Mumbai local train, has remained jobless amid this pandemic. Further, she stated, “I was earning an average income between Rs 500-Rs 1100 on daily basis before lockdown. Now am jobless and penniless too. Food supplies are depleting and I am constantly anxious about my future as my savings have already exhausted by this time” (Rosario 2020). As a medical and socially vulnerable group, the transgender community is exposed to numerous health disparities. Amid the COVID-19 pandemic situation, in order to prevent the potential overload of the healthcare system, many healthcare centers have postponed or canceled nonemergency surgeries to prioritize care for COVID-19 patients. This has put a halt in the hormonal treatment of transgender individuals, which has taken a dangerous mental toll in them. Chanayika Shah, a transgender from Mumbai stated that, “If I don't continue my hormonal treatment further, I will have intense dysphoria, anger and sadness. Both medicine and money has become my concern in this hour of Pandemic and unfortunately am unable to access them.” There is a looming fear among the HIV-positive transgender patients about the impact of COVID-19 on them. HIV-positive transgender patients need antiretroviral therapy (ART) medication every month, but unfortunately, doctors have postponed their health checkup as it is considered as an essential but not emergency therapy. Shonali, an HIV-positive Kolkata-based sex worker stated that, “My next health checkup has been postponed indefinitely. If things continue this way, I will probably die. The uncertainty of the persisting situation is creating stress and trauma which is hampering my mental health adversely” (Priyadarshini and Swain 2020b). Further, financial constraints instigate few transgender people to borrow money from informal sources. But as the situation has persisted for a long time now, they are unable to gain their lost livelihood and finally fall into a debt trap. Urmi, a transgender respondent from Odisha stated, “I am in a debt trap as the rate of interest is very high. During lockdown, I rarely have any customer and am left penniless. I do not know how can I pay back the borrowed money.” Last but not least, the transgender staying in hostile homes undergo stress and trauma under this lockdown period. They are constantly criticized and ridiculed by their near and dear ones, which push them toward frustration and depression. Dan Rebello (27), a transgender teacher from Thane, who is stuck with family during the lockdown expressed that, “My parents constantly talk about my gender identity and mock the way I speak and walk. Even, they talk about my marriage. This is so irritating. I have locked myself in my room and stopped talking to my parents. I am scared that their verbal abuse will very soon turn into physical violence.” With a history of anxiety disorder, Dan has started remaining silent and have minimal interactions with others (Rosario 2020). Thus, the

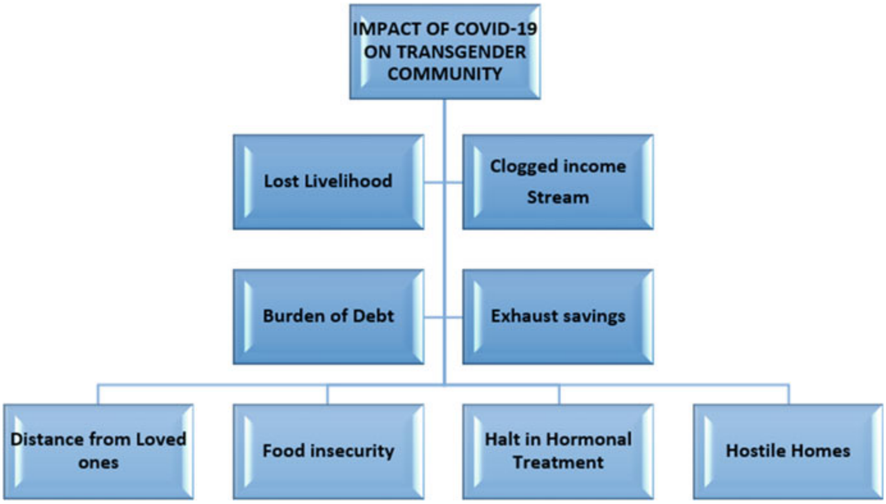

Fig. 20.1 Adverse impact of COVID-19 on transgender community

pandemic situation has not just disrupted their livelihoods but also has put their mental health on stake. The flowchart (Fig. 20.1) has enclosed the adverse impact of COVID-19 on the transgender community. The lost livelihood, clogged income stream, burden of debt and exhausting savings, hostile homes, halt in hormonal treatment, food insecurity, and distance from loved ones have brought in devastating psychological distress among them.

20.3.2 Role of IoT and Social Networking in Maintaining Mental Healthcare Among Transgender Community

Social networking sites and social platforms through IoT such as Facebook, Tumblr, Instagram, Twitter, Snapchat, YouTube channels, Trans chat, and Trans forum have fostered positive senses of social support and connection with closed ones, which impact their mental health to a significant extent amid the pandemic. Social distancing and lockdown due to the pandemic situation have pushed them toward psychological distress resulting from loss of livelihood, hostile homes, halt in hormonal treatment, food insecurity, and distance from loved ones. The life of transgender people has always been a bed of thorns, and social distancing has further made their situation worse. Most of the transgender people are dependent on social interaction for their bread and butter, which seems impossible during this grim situation. The deprivation of daily square meal, financial constraints, exhausting savings, and disconnect from psychiatrist add more miseries to their lives. These miseries bring suicidal thoughts in them. On May 12, 2020, a 38-year-old HIV-positive transgender individual from Mumbai has committed suicide due to loss of livelihood, food insecurity, and inability to access medical facilities (Chakrabarty 2020). Few transgender people who were going through psychological troubles are unable to visit their health professional due to lockdown, thereby battling panic attacks and anxiety issues. Rima, a transgender respondent from Odisha, is going through anxiety issues as she is unable to meet her psychiatrist for the past 3 months. She is a makeup artist who used to earn approximately Rs 7000 a month, but due to lockdown, she is unable to earn a penny. Further, she was also saving for sex reassignment surgery but sadly has exhausted all her savings to meet her day-to-day expenses. This brings lingering tension and stress, leading to sleepless nights and acute depression. Thus, amid this lockdown, a number of transgender individuals are experiencing stress, trauma, fear, anxiety, depression, suicidal ideas, and insomnia, which are shattering their mental health.

However, social networking platforms like Facebook, Instagram, Twitter, Snapchat, YouTube channels, Trans chat, and Trans forum are playing a significant role in facilitating connection and online social interaction. Nevertheless, networking through IoT is helpful in accessing information regarding the government schemes for food supply, telemedicine and online video consultations with their healthcare professional, getting updated news about COVID-19 prevention, detection, and treatment goals, reducing the distance between their beloved ones through video call, accessing information on accurate updates on transmission in their region, and information about closures and shutdowns. Seema, a transgender respondent from Mayurbhanj district of Odisha expressed, "I had given up during this shutdown as all my savings have exhausted. I tried to commit suicide but one day I saw the video of Laxmi Narayan Tripathy in a YouTube channel and got motivated to start my life with new vigor." Another transgender named Champa from Khurda district of Odisha voiced, "I had lost all my hopes and was under complete depression. In this lockdown, I interacted with a transgender from West Bengal naming Sumi through Facebook. She told me about the Odisha government scheme in which I can register myself so that I can be eligible for the Madhu Babu Pension Yojana (MBPY). My life has become comparatively easy." Similarly, another transgender named Malati, a transgender from Nawrangpur district of Odisha stated, "Empty mind is devil's workshop. I had nothing to do whole day and random suicidal thoughts ran through my mind. But then I made online friends in Facebook and Trans chat room and now I am discussing my problems with them and feeling relieved." Jaya, a transgender from Bhubaneswar stated, "I am glad to carry out online video consultations with my psychiatrist once a week. This keeps me calm and compost (composed)." However, the abovementioned statements of transgender respondents revealed that online platforms are significantly helpful in maintaining mental peace by imbuing confidence in them in this grim situation. Figure 20.2 shows the usefulness of social connectivity in maintaining a stable mindset among the transgender community.

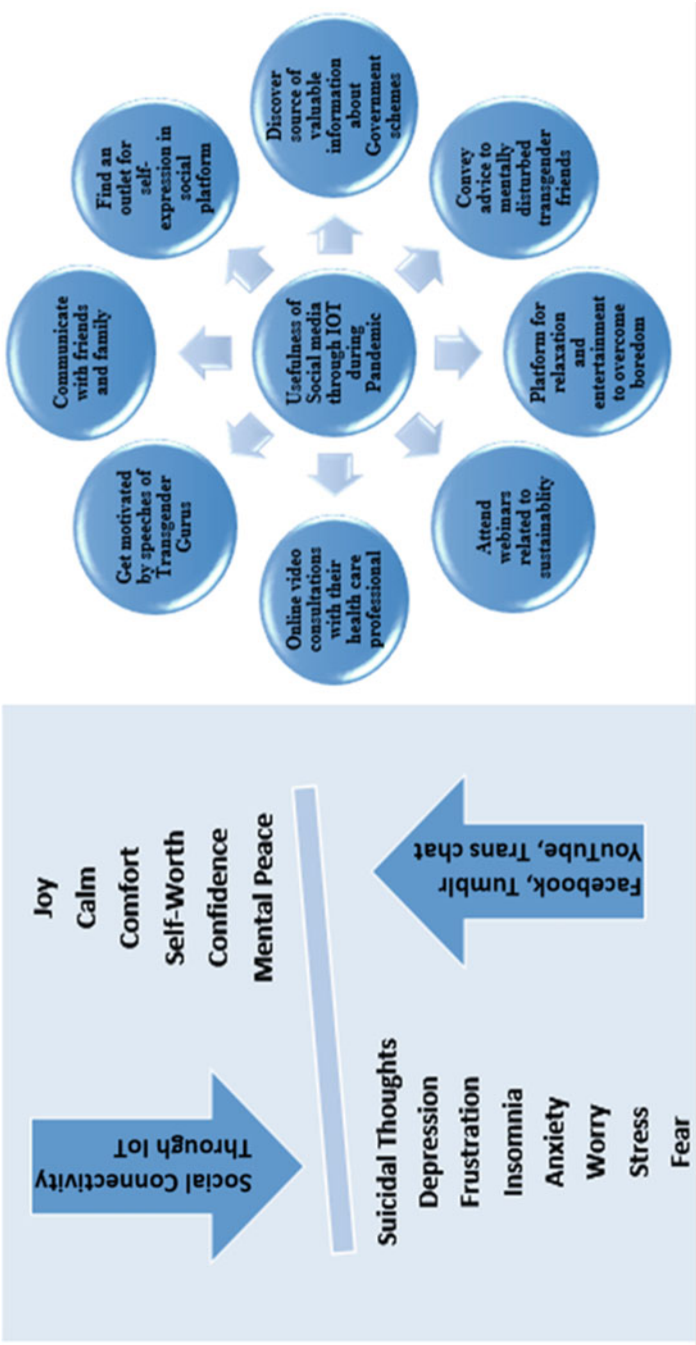

Fig. 20.2 Usefulness of social networking through IoT in maintaining mental healthcare in transgender individuals

20.3.3 ANOVA and Regression Coefficients for Ascertaining the Usefulness of Social Connectivity in Maintaining a Stable Mindset Among the Transgender Community

In order to verify the reliability of the data collected, the data is run in SPSS for Cronbach's alpha. Since the value is 0.949 as presented in Table 20.1, the variables identified and data collected on "usefulness of social networking through IoT in maintaining mental peace among transgender in the pandemic" are reliable.

Null Hypothesis Social networking through IoT is not helpful in maintaining mental peace among transgender people in the pandemic.

In Table 20.2, the *P*-value is 0.000948. Because this value is less than significance level of 0.05, null hypothesis is rejected. The calculated *F* value in the test is 3.012919182, which is larger than *F* statistic value 1.842318, thereby rejecting the null hypothesis. Thus, social networking through IoT is helpful in maintaining mental peace among transgender people in the pandemic.

Variables The criterion variable is "social networking through IoT is not helpful in maintaining mental peace among transgender in the pandemic" for which ten independent variables are taken into consideration.

- V1: Mobile is useful in connecting with loved ones through voice calling and texting.
- V2: Mobile is useful in providing telemedicine facility.
- V3: Mobile is successful in online video consultations with healthcare professionals.
- V4: Social platform is useful in providing updates on transmission of coronavirus infection in their region.
- V5: Social platform provides information about government schemes for food supply and ration card.
- V6: Social platforms keep you updated regarding the pandemic and its prevention.

Table 20.1 Reliability statistics

Cronbach's alpha	No. of items
0.949	11

Table 20.2 ANOVA output

ANOVA						
Source of variation	SS	Df	MS	*F*	*P*-value	*F* crit
Between groups	47.09333	10	4.709333	3.012919182	0.000948	1.842318
Within groups	1272.32	814	1.563047			
Total	1319.413	824				

- V7: Mobile is useful for relaxation and entertainment to curtail boredom during the pandemic.
- V8: Motivated speech of intellectual Gurus in YouTube channels provide peace of mind.
- V9: Social networking sites are helpful in looking for help for expressing troubles through the pandemic.
- V10: Advice received by transgender friends through social networking sites during the pandemic keeps the mind calm and composed.

The analysis determines the predictor variables that significantly influence the criterion variable, that is, V11. However, variables that contribute to maintain peace of mind among transgender people during the pandemic situation are enlisted in Table 20.3.

Since for the variables V1, V3, V4, V5, V9, and V10 the calculated significance level is less than the accepted level of significance of 5% (i.e., 0.05), these six variables influence the criterion variable to a substantial extent (values mentioned in bold within Table 20.3 represent the significant variables influencing "utility of social networking through IoT in maintaining mental peace among transgender in the pandemic").

The output furnishes the following regression model:

$$\mathrm{V11} = 0.231 + 0.010\ \mathrm{V1} + 0.260\ \mathrm{V3} + 0.254\ \mathrm{V4} + 0.292\ \mathrm{V5} + 0.252\ \mathrm{V9} + 0.200\ \mathrm{V10},$$

where V11 is "social networking through IoT is helpful in maintaining mental peace among transgender in the pandemic."

Standardized coefficients (β value) for V1, V3, V4, V5, V9, and V10 are 0.515, 0.244, 0.313, 0.210, 0.077, and 0.081, respectively. As per the model, standardized coefficients (β value) for V1 is 0.515, which is the highest. Hence, owing to the variables identified, variables influencing "utility of social networking through IoT

Table 20.3 Standardized and unstandardized regression coefficients

Coefficients						
		Unstandardized coefficients		Standardized coefficients		
Model		B	Std. error	Beta	*t*-stat	Significance
1.	(Constant)	0.231	0.159		1.454	0.150632742
	V1	**0.010**	**0.096**	**0.515**	**0.109**	**0.000**
	V2	−0.041	0.096	0.008	−0.433	0.666
	V3	**0.260**	**0.078**	**0.313**	**3.325**	**0.001**
	V4	**0.254**	**0.092**	**0.081**	**2.770**	**0.007**
	V5	**0.292**	**0.091**	**0.244**	**3.205**	**0.002**
	V6	0.043	0.065	0.004	0.662	0.510
	V7	0.025	0.071	0.005	0.358	0.720
	V8	0.067	0.065	0.001	0.977	0.332
	V9	**0.252**	**0.084**	**0.210**	**2.991**	**0.003**
	V10	**0.200**	**0.081**	**0.077**	**2.477**	**0.015**

Criterion variable: V11

in maintaining mental peace among transgender in the pandemic" on the basis of significance are as follows: V1 (Mobile is useful in connecting with loved ones through voice calling and texting), V3 (Mobile is successful in online video consultations with healthcare professionals), V5 (Social platform provides information about government scheme for food supply and ration card), V4 (Social platform is useful in providing updates on transmission of coronavirus infection in their region), V10 (Advice received by transgender friends through social networking sites during the pandemic keeps the mind calm and composed), and V9 (Social networking sites are helpful in looking for help for expressing troubles through the pandemic).

20.3.4 Mental Health of Transgender Having a Smartphone Vis-a-Vis Transgender Not Having It

The lost livelihood and restriction on social movement push transgender people to depression, which was identified by noticing constant symptoms of loneliness, insomnia, and poor appetite among them. However, the use of smartphones and accessing social networking sites through it have successfully kept them engaged and have constantly updated them regarding the pandemic situation. This has resulted in keeping their mind calm and composed, which ultimately has overcome their anxiety and melancholy imbuing from uncertainty in the pandemic situation. However, a comparative study on the level of depression has been carried out between transgender people with smartphones and transgender people with just mobile phones. The 20-item measure of the CES-D is used to quantify the level of depression in transgender adults aged 8–22 years. Equal number of transgender respondents (20 in number), with and without smartphones, were taken into consideration for testing their level of depression. In order to identify transgender respondents with clinical level of depression, a dichotomous variable was framed by putting forward a cutoff score of 16, which shows the level of sensitivity and internal consistency. A set of 20 questions are asked, which were predecided by CES-D scale, and the respondents replied on the basis of their past experiences associated with loneliness, insomnia, poor appetite, and depression. The responses of the transgender respondents ranged from 0 to 3 for each question (0 = Rarely or None of the Time, 1 = Some or Little of the Time, 2 = Moderately or Much of the time, 3 = Most or Almost All the Time). However, the scores ranged from 0 to 60 after summing up for every individual response. The analysis established a strong reliability of 0.94 for α value. It was found that 75% of transgender people without smartphones were suffering from clinical depression. On the basis of their statement, it was clear enough that the void created due to the lack of social connectivity during the pandemic has pushed them toward depression. By contrast, it was observed that 20% of transgender people with smartphones were suffering from clinical depression. This significant difference can be associated with the benefits of having a smartphone that facilitates virtual social ties and maintains mutual support amid the COVID-19 pandemic. A comparison of the mental health of transgender people

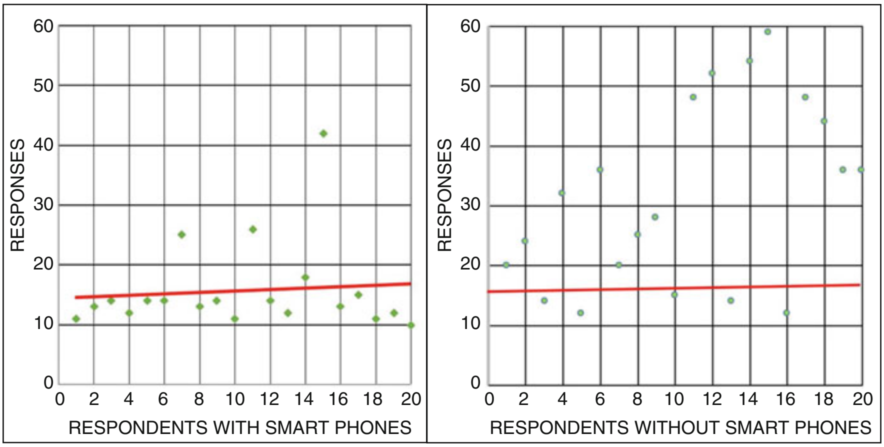

Fig. 20.3 Comparison of the mental health of transgender people having smartphones with that of the transgender people not having smartphones

having smartphones with that of the transgender people not having smartphones is presented in Fig. 20.3.

20.4 Summary of Result

As evidenced from the data analysis and discussion in previous sections, it is inferred that social networking through IoT is not helpful in maintaining mental peace among transgender people during the pandemic. It is also inferred that variables, such as (1) Mobile is useful in connecting with loved ones through voice calling and texting, (2) Mobile is successful in online video consultations with healthcare professionals, (3) Social platform provides information about government scheme for food supply and ration card, (4) Social platform is useful in providing updates on transmission of coronavirus infection in their region, (5) Advice received by transgender friends through social networking sites during the pandemic keeps the mind calm and composed, and (6) Social networking sites are helpful in looking for help for expressing troubles through the pandemic, do significantly influence the criterion variable, that is, social networking through IoT is helpful in maintaining mental peace among transgender in the pandemic.

On ascertaining mental health of transgender people having smartphones vis-a-vis that of transgender people without smartphones, it was found that 75% of transgender people without smartphones were suffering from clinical depression. On the basis of their statement, it was clear enough that the void created due to the lack of social connectivity during the pandemic has pushed them toward depression. By contrast, it was observed that 20% of transgender people with smartphones were suffering from clinical depression. This significant difference can be associated with the benefits of having a smartphone that facilitates virtual social ties and maintains mutual support amid the COVID-19 pandemic.

20.5 Conclusion

The longevity of the COVID-19 pandemic situation is unpredictable and uncertain. Social distancing and good hygiene are the only possible ways to check the spread of coronavirus infection till the discovery of vaccination. Unfortunately, majority of the transgender community are solely dependent on social interaction for their daily bread and butter. The nationwide lockdown has left them jobless and penniless too. This grim situation has adversely affected not just their financial standards but also their mental health. Lost livelihood resulting in clogged income stream has financially and morally shattered them. Empty minds and hands have subjected them to stress, trauma, frustration, anxiety, depression, and other psychological disorders. Social networking through IoT devices has been very helpful in maintaining their mental healthcare by engaging them in different entertainment platforms, motivating them to fight against the novel coronavirus in this grim situation, creating awareness regarding the new government schemes, eliminating ignorance about the uncertainty arising from the COVID-19 pandemic, visually connecting them with peers and family, and making new friends who can give advice regarding their persisting problems and many others. Although social media can never be a replacement for real-world human connection, social networking through online platforms has the potential to alleviate their stress, anxiety, and depression, boost their self-worth, and make them happy and healthier by facilitating connectivity and engaging their minds in different informative and entertaining activities.

In the online world, relationships are ethereal, but no less important: people can take care of others, offer and receive help, reinforce self-esteem, and find solutions to intimate problems and difficulties that are part of their everyday life (Cipolletta et al. 2017; Cipolletta and Mocellin 2017). Online communication can encourage people to confess their secrets and their most intimate thoughts to other people (Greene 2006; Faccio et al. 2011). Internet-based behavior is characterized by a high level of self-disclosure (Boase et al. 2006). Therefore, it is possible to see how the online environment can be used to establish and maintain social ties.

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Technology Acceptance Using COVID-19 Pandemic: Case Study of Health Sector in India

21

Seema Sahai, Richa Goel, Mashiur Rahman, and Sachi Nandan Mohanty

Abstract

The world has experienced a seismic shift in the last 2 months in terms of the needs of organizations, and workers have shifted drastically almost overnight. Challenges emerging from the dissemination of the latest coronavirus (COVID-19) will speed up the use of existing technology and experimental devices. In many healthcare systems, accelerated scale up of the Internet of Things (IoT) technologies recently received many opportunities. However, there is concern about the degree to which patients use IoT technology. The lack of consumer approval is known as a barrier to the adoption of modern technologies. It is important to identify the factors affecting IoT adoption. Consumers can be more wanting but less likely to use successful technical approaches to assist their everyday activities such as shopping, online health consulting and shopping medicines online. This process may be a completely new activity for certain customers (e.g. first online grocery shopping) although it may mean wider use of web or modern technologies, and resources and applications for others. This research was aimed at analysing the contributing factors to the use of technology by people during the COVID-19 pandemic. The study showed four key aspects, which are performance expectancy (PE), effort expectancy (EE), trust (T) and

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perceived risk (PR) that have a substantial and optimistic impact on users' intentions to use online technologies.

Keywords

IoT · Pandemic · Performance expectancy (PE) · Effort expectancy (EE) · Trust (T) and Perceived risk (PR)

21.1 Introduction

A new strain of coronavirus, called COVID-19 disease, has emerged in 2020 leading to a global crisis. Most countries around the world are affected by the disease (World Health Organization 2020). Data on August 28, 2020, show that more than 24,662,000 people worldwide have been affected, leading to the death of more than 836,346 people, and created a lot of damage. India has about 3,392,295 active cases and 61,725 deaths, third highest of infected population in the world (July 2020). The World Health Organization, despite its inability to reach places where the epidemic has spread, has provided guidelines and strategies to prevent illness and contamination. Therefore, interaction between people and others is prevented, especially those at risk of infection (World Health Organization 2020). Countries have taken various steps to combat the COVID-19 epidemic. Staying at home and maintaining social distancing are the important significant steps. Such steps have contributed to different modes of employment. There are also travel restrictions. Inland and international exchanges have now evolved into electronic trading. So what's wrong? Is the delivery of goods or logistics, which are a vital part of people's life, responsible for the spread of the disease? India is one of the countries that have an epidemic of this disease. The Indian government has implemented various measures to effectively control the disease. Overall, India has a high number of people infected with a medium mortality rate (Figs. 21.1 and 21.2).

The Indian Government has already declared that the people of the country will stay at home, stop visiting friends and family, work from home, avoid joining groups and avoid all social meetings to prevent the spread of COVID-19 between people. All education institutions in India also participate in this initiative. In order to conform with the government policy of social distancing and self-quarantine, schooling in India must take place online. This resulted in students interacting and studying online during the lockdown period as per rules laid out by the government. Coronavirus outbreak 2019 (short: COVID-19) unexpectedly forces millions of people to work at home. With a wide variety of technology available, many workers must first use conference tools, teachers must create and generate online seminars and psychologists may start treating patients online. This is without a long duration of preparation and without a seamless transition. A big technical factor has arisen with a new way of operating with a massive bang. Some workers use these new technologies easily and some fail for a variety of reasons or even hate technical use because of other concerns.

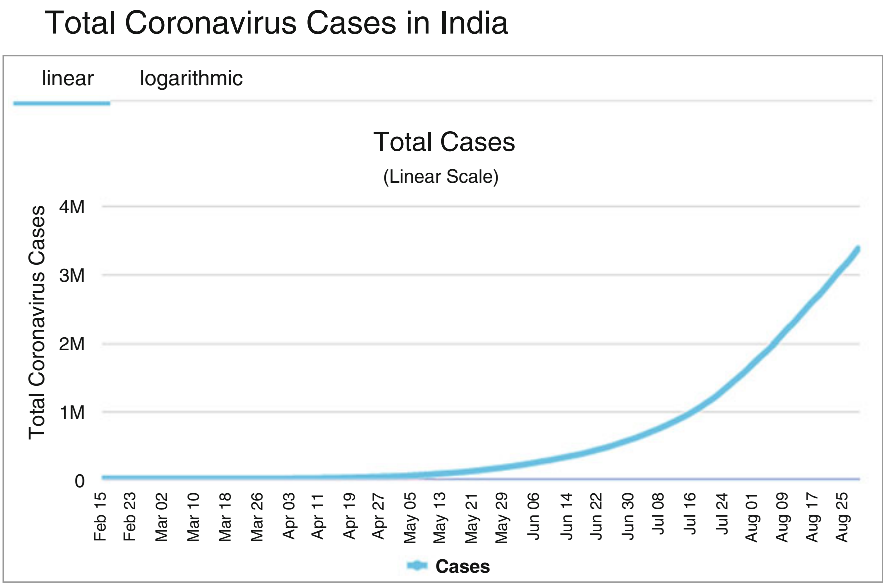

Fig. 21.1 Overall COVID-19 cases in India

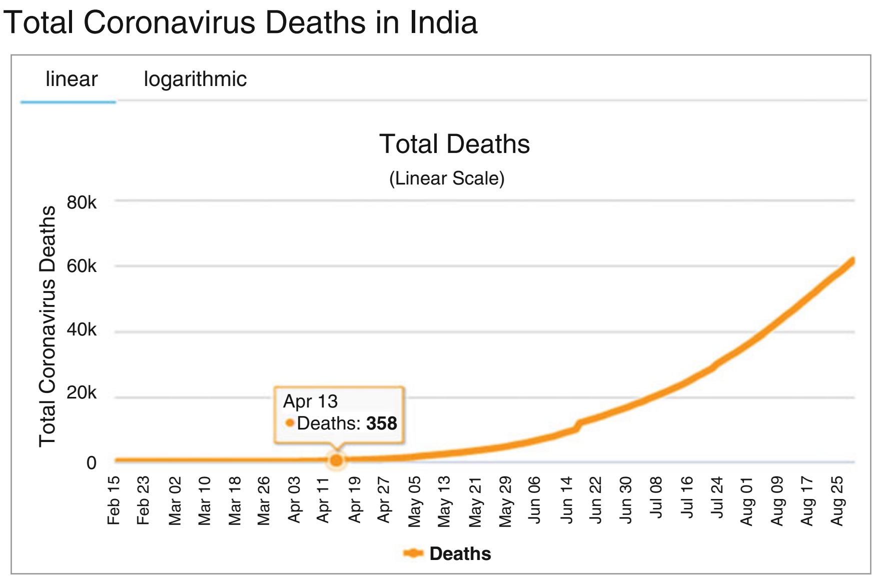

Fig. 21.2 Overall COVID-19 deaths in India

However, do they have a choice? Managers pursue effective management approaches, initiatives, modes of teamwork and help systems that allow workers to take up and implement accessible technology within (or across) the organization. In addition, organizations are increasingly beginning processes for the procurement of (additional) devices, whether it applies to electronic research applications in educational establishments or simulated meetings consistent with therapeutic institutions' privacy laws, to promoting these different directions in which they operate.

There is no question that the economic success of many companies will rely over the coming months primarily on how well workers embrace these emerging innovations and use them. The problem arises: what do we know about the adoption and application of emerging technology by scientific research? Or how can such aspects be affected? The need to learn to use more technology online or to continue learning how to connect electronically because people have never used such devices is a main problem emerging from quarantine at home or from home. The study showed that there were many innovations to be learnt by the public, such as Google Meet, Zoom and Microsoft Teams training, entertainment and leisure services such as internet videos, VDO cutting, photo editors, film makers; LINE party, Facebook group, WhatsApp informal networking systems; financial services such as mobile banking; and shopping for private companies and other industries (Fig. 21.3).

The study suggests that technological use will certainly be seen in other fields more often. However, there is also little strong evidence as to how people use more equipment or services during quarantine illness. New innovations are being used for promoting a global public health response to COVID-19, including population screening, case recognition, touch recording and action assessment focused on accessibility data and public communication. The future of public health will eventually become increasingly digital, and approaches for managing, analysing and leveraging emerging technology to improve the situation surrounding the pandemic and future preparation for COVID-19 and other infectious diseases should be developed. These fast responses exploit the millions of mobile phones, vast electronic data sets, smart computers, and fairly low-cost computing services. The number of calls from patients wishing to chat with their doctors about potential signs of COVID-19 has been swamped following the coronavirus outbreak. Some hospital programs use self-testing services to help patients track conditions before calling for a doctor. The Washington State's Providence Wellness, ground zero for the pandemic in the United States, has reconfigured the Grace talk with FAQs and COVID-19 symptom evaluations.

Pharmacy providing services at home has been popular as a customer responsive to hospital admission, home care facilities have shot up across the whole treatment cycle: diagnosis, diagnostics and medical care. The study entitled 'Changed patient expectations in healthcare services: the effects of COVID-19' said that social isolation with a fear-led mentality resulted in the attraction of the customer to electronic appointments rather than in-person encounters. You expect that the healthcare providers will make complying with safety standards a priority. Telemedical demand is projected to grow because of a growing customer desire for quick consultation to reduce traffic and time to wait.

Fig. 21.3 Use of mobile apps

The effect of COVID-19 on our culture and our economy remains unparalleled. There is also clear evidence that other devices will be adopted more quickly in the coming years, as people become more technologically conscious as they embrace technology at home. The invention allows us to accomplish the extraordinary steps adopted in response to the worldwide COVID-19 pandemic, and it is clear. Currently, throughout the world, updates and the use of networking software such as Zoom, Microsoft Teams and Slack have drastically improved and allow businesses to maintain order and stability.

Around the same time given physical separation in many ways, social media and video calling systems such as FaceTime allow families to remain together. In addition to the same subject, video streaming services deliver some entertainment and a welcome break from the news. Increasingly, research is helping to deter the further dissemination of COVID-19 and treating sadly infected people as well. IoT has been used since the crisis in a wide variety of applications, especially when paired with other transformational technologies such as cloud and AI.

Consumers who use technology in order to keep themselves updated and to maintain their well-being are confident and can trust technology in times of uncertainty. Advances in the use of technology will start with simple smartphone features such as product discovery and mobile payments. With this method increasing ease, further advances such as auto-downloads and personalized position warnings shift the way customers purchase more sophisticated instruments such as A/VR and increase the acceptance route. And these are starting to grow. Technology will be one of the most significant game changers in the immediate and longer term.

The research aims to study the usage of technology in the homes of Indians who are quarantined due to the pandemic. It also looks at the responses of different age groups on use of technology. Also, this research should examine the acceptance of technology and the behaviour of Indians in quarantine and examine factors influencing their intention to use these technologies, including the factors impacting the technology usage and programs in the study.

The study showed four key variables, which are performance expectancy (PE), effort expectancy (EE), trust (T) and perceived risk (PR) that play a substantial and optimistic impact on users' intentions to use online technologies. It is also suggested that the practical and real use of technology under quarantine was positively affected by behavioural intent.

The chapter is grounded on the Unified Theory of Acceptance and Use of Technology (UTAUT) model, in which researchers have inserted major variables in the fundamental model for the greater benefit of this analysis and for a better understanding of variables touching the use and application of new technology by Indian citizens.

UTAUT is a hypothesis that is logical to investigate the recognition and usage of IoTs as it allows one to analyse the factors. The UTAUT is one paradigm that also explores the reception and implementation of information technology. In 2003, Venkatesh et al. (2003) suggested UTAUT on the basis of an analysis of experimental models and other literature on development adoption and its predictors. The UTAUT is a common platform for work on technology adoption and use. It is a well-known hypothesis that was subsequently extensively evaluated in different contexts. The central concept is to make the behavioural intent of a method or technique embrace and use a variety of variables, while this behavioural intention, combined with the ease of use, contributes this structure (Sykes et al. 2009).

21.2 Contribution of the Study

The study contributes a lot to the Indian economy. Primarily, it is intended to provide and acknowledge statistical proof of the decision by Indians during the COVID-19 period to use the device. Second, the research will increase people's understanding of the decision to use innovations which are influenced by five key factors: social influence, facilitating conditions, T, PE, EE, and then advice is offered to an entire economy as a suitable method to forecast the decision of people to use technology to keep pace with the increasing market speed to earn incomes and improve incomes. The main variables of this research include T and PR to increase the UTAUT model.

The researchers intended to examine the effect of T and PR on the desire of Indians to use technology.

21.2.1 Objective Analysis

1. To study the volume of usage of technology or programs of Indians who are under home quarantine.
2. To study the increasing use of technology and programs used by Indians in each age group during home quarantine.
3. To study the factors affecting user intention to accept those technologies and programs.
4. To study the influence of user intention and facilitating conditions on the use of those technologies or programs.

21.2.2 Research Questions

Four key concerns were discussed for the sake of this study.

1. What is the degree to which people believe that using IoT will enhance learning and research?
2. To what extent do people perceive the IoT as relatively difficult to use?
3. To what extent do peers, colleagues and society influence other people's intention to use IoT?
4. How does technological assistance impact the use of IoT by people?

21.2.3 Recent Research

The researchers studied literature and previous research from multiple databases in order to consider creating a conceptual framework of research that is new and different from other researches, including to be suitable for studies in Indian context.

21.3 Related Literature and Previous Studies

21.3.1 Performance Expectancy

Performance expectation is here described as 'the degree to which an individual assumes that a program is going to allow them to achieve job performance gains' (Venkatesh et al. 2003: 447). Previous work indicates that the most important predictors of behavioural intent are success expectation and its associated mechanisms (Duyck et al. 2010). For example, Davis (1989) notes that the degree to which people assume that a given request would allow them to carry out their job better decides whether or not to apply.

Venkatesh and Speier (1999) also agree that technology inspiration is important in producing appreciated outcomes, including better pay and increased work efficiency. In the case of open data, it may make it more likely that people will use conventional working practices if they feel that open data technology and software would not help them perform more or gain more income. This theory is backed up by Helleman et al. (2014) suggesting that businesses rely primarily on open-ended data because there may be many difficulties, including hindered usability and the absence of consistency of open data provision. For example, a lack of user-friendly application opening interfaces is expected to deter open data users (Martin 2014). As a consequence, the nature and type of the use of data for different actors participating in open data can vary greatly (Hunnius and Krieger 2014). The success goal thereby explicitly and strongly affected the purpose of adopting and embracing open data technology.

There have been several empirical issues related to the relationship between success standards and the ability to use emerging technology or their practical usage in healthcare settings. Research carried out around the world includes different methods or technologies, from electronic medical records to robotic surgery.

21.3.2 Effort Expectancy

Expectation of effort was described in the sense of ease of using technology (Venkatesh et al. 2012) and recognized as a crucial indicator of the user's behavioural intentions (Wong et al. 2015). Wong et al. (2015) showed that technology usability has had a big impact on its adoption as less effort is expected of us. Prior research showed that interventions play a significant role in assessing personal intent to use technologies and real application. There is also a crucial factor in the assessment of consumer intent to use such technologies, owing to the unique existence of technologies needing a degree of experience and skill (Wong et al. 2015). Many scholars across the related interest spectrum have confirmed the impact of commitment perceptions on customers' decision to use online platforms (Alalwan et al. 2016). The early experiments (Arman and Hartati 2016; Jahanbakhsh et al. 2018) frequently indicate a beneficial impact on the behavioural purpose for using as well as on the actual application of a strategy or technology. Most scholars have found evidence for this relationship, but others have argued that there is no major contribution on EE (Arman and Hartati 2016).

21.3.3 Social Influence

The third factor of the behavioural intention to use the technology is based on the UTAUT effect of 'this degree to which a person perceives significant others to suggest using the new method' (Venkatesh et al. 2003: 451). Social effect involves three concepts: subjective norm, social influences and image—of these, definitions apply to the idea of a significant effect on how people behave in the social world (Venkatesh et al. 2003). In the TRA (Ajzen and Fishbein 1977), a descriptive form has been adopted and (Ajzen 1985) is included in its C-TAM-TPB (Taylor and Todd 1995). The Technology Acceptance Model (TAM) (Venkatesh and Davis 2000) has been generalized with the addition of contextual expectations as an extra definition to forecast behavioural intent. Their latest concept was known as TAM2. The principle is clarified by the belief that others feel he or she can behave. It is necessary. Social factors are the internalization of culture and social relationships, which a person shares with others as the second definition incorporated into social impact (Venkatesh et al. 2003). Social considerations are a central component of the PC model (Venkatesh et al. 2003).

Social considerations are a central component of the computer usage paradigm (Thompson et al. 1991). The third term, photo, is incorporated into IDT and can be used to improve the appearance or social status of an individual with the use of a digital technology. On the basis of UTAUT, researchers also wish to explore the hypothesis that social impact influences the plan to use habits and real use of technology (Arman & Hartati), while some researchers find social influence to be the most promising indicator (Alaiad and Zhou 2014).

In fact, some studies have already dismissed the theory because the influence of social impact was overwhelming (Bennani and Oumlil 2013). The timing of the analysis is a potential reason for the absence of benefit. If improvements are only introduced, social impact cannot be important. Another possible factor is the personalities of the subjects. Individuals more positive and conditioned with social pressure are less powerful.

21.3.4 Basic Model of Acceptance and Use Behaviours

The UTAUT model is the basis of this research, and the methodological structure of this research is considered. The concept was developed from a large range of technologies, including TAM, TRA and TPB (Venkatesh et al. 2012). In 2003, this model was developed by Venkatesh, Morris, Davis and Davis who created numerous models that connected the adoption of technology and using behaviours from different viewpoint. This model consists of three key factors: PE, EE and social influence that influence the user intention to adopt technology and two key factors: user intention and facilitating conditions that affect the use behaviour of technology (Venkatesh et al. 2012). The main focus on behavioural intention was related to three factors that included PE, EE and social influence. Also, it uses key variables like gender, age and experience for the moderating influence of key factors on the intention of users in using online technology. From this model, PE means people believe that the use of technology can attain gain in the job performance (Venkatesh et al. 2012), while EE is the ease utilization of the technologies for people who expect to practice the technology (Venkatesh et al. 2012). Many studies support this stimulus of PE and EE on behavioural intention about technology use. Another key factor is social influence that reflects people are convinced by others who believe the benefit of technology use (Venkatesh et al. 2012). Also, it found that many previous studies confirmed the influence of social factors on the intention of users in using technology, but some studies found different results, where social factor did not influence behavioural intention. The UTAUT model reveals the direct effect of PE, EE and social factor on user intention to utilize the technologies (Venkatesh et al. 2012) while facilitating condition, which means organizational and technical support is needed for the technologies people use. However, some research showed that facilitating conditions did not influence technology use (Zhou et al. 2019). Finally, the UTAUT model reflects the relationship between behavioural intention and actual use. It reveals that the intention of users in using technology influences the actual use behaviour of technologies (Venkatesh et al. 2012). Previous research supports the effect of user intention on the use behaviour of technologies (Zhou et al. 2019).

The studies revealed that higher behavioural intention would turn to significant use of technologies (Zhou et al. 2019).

21.3.5 Extended Acceptance and Use Model

This pattern of technical adaptation research and use activity is popular in many academic and international aspects. Nevertheless, researchers are also actively refining the model, seeking to define or extend the technical or invention variables or influences (Alwahaishi and Snášel 2013). For example, some studies added T in the research model to investigate user trust-affected behavioural intention to use technology. However, some studies showed that T did not influence user intention (Lafraxo et al. 2018). Previous studies proved the impact of PR on user intention about technology use. Nevertheless, some studies found that PR did not influence behavioural intention (Lafraxo et al. 2018). Much research did the study on the influence of facilitating conditions on behavioural intention to utilize technology. Many studies summarized that facilitating condition influences the behavioural intention to adopt the technology. But some studies did not find the effect of facilitating condition on behavioural intention to technology use (Lafraxo et al. 2018).

Therefore, this research selected the key variables, including T and PR for improving the UTAUT model. The researchers intended to examine the effect of T and PR on the desire of consumers to use technology. The researchers have intended to investigate the link between easing and the purpose of the customer. Many prior experiments have shown different outcomes. Several experiments have not seen the moderating effect of PR on the interaction between anticipated results and consumer expectation although others have seen PRs negatively moderate that relationship (Chao 2019). One research concluded that PR was proven to have a moderating effect in the UTAUT model (Im et al. 2011). This work attempts to show the moderating impact on the study model of the PR.

21.4 The Proposed Study

From the literature review related to this research, the researchers created a conceptual framework of the research as shown in Fig. 21.4, and the researcher determined ten hypotheses for statistical testing (H1–H10).

21.4.1 Hypothesis Development

H1: PE significantly influences user intention in using online technology.
H2: EE significantly influences user intention in using online technology.
H3: Social influence significantly influences user intention in using online technology.
H4: User intention significantly influences use behaviour.
H5: Facilitating condition positively influences use behaviour.
H6: Facilitating condition positively influences user intention in using online technology.
H7: T significantly influences user intention in using online technology.
H8: PR significantly influences user intention in using online technology.

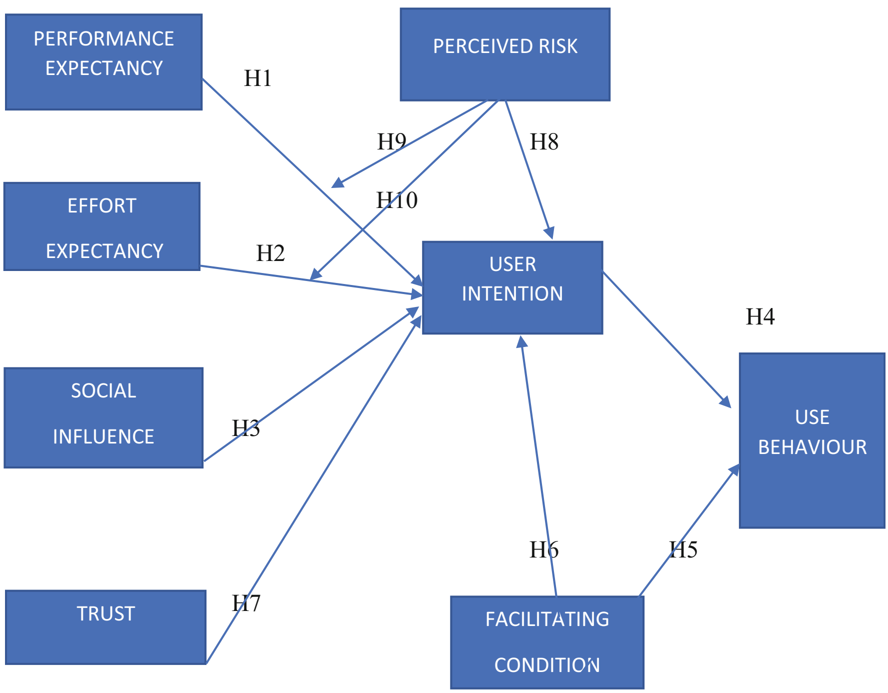

Fig. 21.4 Model framework. (Source: Researcher's own contribution)

H9: The effect of PE on user intention is moderated by PR.
H10: The effect of EE on user intention is moderated by PR.

21.5 Research Methodology

21.5.1 Population and Sample

Indians remaining at home during the time of quarantine during the COVID-19 crisis were the subject of the study. The authors also estimated the number at the confidence level and error rate of 95% and 5%, respectively; the optimal range size was 560. The authors used the Cronbach method for the estimation of the optimal sample count.

21.5.2 Research Tool

The author developed a structured questionnaire from previous research that relates to the UTAUT model (Table 21.1). It consisted of three parts. The first part was for demographic data (gender, age, education, income and occupation), the second part was behavioural use in technology or programs during COVID-19 situation and the final part was about key variables in the research framework including PE, EE, social influence, T, PR, facilitating conditions, user intention in using online technology and use behaviour of the technology. The questionnaire used five points scale (totally disagree = 1 to totally agree = 5) to measure the key variables in this research. Cronbach's alpha statistic was used for questionnaire reliability. The results were between 0.77 and 0.95 as shown in Table 21.3. This indicated that there was acceptable reliability (Hair et al. 2014).

21.6 Data Analysis and Discussion

See Tables 21.2, 21.3, and 21.4.

21.6.1 Hypothesis Testing

H1: PE significantly influences user intention in using online technology (Table 21.5).

The above table shows that the regression equation can be presented as user intention = 1.337 + 0.690 *PE. This indicates there is a strong positive relation between user intention in using online technology and PE and further paves the path to accept that PE significantly influences user intention in using online technology.

Table 21.1 Description of UTAUT variables and models derived from them

Constructs	Description of perception	Measures
Performance expectancy	The level to which someone expects the framework to help them make work efficiency improvements	PE1—perceived usefulness PE2—perceived effectiveness PE3—meeting needs PE4—motivates you PE5—fits in your job
Effort expectancy	The extent of ease of use of the device	EE1—easy to use EE2—use this technology by yourself EE3—less time to learn this technology EE4—does not require technical expertise EE5—easily access electronic information
Social influence	The extent to which a person acknowledges that others think he or she can use the new systems	SI1—some friends use it SI2—it has a well-known reputation SI3—people who are important to me (e.g. family, friends) think that I should use this technology SI4—people who influence my behaviour think that I should use this technology
Trust	The degree to which an individual lays trust and faith on the use of new technology or system	T1—technology provider is honest T2—quality of this technology T3—protects your job T4—cyber cell machinery, grievances related
Perceived risk	The degree to which the consumer calculates the risk associated with the use of new technology	PR1—(security breach) PR2—(unauthorized access) PR3—data loss PR4—legal implications
Facilitating conditions	Consider customer expectations of the available tools and encouragement for (Venkatesh et al. 2003) behaviour	FC1—recommends and supports usage FC2—assistance when problems occur FC3—compatible with other systems FC4—improves ICT skills effective use FC5—resources to use the ICT system
User intention in using online technology	It refers to the degree to which the user feels comfortable to use this technology and tries to accept it	UI1—technology is interesting UI2—you will use this technology more UI3—my research and other activities do not require me to use this technology UI4—though this technology is

(continued)

Table 21.1 (continued)

Constructs	Description of perception	Measures
		useful, it is not compulsory for me to use
Use behaviour of the technology	How much technology a person actually uses	UB1—enhances work efficiency or QOL UB2—technology consistently UB3—open to learning this technology UB4—interesting as it takes less time UB5—use this technology in future also

Table 21.2 Demographic profile of respondents ($n = 380$)

Criteria	Demographic profile	Frequency	Percentage
Gender	Male	271	69.5
	Female	119	30.5
Marital status	Married	216	55.4
	Unmarried	174	44.6
Age group	18–25 years	152	39.0
	26–35 years	171	43.8
	36–45 years	38	9.7
	Above 45 years	29	7.4

H2: EE significantly influences user intention in using online technology (Table 21.6).

The above table shows that the regression equation can be presented as user intention = 3.444 + 0.044* EE. This indicates there is a positive relation between user intention in using online technology and EE and further paves the path to accept that EE significantly influences user intention in using online technology.

H3: Social influence significantly influences user intention in using online technology (Table 21.7).

The above table shows that the regression equation can be presented as user intention = 3.673 + 0.096* social influence. This indicates there is a positive relation between user intention in using online technology and social influence and further paves the path to accept that social influence significantly influences user intention in using online technology.

Table 21.3 Overview of the constructs

Validity and reliability of the measurement model				
S. No.	Construct	No of items	Loading	Cronbach alpha
1	Performance expectancy	PE1—perceived usefulness	0.821	0.9
		PE2—perceived effectiveness	0.919	
		PE3—meeting needs	0.622	
		PE4—motivates you	0.931	
		PE5—fits in your job	0.892	
2	Effort expectancy	EE1—easy to use	0.939	0.947
		EE2—use this technology by yourself	0.914	
		EE3—less time to learn this technology	0.905	
		EE4—does not require technical expertise	0.912	
		EE5—easily access electronic information	0.874	
3	Social influence	SI1—some friends use it	0.805	0.826
		SI2—it has a well-known reputation	0.851	
		SI3—people who are important to me (e.g. family, friends) think that I should use this technology	0.779	
		SI4—people who influence my behaviour think that I should use this technology	0.798	
4	Trust	T1—technology provider is honest	0.845	0.774
		T2—quality of this technology	0.740	
		T3—protects your job	0.761	
		T4—cyber cell machinery, grievances related	0.738	

Table 21.4 Reliability of construct

S No.	Construct	No of items	Cronbach alpha
5	Perceived risk	04	0.757
6	Facilitating conditions	05	0.872
7	User intention in using online technology	04	0.781
8	Use behaviour of the technology	05	0.715

Table 21.5 Coefficients of UI and PE

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	Std. error	Beta		
1	(constant)	1.337	0.082		16.219	0.000
	PE	0.690	0.020	0.864	33.796	0.000

[a]Dependent variable: UI

Table 21.6 Coefficients of UI and EE

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	Std. error	Beta		
1	(constant)	3.444	0.150		22.962	0.000
	EE	0.044	0.042	0.053	1.048	0.295

[a]Dependent variable: UI

Table 21.7 Coefficients of UI and SI

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	Std. error	Beta		
1	(Constant)	3.673	0.127		28.829	0.000
	SI	0.096	0.035	0.139	2.765	0.006

[a]Dependent variable: UI

Table 21.8 Coefficients of UI and UB

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	Std. error	Beta		
1	(Constant)	4.068	0.182		22.396	0.000
	UI	0.049	0.048	0.051	1.013	0.311

[a]Dependent variable: UB

Table 21.9 Coefficients of UB and FC

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	Std. error	Beta		
1	(Constant)	4.151	0.139		29.914	0.000
	FC	0.024	0.034	0.037	0.727	0.468

[a]Dependent variable: UB

H4: User intention significantly influences use behaviour (Table 21.8).

The above table shows that the regression equation can be presented as user behaviour = 4.068 + 0.049* user intention. This indicates there is a positive relation between user intention in using online technology and user behaviour and further paves the path to accept that user intention in using online technology significantly influences user behaviour.

H5: Facilitating condition positively influences use behaviour (Table 21.9).

The above table shows that the regression equation can be presented as user behaviour = 4.151 + 0.024* facilitating condition. This indicates there is a positive

Table 21.10 Coefficients of UI and FC

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	Std. error	Beta		
1	(Constant)	3.809	0.198		19.213	0.000
	FC	0.051	0.048	0.054	1.062	0.289

[a]Dependent variable: UI

Table 21.11 Coefficients of UI and T

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	Std. error	Beta		
1	(Constant)	3.725	0.271		13.746	0.000
	T	0.063	0.067	0.048	0.948	0.344

[a]Dependent variable: UI

relation between facilitating condition and user behaviour and further paves the path to accept that facilitating condition significantly influences user behaviour.

H6: Facilitating condition positively influences user intention in using online technology (Table 21.10).

The above table shows that the regression equation can be presented as user intention = 3.809 + 0.051* facilitating condition. This indicates there is a positive relation between user intention in using online technology and facilitating condition and further paves the path to accept that facilitating condition positively influences user intention in using online technology.

H7: T significantly influences user intention in using online technology (Table 21.11).

The above table shows that the regression equation can be presented as user intention = 3.725 + 0.063* T. This indicates there is a positive relation between user intention in using online technology and T and further paves the path to accept that T significantly influences user intention in using online technology.

H8: PR significantly influences user intention in using online technology (Table 21.12).

The above table shows that the regression equation can be presented as user intention = 4.187–0.029* PR. This indicates there is a negative relation between

Table 21.12 Coefficients of UI and PR

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
1	(Constant)	4.187	0.140		29.809	0.000
	PR	−0.029	0.037	−0.039	−0.768	0.443

[a]Dependent variable: UI

Table 21.13 Coefficients of UI, PR and PE

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
1	(Constant)	1.384	0.109		12.673	0.000
	PR	−0.012	0.019	−0.017	−0.657	0.511
	PE	0.689	0.020	0.864	33.743	0.000

[a]Dependent variable: UI

user intention in using online technology and PR and further paves the path to accept that PR significantly influences user intention in using online technology.

H9: The effect of PE on user intention is moderated by PR.

This hypothesis has to be tested at two stages:

1. See the effect of PE on user intention without PR. This has been done by proving the first hypothesis.
2. See the effect of PE on user intention with PR (Table 21.13).

The above table shows that user intention decreases when PE is taken with PR. Therefore, to say that PR is a moderator is wrong.

H10: The effect of EE on user intention is moderated by PR.

This hypothesis also has to be tested at two stages:

1. See the effect of EE on user intention without PR. This has been done by proving the second hypothesis.
2. See the effect of EE on user intention with PR (Table 21.14).

The above table shows that user intention increases significantly when EE is taken with PR. Therefore, to say that PR is a moderator is correct (Table 21.15).

Table 21.14 Coefficients of UI, EE and PR

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
1	(Constant)	2.945	0.235		12.518	0.000
	PR	0.140	0.051	0.138	2.740	0.006
	EE	0.039	0.041	0.048	0.945	0.345

[a]Dependent variable: UI

Table 21.15 Overview of the hypothesis

Hypothesis no.	Hypothesis	Supported/not supported
1	H1: PE significantly influences user intention in using online technology	Supported
2	H2: EE significantly influences user intention in using online technology	Supported
3	H3: Social influence significantly influences user intention in using online technology	Supported
4	H4: User intention significantly influences use behaviour	Supported
5	H5: Facilitating condition positively influences use behaviour	Supported
6	H6: Facilitating condition positively influences user intention in using online technology	Supported
7	H7: T significantly influences user intention in using online technology	Supported
8	H8: PR significantly influences user intention in using online technology	Supported
9	H9: The effect of PE on user intention is moderated by PR	Not supported
10	H10: The effect of EE on user intention is moderated by PR	Supported

21.7 Conclusion and Recommendation for Further Research

As per analysis, all the hypotheses are supported, except the one which states that PR is a moderator to user intention when PE is taken.

The first research question is answered by the first hypothesis, which states that PE significantly influences user intention in using online technology. Therefore, it can be said that people believe that IoT will enhance learning and research.

The sixth hypothesis supports the second research question, which states that facilitating conditions positively influence user intention in using online technology. This shows the necessity of facilitating conditions.

The third hypothesis supports the third research question by stating that social influence significantly influences user intention in using online technology.

The fourth research question is again supported by the fifth hypothesis, which states that facilitating condition positively influences use behaviour.

For further research, the same study can be done in semi-urban and rural areas. Also effect of income can be studied.

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Artificial Intelligence: The Strategies Used in COVID-19 for Diagnosis

22

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Abstract

Artificial Intelligence (AI) is a dynamic tool to struggle against the COVID-19 pandemic. It has been broadly employed in our daily lives diversely. As the epidemic prevalence of the pandemic there has been a utility of AI. Due to the expansion of the Corona virus syndrome (COVID-19) Nationwide revealed vulnerability of healthcare and public health vigilance to plan against outbreak/ pandemics. The aid of new technologies is battling as well as look further on in opposition to the new diseases. Here the functionality of AI comes as a significant technology to explore, set up us for prevention and battle against COVID-19 (Corona virus) and other pandemics. For treatment and medical diagnosis there is a community outbreak phenomenon and the research reports that the majority cases to keep asymptomatic. In the areas especially where AI act as a vital component from medical image processing, data analytics, to the analysis of environmental science and therapeutic. This is the study for the AI researchers and the broader community the present status of AI applications as well as encourage us to connect with the new technologies in this pandemic situation. In this chapter to fight against the virus by using Artificial Intelligence methods namely Extreme Learning Machine and Long /Short Term Memory (LSTM) of Deep Learning have been emphasized. It is a kind of pathway to put collectively the data which may be structured as well as unstructured data to provide accessible platform for the benefits of the researchers. This helps to diagnosis the diseases.

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Keywords

Public health · COVID-19 · Epidemics · ELM

22.1 Introduction

In Corona virus syndrome there are so many confirmed cases and caused death while entangle life in countries and province around the globe (World Health Organization 2020a). The numbers are increasing day by day. Due to non-vaccination and non-cure lessen the extend by taking appropriate measures and separating that contaminated people in a disconnect zone is the only effectual resistance for the humankind against this unpredictable situation. Due to this pandemic outbreak a strategy must be employed to test the portion of the populations those who are not yet been included in the medical system. In the recent studies some measures have been taken for the benefits of the nations. As the pandemic outbreak is effectively increasing so some of the approaches was not working in appropriate manner (BBC 2020). In current learning it is been envisaged that coughing virus is now scattering in the areas where the population had been not diagnosed (Science 2020). As per the data it has been visualize that the persons who are the carrier of COVID-19 don't have any severe symptoms but they are the reason for spreading (National Institute of Health 2020a).The severe effected one has to undergo on the medical treatment after being infected. For this a new strategy has been imposed to grant proactive measures for the isolated tested positive so that no further spreading. Reverse Transcription Polymerase Chain Reaction can be employed for the authentication of COVID-19 thereby tracking the virus. The test for this kind of cases is too costly as well as insufficient to cover up the disease. It is not a big problem to identify the cases in the countries which cannot afford as well as an issue in rich countries also. Though the major test is ultimately done consequently hospitals are filled to capacity, have to patience for the staff for the pharyngeal swab, as the virus is roaming in the rooms. To employ the platforms of AI helps to get desired outcomes. The chapter focuses on COVID-19 to highlight the strategies which can be significant and helps to analysis. It also elaborates the potentiality and the gateway to overcome the challenges. This research chapter includes ANN to be implemented in big data analysis. On the other hand in Extreme Learning Machine the learning speed is quicker and gives better presentation. In other research ELM is being scrutinized with some architecture. So ELM can be suggested on that kind of problems where there is a barrier in cardiovascular systems because it can forecast the patterns of those systems.

22.2 Literature Review

Cough is an indication which states in the studies that most of the spreading is due to this symptom which is also a major issue of dispersal COVID-19 (Science 2020).

The spreading of droplet containing germ widely throughout an area through cough is a proactive issue in COVID-19 (National Institute of Health 2020a).

The analysis of the reports speaks that due to partial protection the medical staff is at risk position which causes the infection is spreading among them and the world are being specially the healthcare workers are affected by COVID-19 (The New York Times 2020a).

Food and Drug Administration had analyzed a testing strategy by which the results can be easily found (CNN 2020a).

To found the solution for the COVID-19 allied problem as well as to take corrective measures high awareness is needed. Though the rising growth of the number of data build up a challenge among the decision-makers.

There are some approaches which helps the testing procedure to be more effective, accurate reliable namely X-ray (Wang and Wong 2020). This is allied with the AI to make better results.

Nowadays Artificial Intelligence are being used in different fields to solve complicated problem And the researchers are also investigating different methodologies to resolve it (CNN 2020b).

The data scientists whose continuous research methodologies act as a vital role in the field of AI. With the help of their research plan as well as their knowledge is applicable in solving the problems (Naudé 2020).

In medical diagnosis to predict more accurate results based on the AI applications the graph of the productivity is on the increasing mode and to improve efficiency huge number of data (World Health Organization 2020b; Lakshmanaprabu et al. (2019)), is being involved to get the desired output (National Institute of Health 2020b).

It has been envisaged that for numerous respiratory diseases, cough plays a vital role and the researchers are analyzing the diagnosis system.

Some carriers are responsible for the spreading of the virus even if they are not tested but they are maintaining social distancing in the areas where they use to visit regularly for the commitment of their job (The New York Times 2020b).

A number of data analytics evaluated that cough from dissimilar respiratory pattern have different effect based upon their features. By applying suitable signal processing and some mathematical alteration the attributes of the cough sounds are extorted. So basically various sounds have a range of outcome.

22.3 Artificial Intelligence and COVID-19

Some AI-based approaches that are applying on the methods dealing with the concerned health care systems in these pandemic situations. These kinds of strategies are very helpful to diagnose the medical system procedure. So everyday there is a need of medical updates for the improvement on COVID-19. The innovative ideas have been employed to accelerate the ANN-based strategies for the betterment of the health care as well as to improve the treatment recognition procedure. The tool that has been used to visualize the effectiveness in this outbreak situation needs human

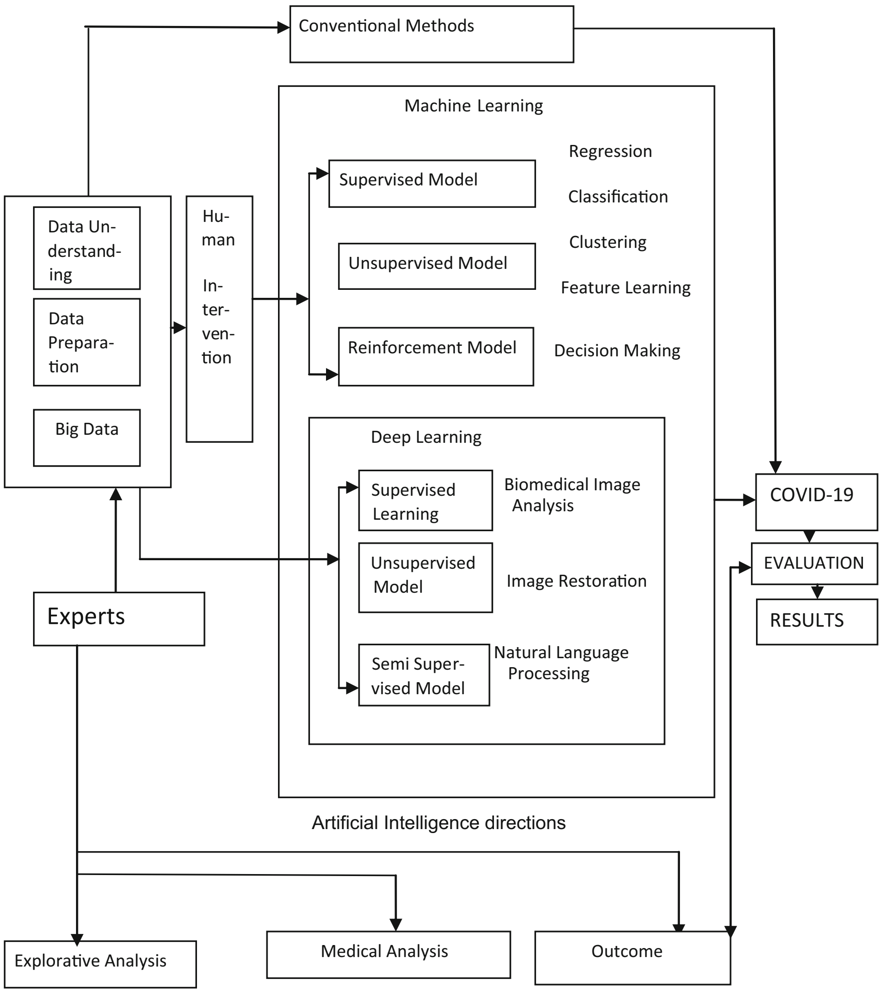

Fig. 22.1 The implementation of AI-based strategies

interaction and collaboration. The data scientists who are dealing with the code used in AI have the knowledge of the boundaries of AI as they are playing a vital role in this situation (Naudé 2020).

The flowchart in Fig. 22.1 is representing the different steps involved to prevail over the situation. The methods are being employed as a challenge for the prevention. The steps that were shown in the Fig. 22.1 describe the training of the data. To train the data during data understanding, data preparation and big data, data mining is the way for the processing. Here the information consists of the medical images, previous background, reports that are generated based on the data to be shared and other different sources that are to be understood in a proper format and an appropriate way should be defined by a machine. The information gathered in the data understanding includes large quantity of information to recapitulate the data and the variables that are to be employed within the data. Data preparation is the procedure which is responsible for purifying the raw data and need to be transformed in a way so that outcomes should be qualitative. This is the procedure which will take place earlier than processing. So tin this process information need to be accurate and collective to get the desired output. Involvement of data gathering evaluating and exploring includes medical data analysis, proper information of the patient, their physical health reports, collectively in big data. This is the phase where human interference needed for the genuine experiments, examination thoroughly and analyzing the data to be finest model, prototype and with the appropriate features. To do this suitable survey should be done.

The concept of Machine Learning deals with knowledge that is allied with huge quantity of data whereas human information is not enough to handle in an appropriate manner. In the contrary Deep learning deals with the data which are more complex Khadidos et al. (2020). Figure 22.1 illustrates that the procedure that are used by DL are not based on the human interference. Being the subset of ML, Deep Learning endow with the algorithms that are applicable for the data interpretation, DL differ from ML with respect to data. As it represents data in a way where there is an involvement of Artificial Neural Networks. But ML algorithms deals with structured data.

22.4 The Probable Stage to Accelerate Conventional Methods

It has been observed that keeping a track of the COVID-19 patients in the registry helps to identify the pattern of the cardiovascular complication where a risk is involved for the classification for those complications so that suitable predictive measures should be taken as well as various treatment policies need to be employed accordingly (Madjid et al. 2020; Satpathy et al. (2021)).

The process of application of AI-based methods to conquer challenges associated with COVID-19.

Figure 22.2 describes a model based on the learning strategy known as an Extreme Learning Machine which provides corrective drugs applied on those who are being involved in cardiovascular complications. To get the desired results this strategy and ANN model are being used on those examples. This includes training the model with the help of real data. This model is also called supervised model. So Extreme Learning Machine can propose a probable and a suitable drug for these kind of cardiac complications.

Heart failure is another kind of complication where the specialists are very much conscious for the treatment of those and they provide an appropriate design or a structured approach for these patients. Also algorithms should be developed for the betterment of their treatment. By proper investigation and examinations should be followed until reaching an appropriate stage (Cunningham et al. 2020).

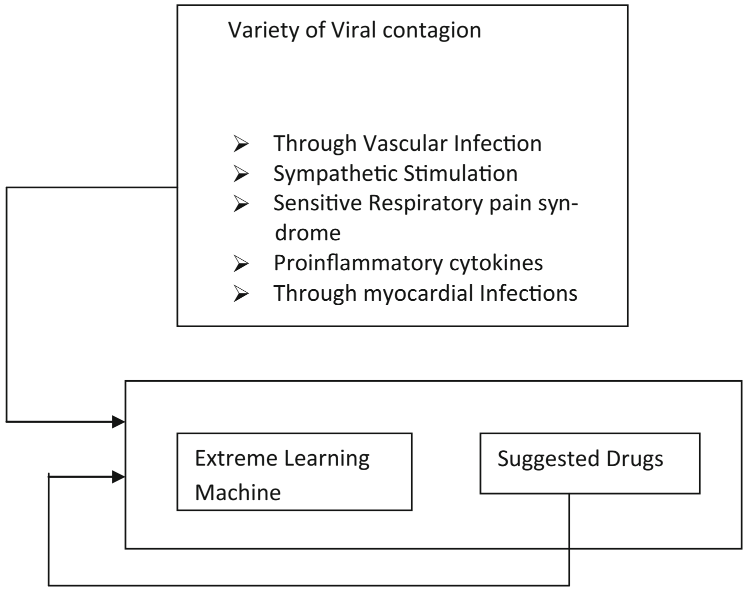

Fig. 22.2 The application of ELM model for the prediction of drugs

The use of fluid and drugs in an extreme manner may change the equilibrium state of salt and water among the patients. So patients should try to get rid of. The patients those are elder should take preventive procedures (Cunningham et al. 2020).

Long-/Short-Term Memory uses a model that has been depicted In Fig. 22.3 which basically depends on the inputs to be applied to get the possible outputs for the improvement of the treatment policy (Cunningham et al. 2020). Long /Short Term Memory is beneficial for learning systems for its long memory which provides an outline of unknown length.(Malhotra et al. 2015).

In health care system cough is a very common symptom caused by either viral respiratory contaminations or from bacterial infection which is apart from COVID-19 patients. Table 22.1 describes the reasons for causing cough. It has been observed that numerous non respiratory. Situations are the grounds for cough.

In Table 22.1, there are the symptoms that cause cough. To discriminate cough from these human ear is not the efficient easy to find out the appropriate reason. As there is no such proper features or by hearing cough sound is not possible to distinguish the COVID-19 patients. So there exists a risk factor in cough-related AI analysis tool which is illustrated in Table 22.1 to identify the patients. A proper AI algorithm should be designed to select the features to COVID-19 infection and a suitable AI diagnosis tool on the data.

The people who are affected by these kind of pandemic disease have the symptoms like fever, dry cough, problem in breathing have pulmonary pathological signs from the inception of COVID-19 (Tian et al. 2020).

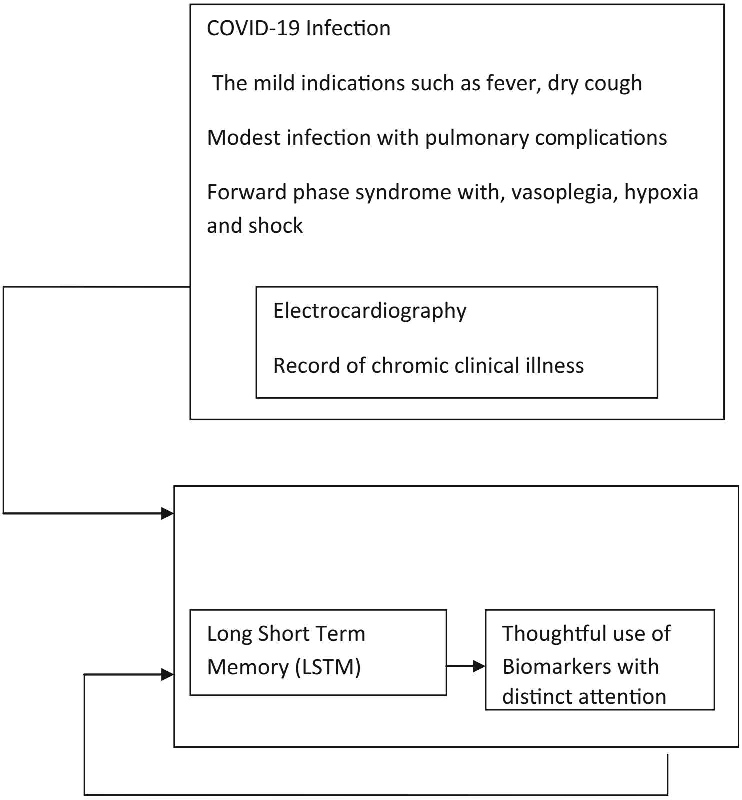

Fig. 22.3 Classifying the finest treatment technique through LSTM ANN method

Table 22.1 Non-COVID-19 medical circumstances causing by cough

Respiratory	Nonrespiratory
Upper airway cough syndrome	Vocal cord dysfunction
Asthma and allergies	Smoking
Laryngitis	Air pollutants
Pleural diseases	Left-ventricular failure

22.5 Conclusion

Different AI-based strategies have been used in the research areas which are appropriate for diagnosing the issues allied with COVID-19. The strategies which have been employed in COVID-19 issues are LSTM and ELM. For gaining desired outcomes these kinds of techniques have been used in diagnosing the systems. Obtaining fruitful results cost and time plays an important role in this outbreak situation. In the practical field it has been noticed that COVID-19 has an effect on the respiratory system which is a common symptom as well as cough is also linked with it. In the research areas it has been examined that the features related to cough is infectious and non-infectious both. The two sounds similar if accurate investigation is done. To overcome this pandemic situation, genuine experiments should take place to achieve the limitations and employing the human knowledge or the advantages for gaining a proper conclusion. Novel strategies should be sited for overcoming the difficulties. To save the lives and to protect the people against COVID-19, suitable strategies, methods, models should be used.

22.6 Future Scope

The technique that are used in this chapter are appropriate for the issues connected with COVID-19. Different strategies have been employed. Considering these kind of techniques which helps to expertise and to analyze the data. Some set of models can be applied to optimize the data for getting accurate results. The work can be extended using different modalities or various techniques for analyzing accurate and appropriate data which provides better outcomes.

Acknowledgments This effort of work is being devoted to those who are suffering with this epidemic disease in this outbreak situation.

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The Effect of Quarantine and Isolation on COVID-19 in General Population and Impact of Potential Role of Technology in Its Mitigation

23

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Abstract

Background and Aim: Ongoing COVID-19 is a new global threat to people globally. The outbreak of COVID-19 was first reported in China and it spreads throughout the globe within a very short span of time. It was declared a pandemic by the World Health Organization (WHO). It causes serious impact on lives, economy, and healthcare systems throughout the globe. The development and support of potent technologies like information communication (IT), Artificial Intelligence (AI), Machine Learning (ML), and Internet of Things (IoT) play a tremendous role in early detection, contact tracing, response and mitigation of the virus. This chapter reports on the impact of a few potent technologies on isolation and quarantine during the ongoing COVID-19 pandemic.

Methods: A broad literature survey was conducted using the database PubMed, Scopus, and Google scholars by using the code word COVID-19 and role of potent technologies to mitigate the virus and at the same time impact of technologies on isolation and quarantine.

Results: Herein, wish to provide a frame of opinions on review of the technology advances used to mitigate the virus. The role of isolation and quarantine is discuss. Though different studies relating to modern technology towards COVID-19 have come up, yet there are still constrained applications and contributions of technology in this fight.

Conclusions: The proper healthcare system are essential to mitigate the virus. These potent technologies make significant contribution to the healthcare system to control the spread of the virus and also provide better health protection. These

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technologies will definitely aid to keep a systematic record on conformation and better medical management.

Keywords

Covid-19 · Isolation · Quarantine · Technology · Mitigation · Information technology

23.1 Introduction

The novel coronavirus disease (COVID-19) was first reported in Wuhan City, Hubei Province of China in December 2019 (Anderson et al. 2020; Backer et al. 2020). In December 2019, a series of cases suffering from pneumonia of unknown origin were reported, which caused global attention. The virus belongs to a class of Betacoronavirus, such as Middle East respiratory syndrome coronavirus (MERS-COV) and severe acute respiratory syndrome coronavirus (SARS-COV). Within a few weeks, it spread throughout the globe, and on 30 January 2020, the World Health Organization (WHO) announced the outbreak as a public health emergency of international concern (PHEIC) and later, on 11 March 2020, it was declared as a pandemic (Prompetchara et al. 2020; Rothan and Byrareddy 2020; World Health Organization 2020a, b). On the other hand, it is well known as a zoonotic disease. It spread over countries and continents within a short period due to highest commercial air travels from Wuhan (Bogoch et al. 2020; Haleem et al. 2020). According to data provided by the WHO, it is found that on 5 July 2020, 11,125,245 people were infected. On the other hand, it is found that around 528,204 deaths were due to COVID-19 in the world. The spread of the virus is due to frequent contact with each other. Based on the fatality rate, it is much lower (near about 3.44%) than SARS-COV in 2002–2003 (34.4%) and MERS-COV in 2012–2013 (9.19%), but the number of infected rate is very high (Mahase 2020). It is very harmful due to its rapid spread through droplets or aerosols that can linger in the air (Lai et al. 2020). It is very difficult to detect the virus. On the other hand, the transmission of the virus is very high in the early phase of illness and also in case of asymptomatic patients (Wilder-Smith et al. 2005; Rothe et al. 2020) (Fig. 23.1).

To encounter the situation, healthcare systems have put tremendous efforts in treating the infected individuals and also in testing the public for COVID-19 infection. Governments are doing their best to mitigate the infection and also to meet the requirements for the healthcare system. Moreover, unfortunately, there is neither a medicine for its cure nor a vaccine for the prevention of this novel coronavirus. However, countries have been trying various treatment methods and usage of different suitable medicines without proper confirmation. Based on past experience of various epidemics and pandemics as well as the current COVID-19 outbreak, the WHO suggested frequent hand washing with soap and water or an alcohol-based hand rub, avoiding touching eye, nose, and mouth, and practicing respiratory hygiene as shown in Fig. 23.2. Apart from that, face masks play a

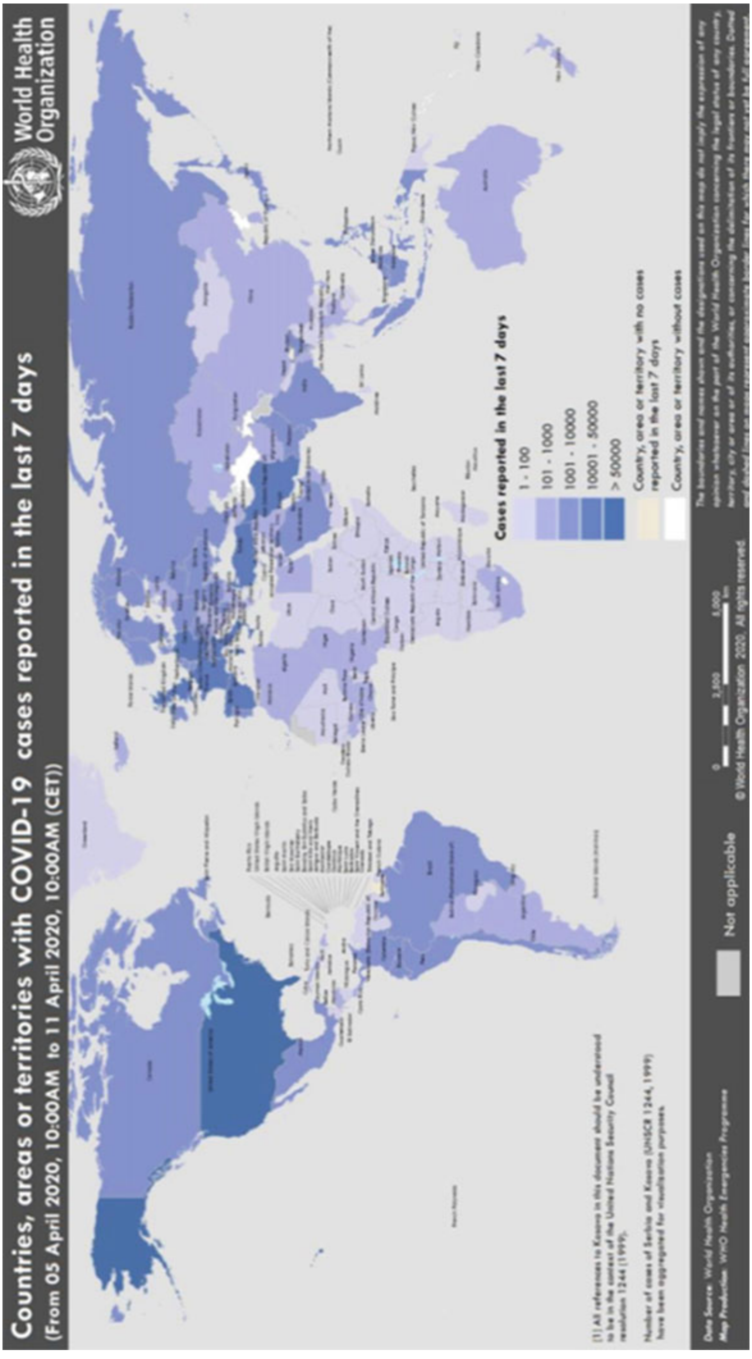

Fig. 23.1 Countries and territories with COVID-19 cases

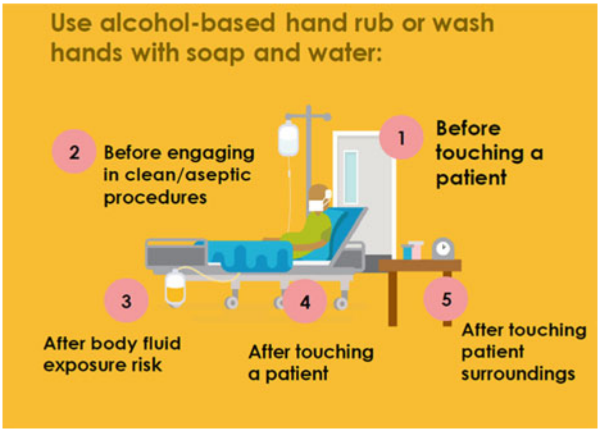

Fig. 23.2 Five moments of hand hygiene for people and health workers

tremendous role in preventing infection, and it is very important to know how and when to properly use face masks (WHO 2020). On the other hand, the spread of infection and contaminant can be reduced by maintaining social distancing, avoiding social gathering, staying at home, detection of infected patients, early tracing of positive cases, isolation, and quarantining who might have been exposed to the virus. As a result, it is necessary for people to take care of their own health during the pandemic. Hence, in day-to-day life, social distancing, isolation, and quarantine should be strictly observed to stop the spread of infection and contaminant (Centers for Disease Control and Prevention 2020; Zandifar and Badrfam 2020; Bai et al. 2020). Apart from that, the use of strong technologies along with active healthcare treatment and strong governance can help to fight against COVID-19.

Nowadays, technology has enabled humans to live at ease. It plays a significant role in advancing health care, education, communication, etc. During COVID-19, it also plays a tremendous role to support humanity (Wan et al. 2019; Madurai Elavarasan and Pugazhendhi 2020). The healthcare system has made a significant contribution to reduce the infection. The novel technology, government, and the public also plays a major role in providing proper health care (Akram 2020) as shown in Fig. 23.3. Fighting against novel coronavirus, technology has a direct and/or indirect impact on controlling infection. Technology helps the healthcare system directly to mitigate the spread of the virus and indirectly it helps the government and the public about how to deal with the virus. This section reports on the impact of isolation and quarantine and the role of potential technologies to mitigate the spread of the virus.

23.2 Impact on Social Alternation on COVID-19

Several countries and continents have implemented various polices based on the population structure as well as the guidance of healthcare organization. It is devised that due to lack of resist power of old age people, people suffering with cold, cough, diabetes are highly transmittable nature of the novel virus, affected 40–70% of

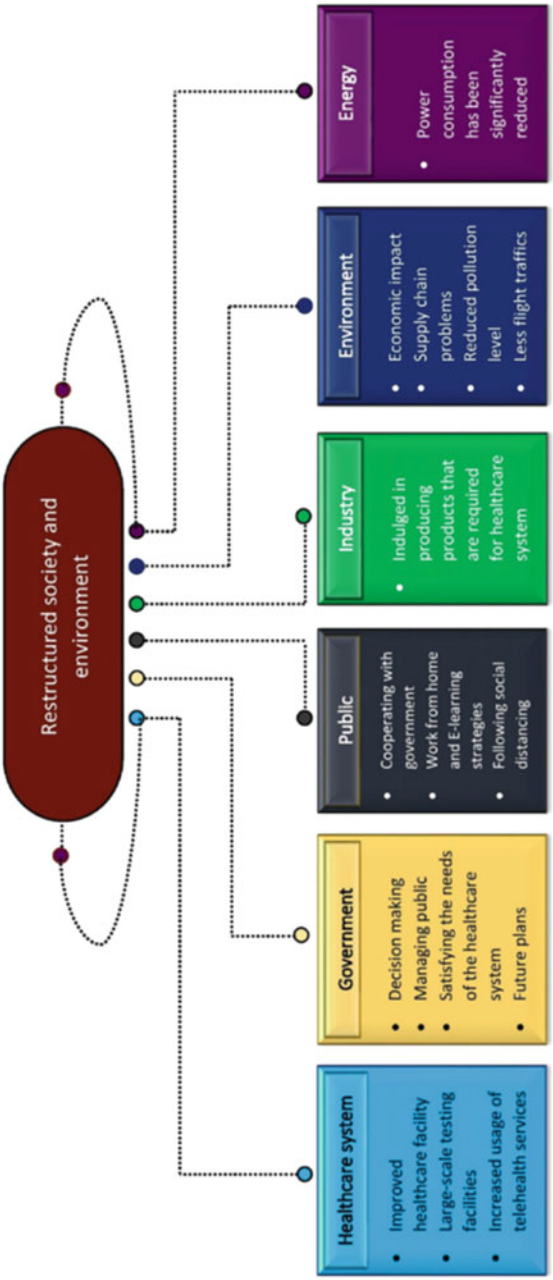

Fig. 23.3 Restructured environment and society

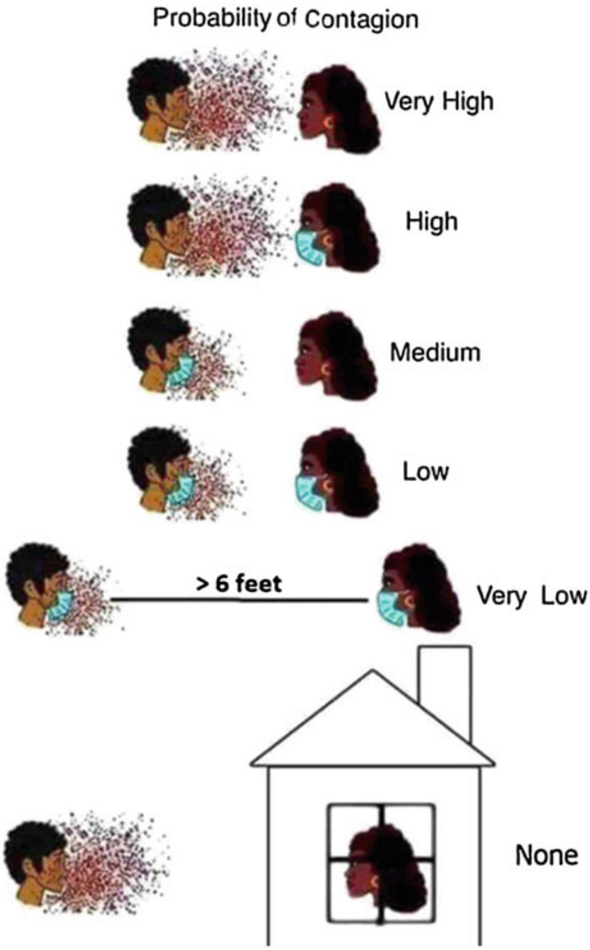

Fig. 23.4 Probably of contagion

population, if precaution could not take in timely (Anderson et al. 2020). So, social distancing, isolation, and quarantine play a major role in preventing the spread of the virus. Social distancing is otherwise known as physical distancing. It helps to reduce the spread of infection and contaminant by limiting face to face contact. The novel virus spreads within those that are in close contact (near about 6 ft.) for a persistent period as shown in Fig. 23.4. The infection and contaminant spread when an infected person coughs, sneezes, or talks, and droplets from their mouth or nose are launched into the air and land in the mouths or noses of people nearby. The droplets can also be inhaled into the lungs. Recent studies indicate that people who are infected but do not have symptoms are likely also to play a role in the spread of COVID-19 (van Doremalen et al. 2020). On the other hand, touching a surface or object that has the virus on it and then touching their own mouth, nose, or eyes a person can get infected with coronavirus. So it is required to avoid to this virus from their family and

Table 23.1 Various effects during self-quarantine and isolation

Main features	Self-quarantine	Self-isolation
Psychological	–	–
Social	–	–
Medical	Possible	Possible
Professional	Possible	Possible

community, which helps to decaying its spread within the community across the world. On the other hand, isolation is essential for the separation of sick peoples along with low immunity peoples with contagious disease from peoples, who are not ill. It is very important to stay away from infected patients to avoid contracting the disease. In a pioneer work, Marchand et al. reported that a patient should kept in a negative pressure room to prevent the transmissions of virus via aerosols (Marchand-Senécal et al. 2020). Jiloha and coworkers reported that during quarantine, people suffer with ostracism, neglect, and abandonment (Jiloha 2020). On the other hand, during isolation, patients suffer from depression, insomnia, and suicidal thoughts. Quarantine is known as separates and restriction of movement of peoples, who were screening to a contagious disease but still are not sick (Brooks et al. 2020; Wang et al. 2020; Mizumoto et al. 2020; Mossa-Basha et al. 2020; Rothstein and Talbott 2007; Lim et al. 2020; Emanuel et al. 2020). It was found that people may not be affected or disease in still in maturation period (approximation 6–7 days) vacillating from 2 to 14 days (Centers for Disease Control and Prevention 2020). According to advice of the WHO, people should be quarantined, who were contacted with infected people with symptoms like fever and cough. It may be at an individual or group level. From the research on social distancing, isolation, and quarantine, it was found that these parameters have played a tremendous role to diminish the spread of the virus, and at the same time they may have also caused some adverse effects in human beings. They also create an extraordinary impact in the health of the public as shown in Table 23.1. These parameters also play an important role to reduce the spread of the disease to a higher magnitude. From the statistics, it was found that the affinity of COVID-19 is 10–20 times higher than other viruses, when it enters human cells, so quarantine plays a significant role to control the spread of the virus as well as the mortality rate (Letko and Munster 2020). On the other hand, it has some adverse effects. During quarantine periods, people may suffer with confusion, anger, and post-traumatic stress.

Due to loss of face to face interactions and traditional social interference main cause for consequence stress during the quarantine period. So there must be an effective public healthcare system in place for a better individual health and economy. However, the *Control of Communicable Diseases Manual* does not recommend mass quarantine for any disease at any circumstance (Schabas 2007). Countries or continents should adopt proper rules and regulations to implement mass quarantine.

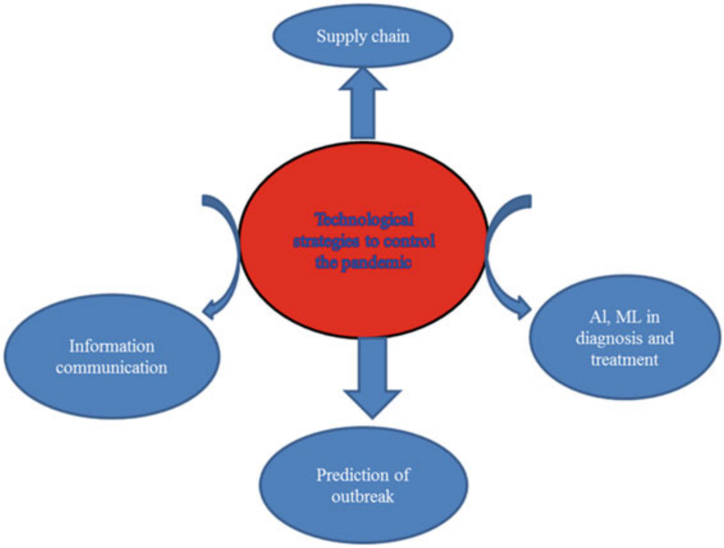

Fig. 23.5 Impact of technology on COVID-19

23.3 Impact of Technology on COVID-19

Technology has a significance role in human lives. It also plays a role in various prospects such as health care, travel, communication, transport, etc. During the pandemic, technology has been assisting to control the spread of the virus. This section reports on various potential technologies and their importance to mitigate the spread of the virus and their direct support to the healthcare system to reduce the infection and also indirectly provide information to governments and the public to deal with the virus. In this context, Information Technology (IT), Artificial Intelligence (AI), Machine Learning (ML), and Supply Chain play a significant role in controlling the pandemic as shown in Fig. 23.5.

23.3.1 Information Technology (IT)

Due to the rapid transmission of the virus from people to people, it is essential to sustain the community and people should take major precaution to avoid the virus or contaminant. So, it is essential to know about the virus and its nature, how to tackle the virus, how it is transmitted, and risks of the virus. Countries and continents have to prepare polices and provide information to the public at the right time. In this regard, mass media and social networking play a crucial role in providing information to the public. So, all the updates regarding the pandemic are intimated via radio, television, newspapers, and internet. From the above, social media make a significant contribution to provide information related to the pandemic throughout the globe across different platforms.

23.3.2 Artificial Intelligence (AI) and Machine Learning (ML)

As the whole world contends with COVID-19, it is essential for development of innovation technology and skill to fight with this destructive pandemic to overcoming it and save the community. In this regard, AI and ML play a major role in understanding the COVID-19 crisis. In the fight against COVID-19, researchers and scientists have been doing their best to control the spread of the virus, discover drugs, provide better treatment, etc. by applying their knowledge on AI and ML. Artificial intelligence (AI), known as simulation of human intelligence in a computer or machine, responds like humans or mimic human intelligence. Originally, it was used to solve simple problems such as winning a chess game and language recognition. With rapid advances in technology, it plays a significant role in solving complex problems. On the other hand, machine learning is a subdomain of AI. ML concentrates on the development of computer programs based on the relationship between input and output data. It may be supervised or unsupervised learning. Both AI and ML have been playing a major role in the healthcare system. Both technologies have made significant contribution to the healthcare system for the welfare of patients, effective diagnosis, and cost effective care. During the pandemic, they play a major role in the healthcare system. The Global Public Health Intelligence Network (GPHIN) is one of such surveillance networks; it showed potent behavior toward early detection and warming of contagious disease outbreak (Marathe and Ramakrishnan 2013). It is found that Blue Dot, an AI-based algorithm, is able to scan more than one lakhs online articles throughout the world in 65 languages for every 15 min. The early detection was confirmed of outbreak of SARS in 2002 at Guangdong Province, China to WHO and GOARN members and around the globe (Christaki 2015). The COVID-19, the first evidence on pneumonia was unknown disease, Wuhan, China and later it was declared as outbreak by BlueDOT, an AI base active surveillance before it was official announced as COVID-19 and informed their customers (Niiler 2020). It is very important to inform the communities and control the disease. It is also necessary to respond early to avoid the spread of the virus and also take necessary action on the affected areas. So, AI-based potent surveillance is very essential in predicting and sending a word of caution about the early outbreak to the world. On the other hand, the mitigation of the spread of the virus is very crucial as it is dependent on several factors such as population density, transmission efficiency, and diagnostics. ML has been playing a tremendous role in analyzing a bunch of data and informing the community about the future of the pandemic. It is also of help to researchers to discover a potent drug to help the community to overcome COVID-19. Only a small difference of infected cases found between the public report of metabiota data and reality data reported by MIT technology review 2020 was found. Lai and Andrew reported that if China had taken necessary action and implemented social distancing, isolation, and quarantine a week earlier, 67% of all cases might have been prevented; however, if implemented, then it found that infection rate decreases 5% by using a mathematical simulation data (https://www.worldpop.org/events/COVID-NPI. Accessed 31 March 2020). Apart from that, AI combined with other potent technologies helps to track the virus and also flag possible carriers of the virus. By use of AI-powered smart glasses, it is possible to track hundreds of people within a very few minutes without creating contact. It is used in large gatherings; it helps to quickly locate. From this, it has provided a clear-cut idea that by using AI and ML, the infection rate decreases and AI and ML have also shown how to handle the situation and mitigate the outbreak. The following section reports on a few potent evident technologies employed to fight against the ongoing COVID-19 outbreak:

- AI can be used for early warning of an outbreak; it also helped to predict the outbreak after that the WHO declared it as a pandemic.
- Scientists from HUST and Tonji Hospita in Wuhan developed an AI diagnostic tool, which helps to quickly analyze patients' blood samples and also predicts the survival of patients with 90% accuracy.
- In Wuhan, China, AI-based diagnosis has enabled them to separate patients within a very short time by using patients' chest CT scan images.
- COVID-NET is a deep learning model, which helps to detect the COVID-19-infected cases from chest X-rays.
- Google's DeepMind helps to predict the structure of the virus.
- AI-based computer-based camera was used in various crowded places in China to scan the infected person.
- Cloud Ginger (aka XR-1) is used in hospitals in Wuhan, China, to deliver food and medicine to patients.

23.3.3 Supply Chain

Supply chain refers to the production and distribution of products to community for their betterment. In the case of COVID-19, as active cases started increasing drastically day by day, it is essential that the healthcare system must have adequate facilities such as testing, equipment, masks, and hand sanitizers for the safety of the public. Apart from that the telehealth facility must be required during the pandemic. The telehealth system reduces the workload of hospitals. As the number of patients increases, it is essential to use AI-based surveillance to handle the situation. Due to increases the infection in hospital, purchasing medicine and stocking and handling the medical waste etc. is very strain. It prevents the front-line health workers from infection (World Economic Forum 2020; Jordona et al. 2019).

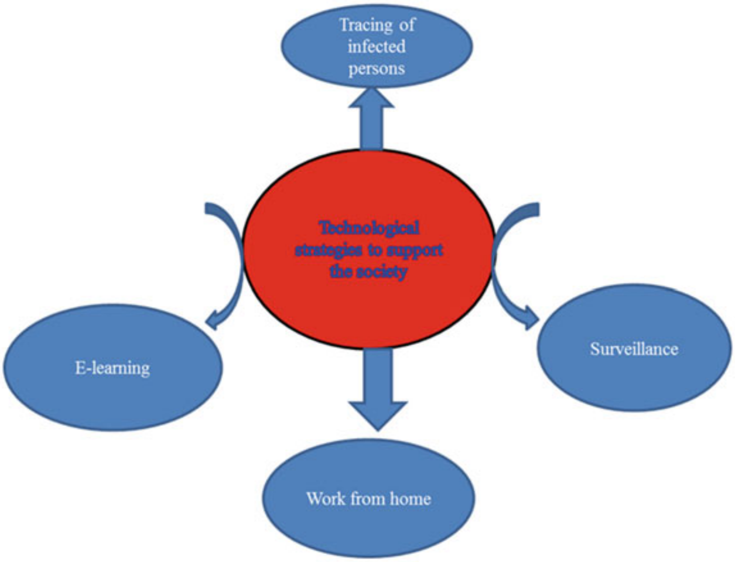

Fig. 23.6 Impact of technology on society during the pandemic

23.4 Impact of Technology on Society During a Pandemic

The spread of the virus has been drastically increasing day by day due to tiny droplets carried in the air or any contaminant surface. So, social distancing, isolation, and quarantine play a major role in preventing the spread of the virus. The infection rate is decreasing during this process but there must be a few adverse effects. So potent technology is essential to control their adverse effect during the pandemic and helps to control the spread of the virus. It is possible that people can perform their daily routine by maintaining social distancing such as (1) Working from home, (2) Distance learning, and (3) Surveillance as shown in Fig. 23.6.

23.4.1 Work from Home

Due to the rapid spread of the virus from person to person, it is very difficult to predict whether one is infected unless development of symptoms from 1 to 14 days. It is a main factor for the rapid growth of patients. By keeping this in mind, several companies instructed their employees to work from home for smooth functioning of their lab. Advanced technology and potent network connectivity help implement these strategies.

23.4.2 Distance Learning

Due to the rapid spread of the virus, local governments and communities have instructed to shut down all educational institutes. Governments initiated E-learning for students. Due to innovative technologies such as web-based learning, this provides rich learning experience. It also helps people indirectly to stay at home.

23.4.3 Surveillance

It is a great challenge to keep a record of infected persons and their travel history. So it is necessary to keep their data to control the spread of the virus. In this context, CCTV and mobile phone location data help to track the infected person.

23.5 Effects of COVID-19 on Daily Life

The ongoing COVID-19 outbreak affected the daily life of sustainable communities and slowed down the economy. It affected day-to-day life, movements, and businesses. It has affected areas like healthcare, economy, and social life.

23.5.1 In Health Care

1. Major task is to diagnose and provide proper treatment to infected patients.
2. Lack of medical facility during the outbreak and heavy burden on the existing medical system.
3. Other patients are neglected as focus is toward COVID-19 care.
4. High burden of duties on paramedical staff.
5. Need for protection and improper supply of medical chain.

23.5.2 In Economy

1. Decline of manufacture of needy items.
2. Interrupts the supply of essential products.
3. Damages the national and international businesses.
4. Disrupts the flow of cash in market.
5. Affects the revenue growth

23.5.3 In Social

1. Difficulty in providing proper service.
2. Dissolution of major programs such as sports and or tournaments.

3. Stops the celebration of various prestigious festivals.
4. Bans movements such as international and national traveling.
5. Suspension of various examinations.

The ongoing outbreak has created major problems for human lives and economy. During these days, it is very difficult for doctors and paramedical staff to provide proper health care to other patients. Government and healthcare organization have put their best effort to mitigate the virus.

23.6 Conclusions and Global Impact of COVID-19

This chapter discussed the impact of potent technologies and strategies on isolation and quarantine. COVID-19 has emerged as a global outbreak and affected people throughout the globe and disturbed their daily work routine. To mitigate the virus, countries and continents have implementing several rules such as social distancing, isolation, and quarantine. Apart from that, proper governance, adequate facility of health care, proper coordination between government and public, and potent technologies can play a significant role in reducing the infection and contaminant. On the other hand, the support of effective technology to mitigate the virus is noteworthy. Technologies and effective governance play a major role to face the situation and deal with it. Therefore, technology will be a major weapon to fight against the novel coronavirus.

As the impact of COVID-19 is not limited to community infection and death, it also has a great impact on social discrimination. It has affected many sectors such as tourism, entertainment, industries, and restaurants with a tremendous acceleration of job losses. Thus, it has affected the global economy.

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24 Impact of Loneliness and Quarantine on COVID-19 Patients with Artificial Intelligence Applications

Atasi Mishra and M. S. Usha

Abstract

Coronavirus is a newly discovered virus and an infectious disease, which is responsible for COVID-19 pandemic. The significant symptoms of this COVID-19 include dry cough, high fever, sore throat, tiredness, and difficulty in breathing. It mainly spreads through the air by coughing or sneezing, mass gathering, personal contact, and touching contaminated objects. Older people are at high risk for this infectious disease. People having breathing problems, high blood pressure, diabetes, heart and lung problems can face severe difficulties in this illness. COVID-19 can be stopped by frequently washing hands using soaps and sanitizing hands properly. Social distancing, self-isolation, self-quarantine are the best ways to prevent the spread of disease. Artificial intelligence (AI) is a new efficient technology helps to control the pandemic. Applications of AI are mainly designed for detection and analysis of the infection. This chapter's primary aim is to focus on the impact of isolation and quarantine on COVID-19 patients with artificial intelligence applications.

Keywords

COVID-19 · AI applications · Coronavirus · Quarantine · Impact of isolation

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24.1 Introduction

Coronavirus is a newly discovered virus and an infectious disease, which is responsible for COVID-19 pandemic. The significant symptoms of this COVID-19 include dry cough, high fever, sore throat, tiredness, and difficulty in breathing. It mainly spreads through the air by coughing or sneezing, mass gathering, personal contact, and touching contaminated objects. Older people are at high risk for this infectious disease. People having breathing problems, high blood pressure, diabetes, heart, and lung problems can face severe difficulties in this illness. COVID-19 can be stopped by frequently washing hands using soaps and sanitizing hands properly. Social distancing, self-isolation, and self-quarantine are the best ways to prevent spread of the disease. This coronavirus pandemic has resulted in a rapid rise in the number of cases and casualties and there has been a remarkable social, political and psychological impact. Several people are isolated in their own houses, some in hospitals, hotels to maintain social distancing; as a result to minimize the extend of disease. Several countries have declared complete lockdown due to this pandemic. People traveling to different parts are advised to stay quarantined for 14 days. Those persons will undergo further medical examinations post quarantine. This quarantine helps symptomatic people to stay away from others, so that they do not infect anyone unknowingly in their surroundings. This COVID-19 outbreak has affected several countries and has made a major consequence on the available healthcare amenities with management systems. Artificial intelligence (AI) is a new technology that helps to control the pandemic. AI technology helps in appropriate broadcasting, tracing, and forecasting the existing and future patients. AI applications are mainly meant for the detection and diagnosis of the infection. With the help of AI technology, it is easy to study the irregular symptoms and thus alarm the medical authorities and the patients. AI can easily check and predict the increase of coronavirus. It can provide daily updates of the patients and provide solutions to be followed to control the pandemic. AI can trace and predict the type of the coronavirus from the accessible information, media platforms, social media about the possibility of the disease and probable spread. It can also forecast various positive and death cases in any region. AI can recognize the most unsafe regions and categorize them by different zones like hotspot, red zone, orange zone, and green zone. Green zones are the safe zones where the spread of the virus is least, red zones being the zone with more cases of disease. Routine monitoring and prediction of the spread of coronavirus can quickly be built by artificial intelligence platform. AI helps in testing drugs in real time, which may not be possible by a human, whereas standard testing takes a long time to accelerate this process. AI technology helps to recognize functional medicine for the treatment of COVID-19 patients. The main objective of this study is to control the COVID-19 patients with AI technology, which will work faster and control the pandemic.

24.2 Literature Survey

The severe acute respiratory syndrome coronavirus is responsible for COVID-19 pandemic. The objective of this study was to control the outbreak of COVID-19 using AI technology. Various scientists, researchers, laboratories and organizations to carry out large scale research to develop vaccines and other treatment strategies for the huge outbreak of COVID-19 pandemic. Various papers are investigating different features of COVID-19. Few of the papers are available and cited in reference.

A thorough review of literature is done on impact of isolation and quarantine on COVID-19 patients with AI technology using keywords of COVID-19 or coronavirus on the databases of Google scholar, PubMed, Scopus, Research Gate. Collected the recent information regarding applications of AI for COVID-19 pandemic.

24.3 Model of AI Applications

AI is a necessary tool and it can be very useful to battle against COVID-19 pandemic. It helps in tracing the infection with its powerful tools. It can screen the infection through models based on big data for recognizing symptoms. AI with its unique tools helps to minimize the spread of virus. This AI technology stores a huge amount of information of the patient contaminated by the virus (Fig. 24.1).

24.3.1 Tracking

Tracking the disease with AI-based tools: AI can quickly detect the symptoms of COVID-19.

AI has helped in tracing of people and their increase of infection.

AI-based tools for example migration maps which use mobile phones, social media to collect the information regarding location of people who had visited different hot spot places.

Immigration records as a tool to check the airline travelers to accesses the patients travel histories and can identify them with COVID-19 testing.

Real-time data on volumes of a patient as a tool help to track the resources regarding personal protective equipment, staffing, and ventilator usage to track the status of hospital bed facility and allocate healthcare resources.

24.3.2 Screening

Screening for possible match of COVID-19 and proceeds for further investigation:

COVID-19 can be screened easily by AI applications using web-based and cloud-based resources. In airports, infrared thermal cameras are used to capture thermal images and notice persons with high temperature and fever.

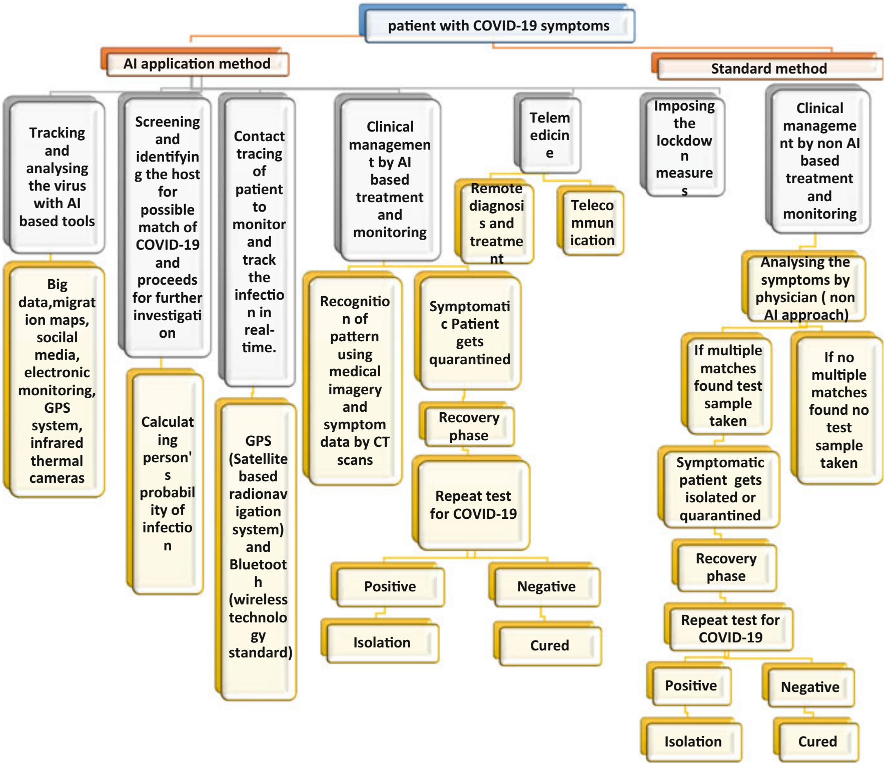

Fig. 24.1 AI and non-AI-based applications to recognize COVID-19 symptoms

Screening can be done on patients with symptoms using mobile technology by collecting information and combines this information with additional data sets for example medical and geometrical sequencing to reveal the spread of infection.

24.3.3 Contact Tracing

AI can analyze infection by using AI tools like camera footage, facial recognition, GPS data from vehicles, cell phones, and by identifying the clusters and hot spot of the individuals and can be able to effectively do the contact tracing.

24.3.4 Quarantine and Self-Isolation

Quarantine is an effective way to protect individuals by separating them from people who are exposed to the infection. It helps to keep people away from others so they do not infect others from their surrounding unknowingly. Quarantine and self-isolation is done to minimize the spread of infection among others. With AI technology individuals who are quarantined are require to complete a symptom study and trace their temperature, which helps the healthcare authorities to supervise and control the infection. This AI tool is used as a COVID-19 healthcare category certificate and travel pass.

Green codes individuals are allowed to travel and with red codes are necessary to self-isolate them for 14 days.

Electronic monitoring of home quarantined persons is done through mobile phones GPS facility. GPS facility helps to monitor and ensure individual remain in self-isolation. These AI-based tools help to monitor individuals who are quarantined and self-isolated.

24.3.5 Clinical Management with AI-Based Treatment and Monitoring

With the help of AI-based treatment, it is easy to prevent the disease as it predicts the possible sites of disease, the future virus and its disease prevention with real-time data analysis. AI helps in quick analysis and risk prediction of COVID-19.

24.4 Treatment

The treatment of COVID-19 mostly counts on the particular symptoms showed by the patient. Until now, precautionary vaccine for COVID-19 is accessible but several trials are being in use to make commercial use as soon as possible.

24.5 Preventive Measures

It is necessary to follow useful measures to control the COVID-19 health crisis. If individuals do practice these following measures then the world may soon observe a flattened COVID-19 curve. Flattening the curves suggests bringing down the increase of COVID-19 to the level where healthcare facility are capable to only hold the impact of the infection.

– Cleaning hands repeatedly with an alcohol-based sanitizer
– Practicing social distancing
– Staying at home
– Avoiding touch to the eyes, nose, and mouth without rigorously sanitizing the hands
– Wearing masks

24.6 Results

From the AI model, we have acknowledged several applications of AI for COVID-19 outbreak. AI technology engaged in significant function in tracking several COVID-19 cases and predicts where this virus will have an influence in future with AI-based tools by collecting and analyzing all prior information. However, several studies related to AI technology have arisen, but there are still controlled applications and contributions of AI technology in this battle toward COVID-19.

24.7 Discussions

COVID-19 is caused by the novel SARS-CoV-2 virus. AI is a most influential tool to fight against the COVID-19.

Several applications of AI discussed:

- Tracking, screening, and contact tracing the disease using several AI-based tools.
- The AI-based app can be able to help in qualifying and continuing well-informed social distancing and self-isolation to control the COVID-19 pandemic.
- AI mainly concentrates on analysis of the patients and the virus by medical imaging process.
- AI plays a major role in alertness and social monitoring via. Internet, using tools such as Smartphone thermometer as an authenticate equipment for accessing temperature of infected people.
- AI helps to forecast the possible sites of infection, the future virus and its disease prevention by real-time data analysis.
- AI plays a vital role in drug discovery by integrated AI-based drug discovery pipeline to generate novel drug compounds.
- AI helps to save from unnecessary exposure, mainly for non-critical patients where the therapeutic guidance for whom at least would be stay at home or self-isolate.
- AI technology can be used as a low cost showing instrument, and as well as the thermal scanner at the airports, borders, or somewhere else as required. Since AI-based app illustrate that can identify COVID-19. The price of using such an app-based resolution probably small, because it can be readily installed on any Smartphone with the internet connections, by a lot of people at the same time.

24.8 Conclusions

AI is an important role in handling the virus and as proper decision-making technology. It plays vital role in evolution of vaccine for COVID-19. This AI technology act as an appropriate tool for screening, analyzing, following and predicting the current and the future patients. In this COVID-19, pandemic AI technology acts as characteristic feature in flattening the COVID-19 incidence curves and maintaining the mortality rates. This chapter has presented a study of several applications of AI until now in the literature relevant to the COVID-19 pandemic. There is a large scope of AI technology covering clinical difficulties made by the coronavirus. Although different studies have been published, we examine that there are still comparatively inadequate applications and contributions of AI in this COVID-19 pandemic.

24.9 Future Scope of the Work

In future AI technology would be relevant to reserve susceptible information of our healthcare organization can be designed for a further pandemic similar to COVID-19. It can be used to concentrate all medical apparatus, technical tools for treatment. AI would create smart healthcare system in medical industry by adopting the latest software devices and systems.

24.10 Summary

COVID-19 disease caused by the SARS-CoV-2 virus was identified in December 2019 in China. This pandemic has created urgent demand for healthcare equipments and support of new technologies such as artificial intelligence (AI), big data, and machine learning. AI is being used as a tool to battle against the COVID-19 pandemic. AI is an important technology for quick detection and analysis of the infection. The major functions of AI contribute early warning, tracking and prediction, information, diagnosis, treatment and cures, social control. AI is designed for the evolution of drugs and vaccines for the COVID-19, but through high transmittable and no successful vaccine. COVID-19 is currently a worldwide pandemic by WHO on 11 March 2020.

Acknowledgments This chapter is dedicated to all the COVID-19 warriors around the world.

Conflict of Interest None

Further Reading

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25 Can Technology Fight the Loneliness Lockdown: A Study of Factors Affecting Loneliness in NCR During COVID-19

Richa Goel and Seema Sahai

Abstract

COVID-19 as a global health threat has led to many precautionary steps, such as quarantines, social distancing, or even a complete lockdown in regions or countries around the globe. This has led to something called the pandemic of loneliness. It has become unpredictable, particularly for those already in a difficult situation, to hold up their job and to maintain life contributing to greater tension and anxiety. Furthermore, reducing exposure not only to work but to social contact creates difficulties in mental health and diminishes physical health. Social alienation and mental health problems also impact children and elderly people. Feelings of loneliness and social isolation, reinforced by the current public health crisis, can lead to many people having serious health consequences. Increased feelings of depression and stress can persist long after the end of the pandemic. At a time such as this, when people can't meet their regular friendly circles to not get infected by the deadly virus, what can they do to fight the loneliness?

Technology may be the answer to many questions over the pandemic. The objective of this study is to determine the factors affecting behavioural epidemic of loneliness among individuals during the lockdown period of COVID-19 pandemic. Also to investigate whether the rising technology can help ease this loneliness to an extent. A survey was done of 534 respondents. Analysing the results showed that there was a strong relation between overcoming lockdown loneliness and technology. Descriptive study shows that people of all age groups especially elderly and children have suffered from anxiety and loneliness due to social distancing.

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Keywords

Technology · Loneliness · Pandemic

25.1 Introduction

The 2019 coronavirus (COVID-19) currently represents the most serious infectious virus after Spanish flu, a pandemic that has significant impacts upon global public health (Ferguson et al. 2020). With preparation of the production of an appropriate vaccine, several nations have adopted a number of steps to restrict the dissemination of this virus around the world through non-pharmacological (NPI) treatments. Although social activity was restricted in most countries, quarantine prevented almost all nonessential movements, while the local hospitals received thousands of COVID-19 patients who were suddenly critically ill and were obliged to implement their emergency protocols.

In this sense, both the population and most health care staff in the frontline have become exposed to the traumatic impact of the COVID-19 infection owing both to the pandemic and its consequences worldwide. A variety of psychiatric problems and major mental health effects, including fatigue, anxiety, depression, anger and fear, have been seen steadily across COVID-19 outbreaks. General psychological reactions to forced mass quarantine to attenuate COVID-19 spread are generalized panic and general population distress, usually related to outbreaks of disease, which are escalated along with the escalation of cases with inadequate, anxiety-provoking information which was provided by media.

The pandemic and the procedures to isolate the virus from society had serious implications for mental health. There is no question that the economies of the country and the world fail, welfare services are under tremendous pressure, mass hysteria has risen frenetically, and the hope and appetite of people is being met with misericordia. Anxiety is exacerbated by lockout isolation by the fear of a new and largely unknown virus. As the World Health Organization (WHO) and the Centre for Disease Control and Prevention (CDC) are fighting to stop the outbreak, social distancing is repeated suggested as one of the most useful preventive strategies.

The world of modernity is hardly so disconnected and small. Human travel has been subject to several prohibitions to prevent the dissemination of the virus. There is a heft of isolation among the people who are expected to live at home. People wake up in a cold chest of mutual loneliness, utter frustration and an inspiring sense of solitude every day. In an age of fast travel and contact, the average man understood nothing about that (Fig. 25.1).

While the world of Spanish flu, Ebola and Plague shook millions of patients during the past outbreaks of (SARS), (MERS) the superiority of technology did not intensify the gap experienced. In this era of digitalisation, internet media, social channels, grocery shops, restaurant, bars, cinemas and film theatre confuse us by making apparent "natural links." Humanity has always known what to do next, usually following a regular route in their lives. Nonetheless this unexpected

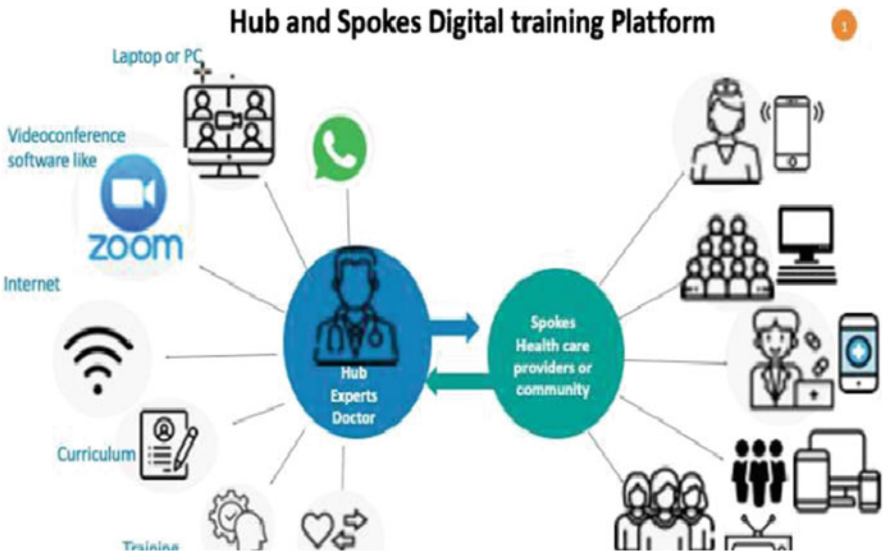

Fig. 25.1 Digital Hub platform

disastrous turn of events has presented them with a grim evaluation of how they will survive together. It is in fact a terrifying comprehension when a generation or two know how to deal with a nuclear fallout but end up with how you can spend time with yourself.

They were stranded with their families (those not affected by the disease) and the relationship should be strengthened. Yet, as previously described, the "internet interaction" of the social network undoubtedly made us miss the closeness of connections. This may be a double-edged knife, able to alter or disrupt relationships based on current patterns of affection and contact. It's such a big challenge to live with yourself and your loved ones, as the pandemic is spreading across the world.

In this chapter we discuss the impact of COVID-19 on isolation through various social strata, the implications of it for the new digital world, and outline potential responses to it.

The isolation and loneliness which has been shown in previous pandemics is likely to develop. Soon loneliness can be described as a disagreeable condition in which the desired amount of social contact and emotional support are disconnected from what is available from the community. Social isolation policies limit the likelihood of mutual interaction by splitting people and families from employers, acquaintances and family within their households.

The NPIs may therefore increase pre-existing loneliness and cause adverse loneliness for people who do not suffer from this problem especially before NPIs. Sole ness is characterized by a painful condition with large neurological resemblances to physical pain, with findings revealing similar somatosensory representations in the brain between physical pain and social disapproval. Loneliness

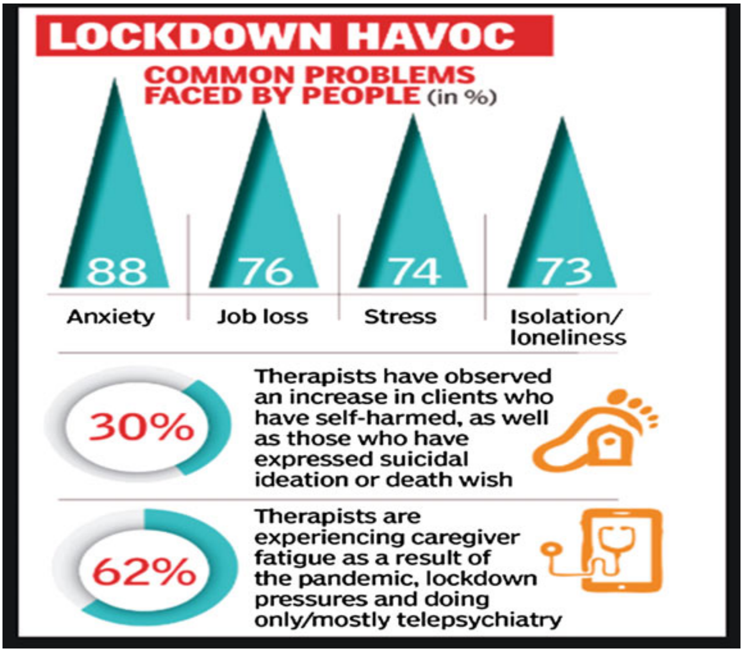

Fig. 25.2 Problems faced during lockdown

includes suicidal ideation and para-suicidal activity that leads across the continuum of emotional and somatic (e.g., coronary, hypertensive) disorders (Fig. 25.2).

Therefore, loneliness has been correlated with increased morbidity and death. Objective social alienation and subjective Sole hood have been seen in a rise in mortality of nearly 30% and new studies suggested that solitude is now the most deadly in Great Britain. In addition, sole-sustaining feedback between the symptoms of those states will continue even after the social distance steps are removed. In addition, reports of previous pandemics have demonstrated the long-term impacts of prevention measures such as quarantine on mental well-being and behaviour, and the resultant consequences are known to exacerbate anxiety and distress well after the causes have vanished. As practitioners in mental health, we must be responsive to and respond to the individual needs of individuals in quarantine. They will listen to their emotional and psychological needs. Digital contact with your loved ones will be preserved (Fig. 25.3).

In order to detect dysfunctions and lifestyle changes which might lead to the onset of psychiatric conditions early, anxiety-inducing issues associated with this emergence of the health and socioeconomic crisis need to rapidly be identified in the general population.

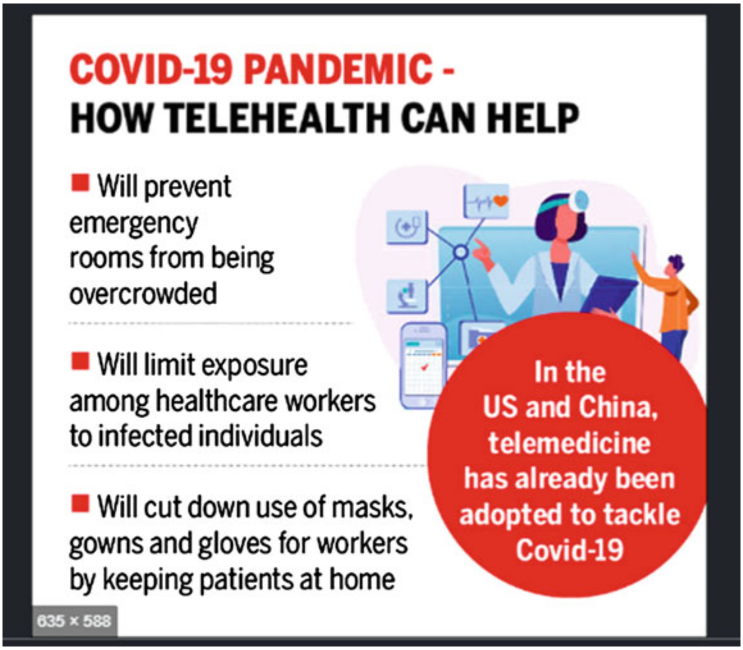

Fig. 25.3 How telehealth can help

25.2 Objective

The present research has been intended to provide the general population of India a beneficial contribution to the epidemiology of mental strain.

The objective of this study was to

- Identify the factors leading to loneliness during COVID-19 pandemic.
- Identify the effect of loneliness on mental health.
- Examine if different age groups and gender are effected differently by factors leading to loneliness.
- Lastly to study technology as a tool will help ease loneliness to an extent or not.

25.3 Research Questions

- Are the social distancing measures designed to reduce viral transmission during the pandemic associated with increased loneliness?
- Do loss of job and income increase loneliness to a greater level?
- Is there a difference in levels of loneliness during COVID-19 across different age groups in the sample?

- Is there a difference in levels of loneliness during COVID-19 across different gender groups in the sample?
- Does elevated loneliness is associated with more depression and anxiety symptoms?
- Do the digital online platforms used by the people during COVID-19 help ease loneliness to a certain extent?

25.4 Literature Survey/Related Work

The researchers studied literature and previous research from multiple databases in order to consider creating a conceptual framework of research that is new and different from other researches, including to be suitable for studies in context of India.

Past to the COVID-19 pandemic, loneliness and social isolation were so widespread in Europe, the USA, and China (10–40%) (Leigh-Hunt et al. 2017) that it was described as a "behavioural epidemic" (Jeste et al. 2020). With the enforced limitations to deter infectious transmission, this problem has only escalated. In older people aged 60 who are at higher risk of adverse health problems, hospitalization, referral to an acute treatment facility and mortality (Bialek et al. 2020) the risk of COVID-19 infection will be raised.

Loneliness effects mental health in many ways. Less isolation (Cacioppo et al. 2002) has resulted in decreased sleep time (7% decrease in productivity of sleep) and improved waking time after sleep started. An increasing amount of depressed symptoms, together with poor self-evaluation, functional impairments, vision deficiencies, and a perceived negative change in one's life quality can also be caused by soleness (Lee et al. 2019) A systematic suicide risk review has also found that loneliness is linked to suicide attempts and completed suicide of older adults (Fässberg et al. 2012).

Solitude and depressive signs are associated with a period of decline of cognition. The possibility of other psychiatric illnesses such as depression, anxiety, transition, chronic stress, insomnia and even late-life dementia (Wilson et al. 2007) is known as isolation as an mysterious and unpleasant sensation. A systemic review found that loneliness and social isolation are substantially related to dementia incidents (Kuiper et al. 2015). The suggested cause for negative depression health consequences centres on the systemic stress response (e.g., elevated cortisol) (Xia and Li 2018).

Abnormal emotional responses contribute to adverse health effects. The mechanism for social isolation may be associated with behavioural changes such as unhealthy lifestyles (such as smoking, drinking, reduced physical activity, poor food choices and medical prescription inefficiency (Kobayashi and Steptoe 2018).

Long confinement in prison or quarantine with a disorder has been well reported to have negative implications with mental well-being (Stickley and Koyanagi 2016). Loneliness is also one of the main social security measures (Ferguson et al. 2020).

If this is extended, chronic soleness may reduce physical activity, which leads to an increased risk of vulnerability and fractures, if this auto-isolation and lockdown continues (Mushtaq et al. 2014).

When simple living services are inadequate, it is a vague fallacy to find destruction or sanitation by hand according to the requirements recommended. Divorce from one's own personality may also provide a foundation for alienation, even as it varies across different socioeconomic strata (Valkenburg and Peter 2008).

Once again, it is ironic that the single framework differs depending on the social strata that generate the psychosocial dimensional needs. Specific procedures have shown better quality of life for the isolated in China during the first phase of epidemic (Duan and Zhu 2020).

25.5 The Proposed Study

From the literature review related to this research, the researchers created a conceptual outline of the research as shown in Fig. 25.1 and the researcher determined six hypotheses for statistical testing (H1–H6).

25.5.1 Research Framework (Fig. 25.4)

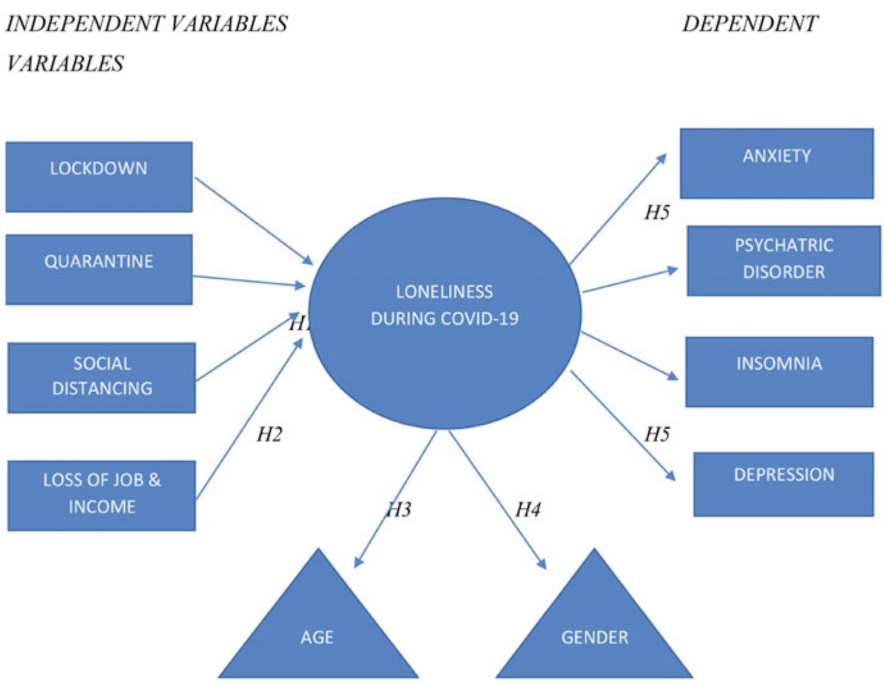

Fig. 25.4 The factors effecting loneliness during pandemic and the consequences

25.5.2 Hypothesis

H1: The social distancing measures designed to reduce viral transmission during the pandemic are associated with increased loneliness.
H2: Loss of job and income will tend to increase loneliness to a greater level.
H3: There is no difference in levels of loneliness during COVID-19 across different age groups in the sample.
H4: There is no difference in levels of loneliness during COVID-19 across different Gender groups in the sample.
H5: Elevated loneliness will be associated with more (i) depression and (ii) anxiety.
H6: Digital online Platform used by the people during COVID-19 will help ease loneliness to a certain extent (Fig. 25.5).

25.6 Research Methodology

25.6.1 Population and Sample

The Indians remaining at home during the time of quarantine in the COVID-19 crisis were the population of the study. The authors also estimated the number at the confidence level and error rate of 95% and 5%, respectively; the optimal range size was 560. The authors used the Cronbach method for the estimation of the optimal sample count.

25.6.2 Research Tool

The author developed a structured questionnaire from previous research that relates to the UTAUT model (Table 25.1). It consisted of three parts. The first part was for demographic data (gender, age, education, income, occupation), the second part was behavioural use in technology or programs during COVID-19 situation, and the final part was about key variables in the research framework including perceived risk, performance expectancy, social influence, effort expectancy, trust, facilitating conditions, user intention in using online technology, and use behaviour of the technology (Table 25.2). The questionnaire used 5 points scale (totally disagree = 1 to totally agree = 5) to measure the key variables in this research. Cronbach's alpha statistic was used for questionnaire reliability. The results were between 0.7 and 0.8 as shown in Table 25.3. This indicated that there was acceptable reliability.

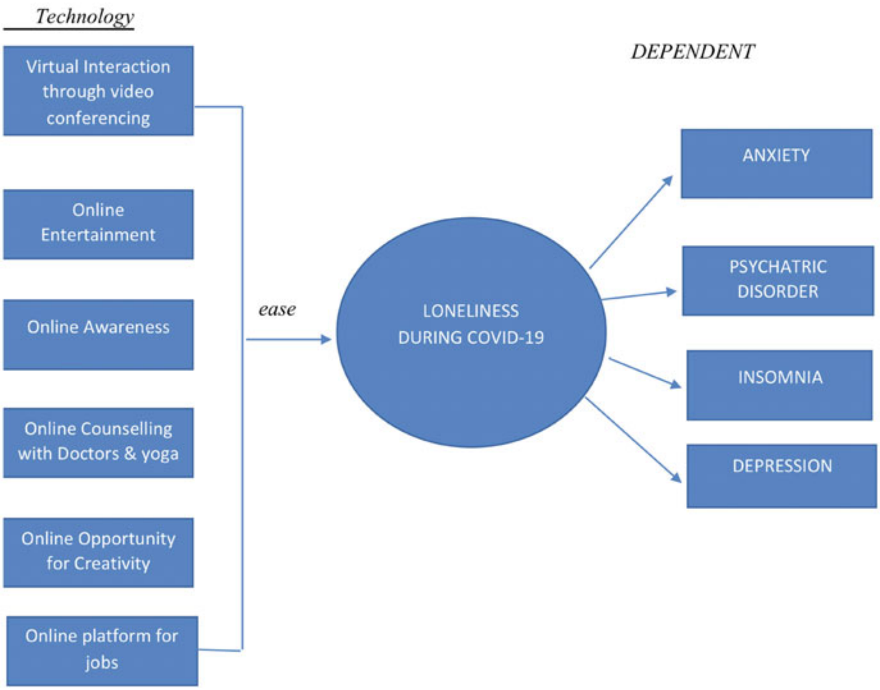

Fig. 25.5 Technology using Artificial Intelligence and robots can help ease this loneliness to an extent

25.7 Data Analysis and Discussion

25.7.1 Hypothesis Development

As per earlier literature and present research purposes, the following study has been done to determine the impact of COVID-19 on Loneliness (Table 25.4).

H1: The social distancing measures designed to reduce viral transmission during the pandemic are associated with increased loneliness.

- Separation from loved ones.
- Wearing face masks, washing hands, maintaining hygiene all time increases anxiety.
- Postponement of marriages and other functions increases anxiety.
- Not able to attend any religious or social event.

Table 25.1 Loneliness Scale

Constructs	Description of factors	Measures
Lockdown	A policy of emergency enforced by authorities that prohibit citizens from leaving the region	L1—loss of freedom leads to loneliness L2—frustration and boredom L6—significant lifestyle changes L7—profound adaptations
Quarantine	A region, time, or place of exclusion for people from other areas of the world who are vulnerable to infectious or contagious disease	Q1—people with COVID-19 symptoms have more psychiatric disorders and are lonelier Q2—fear about own health Q4—Fear of not getting right treatment
Social distancing	Maintaining greater physical distance than normal from other people or preventing close contact with people in public places during the disease epidemic to mitigate exposure or decrease the infection spread	S1—fear of new and unknown infective agents S2—separation from loved ones S3—Wearing face masks, washing hands, maintaining hygiene all time increases anxiety S4—Postponement of marriages & other functions increases anxiety S5—Not able to attend any religious or social event
Loss of job & income	Due to outbreak of COVID-19 people throughout the world has lost their jobs with no income remaining	L1—Being idle at home increases loneliness L2—Zero income levels leads to depression L3—Liability of entire family with zero income leads to anxiety and depression L4—Uncertain future prospects of job
Anxiety	Feelings of tension and worrying thoughts	A1—Watching all time news about COVID-19 increases anxiety A2—Increasing number of COVID-19 cases A3—Poor medical facilities during COVID-19 A4—Changed lifestyle causes social withdrawal A5—Not able to cope up with technology
Psychiatric disorder	Diagnosed mental health providers with a psychiatric disorder that severely disturbs your mind, attitude and/or actions	PD1—Positive with COVID-19 symptoms PD2—Being lonely all time PD3—Death of any family member due to COVID-19 PD4—Domestic violence at home due to COVID-19 PD5—Negative thoughts accompanied with hypertension

(continued)

Table 25.1 (continued)

Constructs	Description of factors	Measures
Insomnia	Insomnia is a common sleep disruption that can make sleeping difficult or sleeping impossible or making you wake too early and cannot return to sleep	I1—Change in sleep patterns I2—More use of mobile phone during lockdown I3—Increased workload at home I4—High frustration I5—Medically unfit problems
Depression	Depression is a serious and extreme psychiatric disease that affects how you look, how you think, how you do it and how you do it	D1—Unhealthy lifestyle (increased smoking, alcohol, poor diet, no exercise) D2—Non-compliance with medical prescription D3—No vaccination for COVID-19 D4—Social distancing leads to depression
Technology		T1—Does digital online platform ease your loneliness T2—Does online counselling with doctors ease anxiety T3—Are you comfortable with technology T4—Does increase dependence on technology during COVID gives you panic attack T5—Are you able to kill your time digitally T6—being online all time leads to insomnia

Table 25.2 Demographic profile of respondents ($n = 534$)

Criteria	Demographic profile	Frequency	Percentage
Gender	Male	271	50.7
	Female	263	49.3
Marital status	Married	318	59.6
	Unmarried	216	40.4
Age group	18–25 years	152	28.5
	26–35 years	244	45.7
	36–45 years	92	17.2
	Above 45 years	46	8.6

25.7.1.1 Interpretation

We see a high and significant correlation between SOCIAL DISTANCING and Loneliness (Table 25.5). This reinforces the rejection of null hypothesis H1 and accept the alternate hypothesis.

R value shows a simple correlation which is 46.9%, which is high. 21.9% variation in loneliness can be explained by social distancing (Table 25.6).

Table 25.3 Overview of the constructs

S No	Construct	No of items	Loading	Cronbach alpha
1	Lockdown	L1—loss of freedom leads to loneliness	0.767	0.701
		L2—frustration and boredom	0.792	
		L6—significant lifestyle changes	0.76	
		L7—profound adaptations	0.8	
2	Quarantine	Q1—people with COVID-19 symptoms have more psychiatric disorders and are lonelier	0.672	0.718
		Q2—fear about own health	0.610	
		Q4—Fear of not getting right treatment	0.5	
3	Social distancing	S2—separation from loved ones	0.748	0.710
		S3—Wearing face masks, washing hands, maintaining hygiene all time increases anxiety	0.694	
		S4—Postponement of marriages & other functions increases anxiety	0.592	
		S5—Not able to attend any religious or social event	0.570	
4	Loss of job and income	J1—Being idle at home increases loneliness	0.749	0.863
		J2—Zero income levels leads to depression	0.893	
		J3—Liability of entire family with zero income leads to anxiety and depression	0.926	
		J4—Uncertain future prospects of job	0.767	
5	Anxiety	A2—Increasing no of COVID cases	0.704	0.736
		A3—Poor medical facilities during COVID-19	0.716	
		A5—Watching all time news about COVID-19 increases anxiety	0.896	
6	Psychatric disorder	PD1—Positive with COVID-19 symptoms	0.890	0.742
		PD2—Being lonely all time	0.930	
		PD3—Death of any family member due to COVID-19	0.816	
		PD4—Domestic violence at home due to COVID-19	0.732	
		PD5—Negative thoughts accompanied with hypertension	0.847	
7	Insomnia	I1—Change in sleep patterns	0.736	0.738
		I2—More use of mobile phone during lockdown	0.731	
		I3—Increased workload at home	0.781	
		I4—High frustration	0.812	
		I5—Medically unfit problems	0.763	
8	Depression	D1—Unhealthy lifestyle (increased smoking, alcohol, poor diet, no exercise)	0.753	0.863
		D2—Non-compliance with medical prescription	0.887	
		D3—No vaccination for COVID-19	0.908	
		D4—Social distancing leads to depression	0.754	

(continued)

Table 25.3 (continued)

S No	Construct	No of items	Loading	Cronbach alpha
9	Technology	T1—Does digital online platform ease your loneliness	0.897	0.735
		T2—Does online counselling with doctors ease anxiety	0.930	
		T3—Are you comfortable with technology	0.816	
		T4—Does increase dependence on technology during COVID gives you panic attack	0.732	
		T5—Are you able to kill your time digitally	0.847	
		T6—being online all time leads to insomnia	0.930	

Table 25.4 Pearson's correlation between social distancing (SD) and loneliness

Correlations			
		Social distancing	Loneliness
Social distancing	Pearson correlation	1	
Loneliness	Pearson correlation	0.469[a]	1

Source: Researcher's own compilation
[a]Correlation is significant at the 0.01 level (2-tailed)

The table shows the independent variable (Social Distancing) predicts the dependent variable (Loneliness) significantly well, which can be seen by the significance value being 0.000. This means it is good fit for the data (Table 25.7).

The regression equation can be presented as Loneliness = 2.993 + 0.256*Social Distancing. This indicates there is a strong positive relation between Social Distancing and Loneliness and further paves the path to accept the alternate hypothesis (Table 25.8).

H2: Loss of job and income will tend to increase loneliness to a greater level.

25.7.1.2 Interpretation

We see a high and significant correlation between Loss of Job and Loneliness. This reinforces the rejection of null hypothesis H2 and accept the alternate hypothesis (Table 25.9).

R value shows a simple correlation which is 78.8%, which is high. 62.1% variation in loneliness can be explained by loss of job (Table 25.10).

The table shows the independent variable (loss of job) predicts the dependent variable (loneliness) significantly well, which can be seen by the significance value being 0.000. This means it is good fit for the data (Table 25.11).

The regression equation can be presented as Loneliness = 2.966 + 0.266*Loss of job. This indicates there is a strong positive relation between Loss of job and Loneliness and further paves the path to accept the alternate hypothesis (Table 25.12).

Table 25.5 Model summary of effect of social distancing on loneliness

Model summary

Model	R	R square	Adjusted R square	Std. error of the estimate	Change statistics				
					R square change	F change	$df1$	$df2$	Sig. F change
1	0.469[a]	0.220	0.219	0.24235	0.220	149.804	1	530	0.000

Source: Researcher's own compilation

[a]Predictors: (constant), social distancing

Table 25.6 ANOVA social distancing and loneliness

ANOVA[a]						
Model		Sum of squares	d*f*	Mean square	*F*	Sig.
1	Regression	8.799	1	8.799	149.804	0.000[b]
	Residual	31.129	530	0.059		
	Total	39.928	531			

Source: Researcher's own compilation
[a]Dependent variable: loneliness
[b]Predictors: (constant), social distancing

Table 25.7 Coefficients table of social distancing and loneliness

Coefficients[a]						
		Unstandardized coefficients		Standardized coefficients		
Model		*B*	Std. error	Beta	*t*	Sig.
1	(constant)	2.993	0.081		36.733	0.000
	Social distancing	0.256	0.021	0.469	12.239	0.000

Source: Researcher's own compilation
[a]Dependent variable: loneliness

Table 25.8 Pearson's correlation between loss of job and loneliness

Correlations			
		Loneliness	Job loss
Pearson correlation	Loneliness	1.000	0.788
	Job loss	0.788	1.000
Sig. (1-tailed)	Loneliness		0.000
	Job loss	0.000	
N	Loneliness	532	532
	Job loss	532	532

Source: Researcher's own compilation

H3: There is no difference in levels of loneliness during COVID**-19 across different ages groups in the sample.**

The table shows that there is not much difference in the loneliness level across different age groups. So here we fail to reject the null hypothesis (Table 25.13).

H4: There is no difference in levels of loneliness during COVID**-19 across different Gender groups in the sample.**

Here again we see that there is no difference in the loneliness across gender. Therefore, we fail to reject the null hypothesis (Table 25.14).

H5(i) & (ii): Elevated loneliness will be associated with more (i)depression and (ii) anxiety.

Table 25.9 Model summary of effect of loss of job on loneliness

Model summary									
					Change statistics				
Model	*R*	*R* square	Adjusted *R* square	Std. error of the estimate	*R* square change	*F* change	*df*1	*df*2	Sig. *F* change
1	0.788[a]	0.621	0.621	0.16889	0.621	869.849	1	530	0.000

Source: Researcher's own compilation
[a]Predictors: (constant), job loss

Table 25.10 ANOVA loss of job and loneliness

ANOVA[a]						
Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	24.811	1	24.811	869.849	0.000[b]
	Residual	15.117	530	0.029		
	Total	39.928	531			

Source: Researcher's own compilation
[a]Dependent variable: loneliness
[b]Predictors: (constant), job loss

Table 25.11 Coefficients table of Loss of Job and Loneliness

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
1	(constant)	2.966	0.035		84.290	0.000
	Job loss	0.266	0.009	0.788	29.493	0.000

Source: Researcher's own compilation
[a]Dependent variable: loneliness

Table 25.12 Comparison of loneliness according to age group

Descriptive statistics						
Age of respondent		N	Minimum	Maximum	Mean	Std. deviation
Between 18 and 25	Loneliness	151	3.19	4.63	3.9590	0.27510
	Valid N (listwise)	151				
Between 26 and 35	Loneliness	243	3.19	4.56	3.9846	0.27792
	Valid N (listwise)	243				
36–45	Loneliness	92	3.25	4.50	3.9796	0.26421
	Valid N (listwise)	92				
Above 45	Loneliness	46	3.56	4.56	4.0408	0.27042
	Valid N (listwise)	46				

Source: Researcher's own compilation

The table shows there is strong correlation between loneliness and depression which is 70.8%. However, there is a very weak or almost no correlation between loneliness and anxiety (8%) (Table 25.15).

Due to weak correlation between loneliness and anxiety we fail to reject hypothesis H5 (ii).

R value shows a simple correlation which is 70.8%, which is high. 59.9% variation in depression can be explained by loneliness (Table 25.16).

Table 25.13 Comparing loneliness across gender

Descriptive statistics						
Gender		*N*	Minimum	Maximum	Mean	Std. deviation
Male	Loneliness	270	3.19	4.56	3.9833	0.28015
	Valid *N* (listwise)	270				
Female	Loneliness	262	3.19	4.63	3.9792	0.26848
	Valid *N* (listwise)	262				

Source: Researcher's own compilation

Table 25.14 Correlation between loneliness and depression, anxiety

Correlations				
		Loneliness	Anxiety	Depression
Loneliness	Pearson correlation	1	0.086[a]	0.708[b]
Anxiety	Pearson correlation	0.086[a]	1	0.012
Depression	Pearson correlation	0.708[b]	0.012	1

Source: Researcher's own compilation
[a]Correlation is significant at the 0.05 level (2-tailed)
[b]Correlation is significant at the 0.01 level (2-tailed)

The regression equation can be presented as Depression = 5.481 + 2.335*Loneliness. This indicates there is a strong positive relation between Loneliness and Depression and further paves the path to reject the null hypothesis H5 (i) (Table 25.17).

H6: Digital online Platform used by the people during COVID-19 will help ease loneliness to a certain extent.

The regression equation can be presented as loneliness = 4.979–0.09* virtual interaction through video conferencing—0.098* online entertainment—0.033* online awareness—0.098* counselling with doctors and Yoga –0.063* online opportunity for creativity—0.176* online Platform for jobs.

This shows that technology has a decreasing effect on the feeling of loneliness and thereby on its consequences (Table 25.18).

25.8 Conclusion and Recommendation

The current study focuses on five major objectives. First, identify the factors leading to loneliness during COVID-19 pandemic. Second, identify the effects of loneliness on mental health. Thirdly, to examine whether different age groups and different genders are effected differently by the factors leading to loneliness. Fourthly, whether technology helps in easing out the loneliness.

The first objective was determined through the literature study and the following factors were identified in leading to loneliness: lockdown, quarantine, social

Table 25.15 Model summary of effect of loneliness on depression

Model summary									
					Change statistics				
Model	*R*	*R* square	Adjusted *R* square	Std. error of the estimate	*R* square change	*F* change	d*f*1	d*f*2	Sig. *F* change
1	0.708[a]	0.601	0.599	0.502	0.601	871.849	1	530	0.000

Source: Researcher's own compilation
[a]Predictors: (constant), loneliness

Table 25.16 Coefficients table of loneliness on depression

Coefficients[a]						
		Unstandardized coefficients		Standardized coefficients		
Model		*B*	Std. error	Beta	*t*	Sig.
1	(constant)	5.481	0.316		17.350	0.000
	Loneliness	2.335	0.079	0.708	29.493	0.000

[a]Dependent variable: depression

Table 25.17 Coefficients table of and technology on loneliness

Coefficients[a]						
		Unstandardized coefficients		Standardized coefficients		
Model		*B*	Std. error	Beta	*t*	Sig.
1	(constant)	4.979	0.053		93.701	0.000
	Virtual interaction through video conferencing	−0.090	0.015	−0.194	−6.167	0.000
	Online entertainment	−0.098	0.016	−0.196	−6.250	0.000
	Online awareness	−0.033	0.017	−0.068	−2.007	0.045
	Counselling with doctors and yoga	−0.098	0.025	−0.137	−3.849	0.000
	Online opportunity for creativity	−0.063	0.019	−0.145	−3.383	0.001
	Online platform for jobs	−0.176	0.018	−0.418	−9.985	0.000

[a]Dependent variable: loneliness

Table 25.18 Overview of the hypothesis

Hypothesis	Supported/not supported
H1: The social distancing measures designed to reduce viral transmission during the pandemic are associated with increased loneliness	Supported
H2: Loss of job and income will tend to increase loneliness to a greater level	Supported
H3: There is no difference in levels of loneliness during COVID-19 across different age groups in the sample	Supported
H4: There is no difference in levels of loneliness during COVID-19 across different gender groups in the sample	Supported
H5: Elevated loneliness will be associated with more (i) depression and (ii) anxiety symptoms	(i) Supported (ii) Not supported
H6: Digital online platform used by the people during COVID-19 will help ease loneliness to a certain extent	Supported

distancing and loss of job. The second objective was identified by depression, anxiety, psychiatric disorder and insomnia as components of mental health. Third objective was obtained through analysis and has been summarized below and the fourth objective through analysis has also been summarized below.

After analysis of data it can be said the loss of job and social distancing measures are leading to a feeling of loneliness amongst people. It has been seen that the effect of loneliness is not different for various age groups and genders (H3 & H4).

It has been further established that technology plays an important role in easing loneliness in people during the pandemic (H5).

The following aspects are there for further research:

1. Besides, loneliness there are many other factors during pandemic that effect the mental health of a person. These factors can further be studied and the impact of technology on these factors.
2. The impact of social distancing and joblessness can be studied in semi-urban and rural area.
3. The penetration of technology in semi-urban and rural area during the pandemic can be studied.

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Psycho-economic Impact of Obligatory Job Switching During Covid-19 Pandemic: A Study of Hawkers in Bhubaneswar (India)

26

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Abstract

There is no vaccine for Covid-19 and hence social distancing, quarantining and cleanliness are the means to avoid the attack of the deadly virus. It has sought for prolonged lockdown across the globe to check the spread of the pandemic caused due to Covid-19. Except essential activities, all other activities have been stopped. Small business units, street shops, small traders including hawkers are struggling a lot for their livelihood. The hawkers who trade in very small scale to maintain their living on daily revenue basis are finding it tough to manage. However, hawkers dealing with essential items like vegetables, Fish and Meat are allowed to trade during lockdown. Thus, the hawkers dealing with non-essential commodities are the hardest hit of the situation. As such, they don't have savings to spend during lockdown and hence under compulsion, they are switching their job and trading essential commodities. Consequently, large number of hawkers dealing with vegetables and fruits are found now in Bhubaneswar, India. The aim of this chapter is to analyze the psychological and economic impact of compulsory job switching on switchers during the pandemic. Qualitative data collected by way of in-depth interviews and observation from 50 hawkers and 50 customers have been used. Besides, data collected on rating scale have been used to find Multiple Regression for assessing psycho-economic impact of obligatory switching of jobs on the hawkers.

Keywords

Socioeconomic · Impact · Job switching · Covid-19 · Hawkers · Bhubaneswar

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26.1 Introduction

Pandemic owing to Covid-19 has made the lives miserable. Self-employed in unorganized sector are the hardest hit owing to prolonged complete lockdown followed by partial lockdown. Small self-employed individuals like street hawkers dealing with non-essential commodities have lost their job. As a result, they are switching their job from dealing with non-essential commodities to essential commodities to earn some income and feed their families. However, their problem of earning income from new line of activities is there with a different dimension like issues of adaptability and acceptability. Getting themselves adapted to the new setup and being accepted by a new set of customers are not smooth sailing for them, that too, midst existing veteran hawkers in their old set up. Street hawkers who deal with essential commodities are continuing their activities as they are allowed to continue even during lockdown. However, their situation is not as it was previously for two counts. First, as such, the demand for their products has been decelerated owing to economical approach of the customers for lockdown restrictions and fall in the average income of the customers' community. Second, advent of new hawkers, i.e., the switchers, in their setup has reduced their sales volume and profit margin owing to unsystematic competition.

Job switching can happen voluntarily or under compulsion. Chadi and Clemens (2014) infer that obligatory job switching has different experience than voluntary job switching. Job switching due to plant closure, per se, which is obligatory, has no causative effect of job changes on job satisfaction. When workers prefer to change the employer voluntarily, they find comparatively high level of job satisfaction, though only in the short run.

Binder and Coad (2013) find that if an individual having regular employment moves from regular employment into self-employment, s/he experiences an increase in life satisfaction after a certain time period. However, if an individual moves from unemployment to self-employment, s/he is not more satisfied than his/her counterpart who moves from unemployment to regular employment. While the former corresponds to "opportunity" entrepreneurship, the latter corresponds to and "necessity" entrepreneurship.

This study is all about obligatory job switching because of Covid-19 pandemic. Moreover, here job switching means switching from one mode of self-employment to another mode. In fact, as the pandemic has disallowed most of the activities that are prone to spread of the deadly virus, there has been concentration in a few activities that are allowed. Consequently hawkers selling street foods like "Dahibara-Aloodam," "Gupchup," "Chat," "Momo," "Idli-Samosa," "Pao Bhaji," "Fast food," etc. lost their livelihood. As they are not that well-to-do to manage their expenditure from their past savings, they ventured to start selling vegetables which comes under essential items and hence are allowed during pandemic. However, their entry into the Vegetables market brought forth distortion in the market as the number of sellers shoot up substantially. Since they are new to this line of work, they don't have the expertise to handle the business smoothly. Thus, there was inconvenience for them and competition to the existing hawkers. On this backdrop, the basic objective of this chapter is to explore psycho-economic status of both the groups of the hawkers after obligatory job switching of the hawkers from non-essential items to essential items. Besides, comparison of satisfaction level of both the groups of the hawkers on different work dimensions is also another objective of this chapter.

26.2 Materials and Methods

This is a descriptive research based on mixed method. Both qualitative and quantitative approaches have been followed at all the stages starting from data collection to data analysis and presentation. In this study, two populations have been considered—(a) Hawkers dealing with essential items and (b) Hawkers dealing with non-essential items but have switched to essential items owing to the pandemic. Accordingly, two samples of size 50 each have been used. Selection of sample units has been done on convenience. Since the entire humanity is passing through a trying situation, collecting data was the toughest task of this study. Street vendors in the vicinity of the researcher's location were approached.

Both direct personal interview and observation method were used to collect data. To have the cooperation of the vendors, business rush hours were avoided for their interview. Instead, during their rush hours, observation method was followed to know exactly how they were handling the situation. Were they really remaining cool or getting perplexed? Were they prone to doing mistakes in calculation, weighing and conversing with customers and fellow vendors? The observation method followed was non-participatory. In fact, some of the variables used in this study to gather data on rating scale are the outcome of observation method.

With the entry of new hawkers, those who switched their business from non-essential to essential items, the market of essential items, particularly vegetables got bifurcated from the seller's point of view. Thus, two samples are picked up to know whether they are impacted in a positive way or negative way. Since the objective of this chapter is to assess the psycho-economic impact of obligatory job switching, the criterion variable fixed was overall satisfaction level for each of the samples. To assess whether both the samples are satisfied or not 15 predictor variables are identified. For comparison purpose, same set of variables have been used for both the samples.

Data collected on rating scale in line with a questionnaire was done during lean time of the day from business perspective. They were not dealing with the questionnaire. In conversation with the vendors, the researcher was rating each variable.

Statistical techniques used in this study are; Reliability Statistics (Cronbach's Alpha), Descriptive statistics, *t*-test, ANOVA, and Multiple Regression.

26.3 Psycho-economic Status of Hawkers of Non-essential Items in the Market of Essential Items

The variables identified to assess the satisfaction of the hawkers of non-essential items in the market of essential items are; There is Security of work in new line of work (V1), Amount of Earning from new line is as expected (V2), Peer support in new line of work is as expected (V3), Chance of doing mistake in new line of work is high (V4), Customers' confidence on you in new line of work is high (V5), Satisfaction level of family members in your new attempt is considerable (V6), Growth Prospects is high in the line of work (V7), New work is Challenging and interesting (V8), Friendly atmosphere is missing in new engagement (V9), Self-respect is there pertaining to work (V10), Duration of work is appropriate (V11), Safe working conditions is there (V12), Tension and pressure at work is huge (V13), Autonomy at work is high (V14), Intent of re-switching if chance comes (V15), and Overall Satisfaction at work (V16). Variable V16 is the dependent variable and Variables V1, V2, ... and V15 are independent variables.

Data collected on these variables from 50 hawkers who were dealing with non-essential items before the outbreak of COVID-19 pandemic and have switched to essential items during the pandemic in a 5-point rating scale.

26.3.1 Reliability Test of the Variables

Table 26.1 exhibits the case processing summary and Table 26.2 depicts the reliability statistics.

Although the undisputed value of Cronbach's Alpha is 0.7 and more, the values of Cronbach's Alpha above 0.6 are also accepted (Van Griethuijsen et al. 2015; Taber 2018). Since it is 0.622 in this case, it is acceptable for this study.

In order to ascertain the level of psychological and economic satisfaction of the hawkers, who have switched their profession from dealing with the non-essential items to essential items, ANOVA and Regression Analysis is done.

Table 26.1 Case processing summary

		N	%
Cases	Valid	50	100.0
	Excluded[a]	0	0.0
	Total	50	100.0

[a]Listwise deletion based on all variables in the procedure

Table 26.2 Reliability statistics

Cronbach's alpha	N of Items
0.622	16

26.3.2 ANOVA for Hypothesis Testing

Null Hypothesis: Hawkers of non-essential commodities, after switching to essential commodities, are not satisfied in the new market psychologically and economically.

For testing the null hypothesis, ANOVA was computed and presented in Table 26.3.

The p-value, as presented in sixth Column of Table 26.3, is 0.048 and the level of significance (i.e., α) is usually taken 0.05 for this type of research. Since the p-value is smaller than the level of significance, we will not accept the null hypothesis. Thus, it is inferred that Hawkers of non-essential commodities, after switching to essential commodities, are satisfied in the new market psychologically and economically. Prior to entering into the market of essential commodities, hawkers of non-essential commodities were jobless and living a miserable life. As they have entered into the market of essential commodities, they are engaged now and earning something for their families although with lot of pain and inconveniences.

26.3.3 Regression Analysis for Identifying the Variables That Matter

In order to know the variables that significantly influence the satisfaction level of the Hawkers of non-essential commodities, after switching to essential commodities, Regression coefficients are considered as presented in Table 26.4.

Out of 15 independent Variables, "p" values for two variables V9 (Friendly atmosphere) and V11 (Duration of work) are less than the "α" value. Thus, these two independent variables significantly influence the dependent variable and the Regression Model is; $V16 = 1.290 + 0.221V9 - 0.601V11$.

Since the algebraic sign of coefficient of V11 is negative, there is an inverse relationship between duration of work (V11) and overall satisfaction of the hawkers who have switched from non-essential items to essential items (V16). It indicates that if the duration of work is more the satisfaction level of the hawkers is less and the vice versa.

Another variable V9 has direct influence on V16. It means, if atmosphere is more friendly (V9), the satisfaction level of the hawkers is more and the vice versa.

To know the level of impact of each independent variable on the dependent variable, the standardized regression coefficients (Beta) is to be considered. If the β value of a variable is greater, the said variable influences the dependent variable

Table 26.3 ANOVA[a]

Model		Sum of squares	d*f*	Mean square	*F*	Sig.
1	Regression	12.176	15	0.812	1.985	0.048[b]
	Residual	13.904	34	0.409		
	Total	26.080	49			

[a]Dependent Variable: v16

[b]Predictors: (Constant), v15, v5, v6, v8, v12, v7, v1, v9, v4, v2, v3, v11, v10, v13, v14

Table 26.4 Regression coefficients[a]

Model		Unstandardized coefficients		Standardized coefficients		
		B	Std. error	Beta	*t*	Sig.
1	(Constant)	1.290	1.905		0.677	0.503
	v1	−0.052	0.170	−0.059	−0.305	0.762
	v2	−0.075	0.173	−0.076	−0.434	0.667
	v3	−0.053	0.198	−0.057	−0.265	0.793
	v4	0.016	0.185	0.017	0.088	0.931
	v5	0.234	0.172	0.231	1.359	0.183
	v6	0.165	0.214	0.121	0.771	0.446
	v7	0.338	0.191	0.327	1.765	0.087
	v8	−0.019	0.126	−0.021	−0.150	0.881
	v9	0.221	0.101	0.351	2.189	0.036
	v10	−0.063	0.318	−0.050	−0.200	0.843
	v11	−0.601	0.290	−0.923	−2.071	0.046
	v12	0.023	0.082	0.041	0.285	0.778
	v13	0.029	0.163	0.049	0.179	0.859
	v14	−0.143	0.319	−0.216	−0.449	0.656
	v15	0.259	0.327	0.530	0.791	0.435

[a]Dependent variable: v16

more. As presented in Table 26.4, β value for two significant variables are; V9 = 0.351 and V11 = −0.923. Absolute value of β is the highest for V11, which means that this variable has the highest level of impact on the dependent variable in an inverse way.

26.4 Psycho-economic Status of Hawkers of Essential Items

The variables identified to assess the satisfaction of the hawkers of essential items are; There is Security of work even after addition of new hawkers (V1), Amount of Earning is as expected (V2), Peer support is as expected (V3), Chance of doing mistake midst competition is high (V4), Customers' confidence on you is high (V5), Satisfaction level of family members in your performance in changed situation is high (V6), Growth Prospects is high in spite of intense competition (V7), Your work now is Challenging and interesting (V8), Friendly atmosphere is missing (V9), Self-respect is there pertaining to work (V10), Duration of work is appropriate (V11), Safe working conditions is there (V12), Tension and pressure at work is huge (V13), Autonomy at work is high (V14), Intent of switching if chance comes (V15) and Overall Satisfaction at work (V16). Variable V16 is the dependent variable and Variables V1, V2, ………… and V15 are independent variables.

Data collected on these variables from 50 hawkers who have been dealing with essential items in a 5-point rating scale.

26.4.1 Reliability Test of the Variables

Table 26.5 exhibits the case processing summary and Table 26.6 depicts the reliability statistics.

Since Cronbach's Alpha is 0.674 in this case, it is acceptable for this study.

In order to ascertain the level of psychological and economic satisfaction of the hawkers, who have been dealing with essential items prior to the outbreak of pandemic, ANOVA, and Regression Analysis is done.

26.4.2 ANOVA for Hypothesis Testing

Null Hypothesis: Existing Hawkers of essential commodities are not satisfied psychologically and economically in the new market that includes new hawkers who have switched from non-essential to essential commodities.

For testing the null hypothesis, ANOVA was computed and presented in Table 26.7.

The p-value, as presented in sixth column of Table 26.3, is 0.359 and the level of significance (i.e., α) is usually taken 0.05 for this type of research. Since the p-value is greater than the level of significance, we will accept the null hypothesis. Thus, it is inferred that existing hawkers of essential commodities are not satisfied psychologically and economically in the new market that includes new hawkers who have switched from non-essential to essential commodities. Prior to the entry of the new hawkers in the market for essential items, the existing hawkers were having a good deal of business with sound customer base. As due to Covid-19 pandemic, the hawkers of non-essential items entered into the market for essential items, the

Table 26.5 Case processing summary

		N	%
Cases	Valid	50	100.0
	Excluded[a]	0	0.0
	Total	50	100.0

[a]Listwise deletion based on all variables in the procedure

Table 26.6 Reliability statistics

Cronbach's alpha	N of Items
0.674	16

Table 26.7 ANOVA[a]

Model		Sum of squares	d*f*	Mean square	*F*	Sig.
1	Regression	19.228	15	1.282	1.142	0.359[b]
	Residual	38.152	34	1.122		
	Total	57.380	49			

[a]Dependent variable: v16

[b]Predictors: (constant), v15, v12, v5, v1, v6, v8, v2, v9, v3, v4, v7, v10, v11, v13, v14

existing hawkers have lost some of their market share. Owing to stiffer competition, the margin per unit of sales and total profit of the existing hawkers have been declined. Besides, they are realizing the pressure of survival. All these are the contributors of their dissatisfaction.

26.4.3 Regression Analysis for identifying the Variables That Matter

In order to know the variables that significantly influence the satisfaction level of the existing hawkers of essential commodities in the new market, Regression coefficients are considered as presented in Table 26.8.

Out of 15 independent Variables, "p" values for two variables V10 (Self-respect) and V13 (Tension and pressure at work) are less than the "α" value. Thus, these two independent variables significantly influence the dependent variable and the Regression Model is; $V16 = 1.290 - 0.909V10 - 0.586V13$.

Since the algebraic signs of coefficients of both V10 and V13 are negative, there is an inverse relationship between self-respect (V10) and overall satisfaction of the existing hawkers (V16). It indicates that in spite of having higher self-respect in the new market owing to their perpetual presence, the satisfaction level of the hawkers is less. There is also an inverse relationship between "Tension and pressure at work" (V13) and overall satisfaction of the existing hawkers (V16). As it is found, in spite of high intensity of tension and pressure to have edge over the new hawkers midst stiffer competition, the satisfaction level of the existing hawkers is deteriorating.

Table 26.8 Regression coefficients[a]

Model		Unstandardized coefficients		Standardized coefficients		
		B	Std. error	Beta	t	Sig.
1	(Constant)	6.485	2.150		3.016	0.005
	v1	0.160	0.207	0.141	0.774	0.444
	v2	0.040	0.221	0.030	0.181	0.857
	v3	−0.172	0.212	−0.146	−0.811	0.423
	v4	−0.306	0.280	−0.217	−1.093	0.282
	v5	0.216	0.272	0.129	0.794	0.432
	v6	0.090	0.358	0.044	0.251	0.803
	v7	0.114	0.309	0.074	0.368	0.715
	v8	0.412	0.215	0.309	1.913	0.064
	v9	−0.105	0.165	−0.112	−0.635	0.530
	v10	−0.909	0.425	−0.485	−2.137	0.040
	v11	0.174	0.417	0.181	0.419	0.678
	v12	−0.078	0.137	−0.093	−0.568	0.574
	v13	−0.586	0.262	−0.659	−2.239	0.032
	v14	−0.196	0.462	−0.200	−0.425	0.674
	v15	0.537	0.475	0.741	1.130	0.267

[a]Dependent variable: v16

To know the level of impact of each independent variable on the dependent variable, the standardized regression coefficients (Beta) is to be considered. If the β value of a variable is greater, the said variable influences the dependent variable more. As presented in Table 26.8, β value for two significant variables are; V10 $= -0.485$ and V13 $= -0.659$. Absolute value of β is the highest for V13, which means that this variable has the highest level of impact on the dependent variable in an inverse way.

26.5 Comparison of Satisfaction Between Existing and New Hawkers in Essential Items Market

After ascertaining whether each of the sets of hawkers satisfied in their performance in the essential items' market that has been restructured, it is pertinent to assess the comparison of their satisfaction on different attributes of their work. In fact, the same set of predictor variables used in rating scale have also been used for comparison through *t*-test as presented in Table 26.9.

As revealed in Table 26.9, overall, existing hawkers are more satisfied than the new hawkers. It is obvious as they were nearly optimally satisfied before the entry of new hawkers to their line. In fact, the new hawkers are not satisfied in their new line of work as the mean satisfaction level is just 34% as against the overall satisfaction level of the existing hawkers is 76% in spite of competition from the new hawkers.

Job attributes that contribute most to the dissatisfaction of new hawkers are tension and pressure at work followed by missing friendly atmosphere. Tension of attracting customers, dealing them suavely, not hurting the existing sellers and not doing any mistake that put them in trouble keep the new hawkers under pressure in the new market of essential items. Besides, they miss friendly atmosphere in new market with which they were accustomed to in their original market.

Attributes that give solace and contribute to the satisfaction of new hawkers are self-respect followed by duration of work. As soon as the outbreak of the pandemic owing to COVID-19, all the hawkers dealing with non-essential items lost their work and could not earn a single penny to feed their families. They had to depend either on transfer payments or on borrowings. Thus, they had lost self-respect owing to sitting idle. As they switched their profession from dealing non-essential items to essential items, they got engaged and earn something to feed their families. This way, they gained then self-respect. Moreover, they are also satisfied with the work duration as the lockdown had condensed the duration of selling hours and selling days.

The only attribute in which the new hawkers are more satisfied than the existing hawkers is "amount of earning." As such, there has been considerable decline in the volume of earnings of both existing hawkers and new hawkers because the market potential has been reduced owing to lockdown. Adding to that, the number of sellers has been increased due to entry of hawkers of non-essential items in this market of essential items. Since the existing hawkers lost some of their earnings to the new entrants, they are highly dissatisfied. On the other hand, hawkers of non-essential items were completely jobless owing to lockdown. As they switch to deal with

Table 26.9 Satisfaction of existing hawkers and new hawkers on different attributes of their work

Job attributes	Respondents	Mean	Standard deviation	*t*-statistic	Significance
Dependability of profession	Existing Hawkers	3.5400	0.95212	26.290	0.000
	New Hawkers	2.6200	0.83029	22.313	0.000
Amount of earning	Existing Hawkers	2.2800	0.80913	19.925	0.000
	New Hawkers	2.5200	0.73512	24.240	0.000
Peer support	Existing Hawkers	3.8200	0.91896	29.393	0.000
	New Hawkers	2.6800	0.79385	23.871	0.000
Chance of doing mistake	Existing Hawkers	3.0600	0.76692	28.214	0.000
	New Hawkers	3.0600	0.76692	28.214	0.000
Customers' confidence	Existing Hawkers	4.3000	0.64681	47.008	0.000
	New Hawkers	2.6400	0.72168	25.867	0.000
Satisfaction of family members	Existing Hawkers	2.1400	0.53490	28.289	0.000
	New Hawkers	2.1400	0.53490	28.289	0.000
Growth Prospects	Existing Hawkers	2.5200	0.70682	25.210	0.000
	New Hawkers	2.5200	0.70682	25.210	0.000
Challenging and interesting work	Existing Hawkers	2.5600	0.81215	22.289	0.000
	New Hawkers	2.5600	0.81215	22.289	0.000
Missing friendly atmosphere	Existing Hawkers	3.3800	1.15864	20.628	0.000
	New Hawkers	3.3800	1.15864	20.628	0.000
Self-respect	Existing Hawkers	3.4400	0.57711	42.148	0.000
	New Hawkers	3.4400	0.57711	42.148	0.000
Duration of work	Existing Hawkers	3.2600	1.12141	20.556	0.000
	New Hawkers	3.2600	1.12141	20.556	0.000

(continued)

Table 26.9 (continued)

Job attributes	Respondents	Mean	Standard deviation	*t*-statistic	Significance
Safe working conditions	Existing Hawkers	3.1600	1.29929	17.197	0.000
	New Hawkers	3.1600	1.29929	17.197	0.000
Tension and pressure at work	Existing Hawkers	3.5000	1.21638	20.346	0.000
	New Hawkers	3.5000	1.21638	20.346	0.000
Autonomy at work	Existing Hawkers	3.3600	1.10213	21.557	0.000
	New Hawkers	3.3600	1.10213	21.557	0.000
Intent of switching/re-switching	Existing Hawkers	3.1200	1.49339	14.773	0.000
	New Hawkers	3.1200	1.49339	14.773	0.000
Overall satisfaction	Existing Hawkers	3.8200	1.08214	24.961	0.000
	New Hawkers	1.7200	0.72955	16.671	0.000

essential items, they could earn something. Although the volume of earnings they are generating in new line is much less, they are satisfied to some extent for at least earning something to feed their family.

Job attributes that contribute most to the satisfaction of existing hawkers are customers' confidence followed by peer support. Since they have been there in this market since long, each one of them has some loyal customers. Thus, customers' confidence is one of the attributes that motivate them. Besides, peer support is also a plus for them as they know each other for long and have been helping each other.

26.6 Conclusion

The pandemic due to Covid-19 has distorted the psycho-economic state of hawkers' community. Hawkers selling non-essential commodities have lost their work and hence earnings. For their living, they have entered to the market of essential commodities, particularly vegetables which has already enough number of sellers. As a result, the competition among the vegetables sellers has gone up, but the demand of vegetables in the market has somehow declined as customers are having fear psychosis for the virus. Thus, the existing hawkers have lost a great junk of their earnings but new hawkers are earning at least something which is better than being idle and earning nothing. This situation has put pressure both psychologically and economically on both the sets of hawkers. While new hawkers are somehow satisfied in the vegetables market owing to their move from zero earnings to some positive earnings, existing hawkers are dissatisfied as their earnings have been declined.

While new hawkers are selling vegetables, without having proper expertise, they are failing to give justice to their work. Since it is a trying period for the entire humanity, intervention from the government and non-government bodies are necessary. The street vending for both essential and non-essential items need it badly. Intervention should not be in the form of transfer payments. Instead, for feeding poor and destitute during pandemic, the service of hawkers dealing with street foods may be utilized so that the hawkers will not lose their work and will earn for their living, staying in their line of work and obeying the Covid-19 restrictions. In fact, obligatory job switching, which has more disadvantages than advantages, needs to be avoided as far as possible. Similarly, intervention in the form of supplying vegetables in the doorsteps of the household may be initiated so that the vegetable vendors won't lose their usual demand.

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Artificial Intelligence's Role in Essential Commodities During a Pandemic Situation

27

Gurinder Singh, Vikas Garg, and Neha Puri

Abstract

Essential commodities are always on demand by people at a nominal rate during normal operations but due to COVID-19 and various other reasons, there is a sudden rise in demand for essentials goods. Every marketer who was not associated with essential goods tried to reposition their marketing strategy and tried to incorporate essential goods. During COVID-19, many people have turned towards essential goods sector for a living, and because of the rising demand and supply challenge, the government has acted to make essential products available to even the poorest parts of society. Artificial Intelligence (AI) would be essential to the supply chains of the next decade, effortlessly combining long haul to last-mile capabilities with commodity production, availability, and markets. Supply chains facilitated by AI can also help to respond to emergencies and pandemics quicker and faster, saving lives. The present study determines the important key points to be considered for formulating the utility and traceability of Artificial Intelligence in making the availability of essential goods.

Keywords

AI · Essential commodities · COVID-19 · Society · Supply chain

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27.1 Introduction

27.1.1 COVID-19 and Its Effect on Essential Goods

In December 2019, an infectious disease called coronavirus (COVID-19) emerged from a seafood market in Wuhan, China. This disease has spread to around 210 countries and it created a nationwide crisis. The first case of coronavirus emerged in the end of 2019 when an unidentified disease was found in Wuhan, China, and after investigation, the World Health Organization (WHO) confirmed this infection as coronavirus. On 11 February, the World Health Organization named the illness COVID-19. This disease resulted in a pandemic; pandemic means which is widespread across the country. In fact, the official name of this virus was given by the International Committee on Virus Taxonomy as 'Severe Acute Respiratory Syndrome Coronavirus' or SARS-Cov-2, since it was identical to the virus that was found in China in 2003, but to clearly distinguish the World Health Organization officially called it as COVID-19. Governments reacted towards the situation as the demand for essential goods increased due to the lockdown announced by almost all the countries. All the industries were shut down except essentials. Industries relating to essentials were provided with necessary permissions to work by avoiding and eliminating contact between people because essential goods were of utmost need for people at this situation as this turned into a nationwide crisis. All the countries are trying to collaborate to uplift the economy as soon as possible by supplying the necessary essentials as neither the government nor the citizens expected that this virus will become such a global crisis and result in aa pandemic.

In India, the Prime Minister of India first declared a lockdown of 21 days and then extended the lockdown until 17 May 2020 and this will continue until the virus is eradicated from the world, while other countries are doing the same by announcing work from home to all industries other than those supplying medicines and basic goods to the people. Stay safe and stay home policy is established by the government to keep the people protected. Staying at home demanded an increased amount of essential goods because people will not skip meals and less availability of junk foods. So, governments gave necessary permissions to set up stores providing essential goods to fulfil the demand of the people, as food is the basic need for living. So, necessary permissions were given by the government to set up stores providing essential goods to fulfil the demand of the people, as food is the basic need for living. So, necessary permissions were given by the government to set up stores providing essential goods to fulfil the demand of the people, as food is the basic need for living. Everything can be controlled like social distancing and working of industries, but the food providers were at the major need, and they were working keeping themselves at risk. But essential goods industries continued to fulfil the needs of the people with limited working hours as prescribed by the government.

27.1.2 Essential Goods

Essential goods are the products which are essential for the survival of human beings. The word essential depicts that these are important for people; it includes products such as food stuff, fuel, fertilizers, edible oils, and seeds of crops—fruits, vegetables, etc. were considered as essential goods before this coronavirus pandemic. During this situation the government felt the need of increasing the products in the list of essential goods. The Government of India has passed an act for essential commodities called Essential Commodities Act 1955 which is about providing essential products at fair prices to all the citizens so the government had decided to expand the list by including masks and hand sanitizers so that they are easily available to all people without any inflated prices.

27.1.3 Market Situation Before COVID-19

Market situation of marketers and consumers before this situation was balanced as both the marketers and consumers were doing their normal operations by buying the essential goods when the consumer needs them and marketers were selling the goods when the consumer has a demand for it. In India the government keeps control on stockpiling of essential goods. Marketers can stock these goods to a limited quantity according to the Essential Commodities Act 1955 and when the government stockpiles up they sell the stock at subsidized rates to the general public. This situation was beneficial to both marketers and consumers.

27.1.3.1 Benefit to Marketers

1. Easy availability of labour: Production of goods needs labours to produce the goods. They need labour for assembly of produced goods and for converting raw material to finished goods. Labours were easily available to marketers.
2. Consumers approach themselves: In normal conditions when the consumers need essential goods, they approach the retail or wholesale stores for their needs, so there was no need for marketers to approach them.
3. Easy availability of raw materials: Before COVID-19, there were no issues with the supply of raw materials because labour and materials were available, so marketers were getting the raw materials easily.
4. Transportation facilities: There was no restriction on the movement of people and vehicles so the marketers were easily avail transportation facilities such as trucks, tractors, railways, airways, ships, etc.

27.1.3.2 Benefit to Consumers

1. Easy access to the market: Consumers can visit any market at any time for the purchase; they were not restricted to purchase from a specific place or at a specific time.

2. Wide offers available: As consumers were the king of the market they were given different offers by the marketers wherein they can smart buy and save their money as well.
3. No need of bulk shopping: As goods were made available to consumers to buy at any time, there was no need for them to do bulk shopping or store the goods for future.
4. Reasonable prices: Consumers were offered reasonable prices for essential goods; they were offered some discounts, but in the case of fast-moving consumable goods, they are always offered at MRP.

27.1.4 Market Situation During COVID-19

In this case, both consumers and marketers faced difficulties in keeping business moving because of this situation and consumers were faced with difficulties in purchasing products, as the situation would not allow them both to travel and to operate in regular activities.

27.1.4.1 Benefits to Marketers

1. Clearance of stock: Marketers got the opportunity to sell the old stock to their consumers at high prices as all the consumers panicked and started bulk shopping.
2. Payments in bulk: Consumers started buying in large quantities thinking of future which helped marketers to get payments in bulk.
3. Advertisement cost is low: During COVID-19 the advertisement cost was low as everything was shut down so marketers started online advertisements and increased the number of ad shown on television to create more awareness about their products by investing less for advertisement.

27.1.4.2 Disadvantages to Marketers

1. Reduced production: There was difficulty in getting labour, raw material, and employees because of the shutdown of industries so there was no new production of goods.
2. Permission to limited stores: Very few retail stores in a particular area are given permission to open with timing constraints so the retail stores which are not provided with permission suffered losses.
3. Rebuilding the trust in the market: In this situation, the marketers have to rebuild the trust in consumers that the marketers are taking proper care and following the guidelines of proper sanitation for the products to ensure sales. This becomes a major issue for marketers to attract customers.
4. Coordination: Coordination became an issue for marketers as the supply of products did not match the demand of products so retaining customers was a major task faced by marketers.

5. Knowledge of online marketing: The marketer who do not have enough knowledge about online marketing has to learn online marketing as people were shifting to online shopping for reducing close contact between people.

27.1.4.3 Benefits to Consumers

1. Access to online shopping: Through online marketing consumers have a major advantage of buying online; otherwise they were not left with the choice of online buying and the only way for them to buy is from retail stores or departmental stores.
2. Increased home delivery options: Consumers were provided with the home delivery option by the local retail and departmental stores in addition to major online retailers.

27.1.4.4 Disadvantages to Consumers

1. Restriction on buying: Consumers cannot move freely to buy at any time when they need as they have to follow specific time and guidelines mandated by the government.
2. Availability of funds: Every consumer needs money to buy goods and as the current situation does not allow them to work many of the underprivileged people do not earn and even some salaried people faced reductions in their salaries so they do not have available funds to buy goods.
3. Compromising needs: The consumer is compromising with their needs according to the availability of goods, e.g. if the consumers used Pepsodent toothpaste earlier but now if Colgate toothpaste is only available, they buy the available product thinking of future and the panicked condition of the market.
4. Inflated prices: Marketers are taking advantage of the situation and are selling goods at inflated prices to consumers. Majorly, vegetables and fruits are offered at inflated prices to the general public.
5. Learn online shopping: Many of the consumers are not aware to how to shop online so they have to learn online shopping for buying.

27.1.5 Industries Working During COVID-19 Relating to Essential Goods

Many industries are working even in this situation as the need for essentials gave rise to the demand and they work for fulfilling the needs of the consumers and will continue to satisfy their wants when almost all the other industries are shut down. Industries related to essential goods continue to make sales, and some are earning high profits at this situation due to the demand for certain products, which are mentioned below.

27.1.5.1 Organic Products

With regard to vegetables and fruits, many people other than farmers touch them, and as this situation is related to touching and getting infected, people are moving to organic products like organic dal which have been produced before this situation which involves less physical contact.

27.1.5.2 Online Sites

Online sites in this situation are not allowed to sell all their products, but they are allowed to sell essential goods which are in high demand; in addition to that they offer home delivery option which attracts consumers to buy from these sites.

27.1.5.3 Online Apps

Online applications such as Grofer's, BigBasket, Easyday, etc. that sell groceries were not well known earlier. These apps become much more prominent and people started buying groceries which are essential goods.

27.1.5.4 Sanitation Products

The government has made hand sanitizers and masks essential goods so this industry had a rapid growth at this time. The demand for hand sanitizers rose too much in this situation as it is essential for self-sanitation and thereby to prevent from this virus.

27.1.6 Marketers Strategy to Fulfil Demand of Consumers

In this situation, as essential goods are in high demand for the whole population, it made marketers think of different strategies and change their marketing plans to fulfil the needs of the consumers. Because of these situations, consumers became more conscious and were demanding goods that are fulfilling their safety needs. Earlier, marketers made the consumers aware of these, but now consumers themselves are becoming aware of the situation and so marketers need to think in that way. Hence, marketers provided various options, and how they are fulfilling the demands are as follows:

27.1.6.1 Launching Apps

Marketers are keeping their main focus on launching apps for their products so that consumers are attracted to buy because during this situation people are unwilling to move out from their homes. Launching apps will help the consumer to buy online, like Domino's started selling Atta, milk, and species. Shiprocket is an app which delivers essentials within 15 km.

27.1.6.2 Providing Home Delivery

Every marketer is ensuring in their policy that they are providing home delivery options to their consumers in this situation as consumers' demand is to get the goods at their door steps with zero contact.

27.1.6.3 Rebuilding Trust

Trust is the major challenge faced by marketers at this moment as people are doubtful of every product they are buying so there is a need to ensure that they are following proper sanitation of their products and providing healthy and fresh products to their customers.

27.1.6.4 Rise in Market of Substitute Goods

Substitute goods that were not on demand among people earlier are now being used because of the non-availability of the main products. For example, if milk is not available, people have started using milk powder, and if ghee is not available, people are taking butter.

27.1.7 Consumer and Their Buying Behaviour

The consumer is a person who is the user of the final product in the market. Consumers are the people for whom the goods have been produced, and it is important to study their behaviour towards the goods so that the marketer designs the products according to the needs of the consumer. Nowadays, consumers have become more and more aware and informative and they need a reason for every change in the products which in turn arises a need for the marketers to know their consumers. To analyse the consumer behavior during COVID-19, the consumers are classified into various types according to some factors that affect the buying behavior of the consumers. These factors are as follows:

27.1.7.1 Education

Education is a factor which helps the person to think of themselves and the country as in this situation the basic factor is to maintain social distancing and avoiding close contact and proper sanitation, and education helps the person think this way that they are responsible citizen of the country. It helps the person to increase their awareness and knowledge regarding the situation. People are divided into three categories:

- Highly educated: Consumers who are highly educated know various alternative from where they can buy goods keeping in view COVID-19; they tend to behave as responsible citizens and shop accordingly; mostly they are the people who go for online shopping.
- Literate: Literate consumers may behave responsibly or may not because they tend to behave according to the situation; if they understand the situation they act responsibly and many times they do not understand the situation and do panic shopping.
- Illiterate: Illiterate people majorly are those who are not aware of the situation and are mainly underprivileged with limited funds who shop every day for their living keeping their lives at risk.

27.1.7.2 Money

Money is the factor which mainly affects the buying behaviour of consumers. As every consumer needs money to buy goods, the availability of funds becomes the prime concern to every consumer during this situation. Money also divides the consumers into three categories:

- Upper class: Upper class people like businessmen operating on large scale, celebrities, and all upper class groups are not compromising with their needs as they do not have any issue with availability of funds, as in India this category of people helped the country by donating to Prime Minister Relief Fund by themselves for providing essential goods or food to the needy. TATA has donated 1500 Crores, Reliance Foundation announced ‘Mission Anna Sava’ for providing food to the poor, Amitabh Bachchan provides monthly essential goods to 1,00,000 households, and many others are doing the same.
- Middle class: Middle-class people are suffering because this situation involve businessmen operating on a small scale industries that are completed shut down, and hence, there is no earning, and salaried people are getting a reduction in their salaries as many companies have cut 50% of the salaries because of working from home. This category of people who are compromising with their needs due to this situation is doing compromised shopping thinking of the future.
- Lower class: Lower class people are earn daily and buy essential goods daily. Now, lockdown has stopped their earning and brought them to roads, keeping their lives at risk. They are moving to their native places wherein they have a hope of getting essential goods, and this section is majorly suffering due to this situation as they are finding some way out to earn and buy their basic necessity, i.e. essential goods.

27.1.7.3 Awareness Level

Because of the COVID-19 situation, consumers have become conscious and their buying behavior have changed accordingly. Awareness level of the individuals affects their buying behavior, and based on that, consumers have been divided into two categories:

- Aware: People who are aware of the situation do smart shopping by mainly opting for online shopping and shopping which involves zero contact delivery, and many of the uneducated people become aware of the situation and deal according to the situation and do smart buying.
- Not aware: Many of the upper class, middle class, and well-educated people tend to behave irrationally and become unaware of the situation and do panic shopping.

In this situation, the government has also taken various measures to cure the infection and to make available essential goods to every person. The government has also reduced the import restrictions and allowed the movement of essential goods. As the demand for daily staples has increased because of the bulk shopping of people as everyone want to store the essentials for the future, the government has provided the retailers with all the necessary permissions, keeping in view of the situation to fulfil the needs of people regarding essentials.

27.2 Literature Survey/Related Work

Education is a factor which enables people to think as smart buyers while making purchase decision. Women make conscious decisions when it comes to buying of products. Sanlier and Seren Karakus (2010) noted that education is an essential factor in making a smart purchase when it comes to food items, but they do not consider the uneducated and how they can be taught how to make smart purchases based on their income level. Future research can be done in the area where it will suggest various ways to people to become more aware while shopping and should shop keeping in view the benefits the goods are providing to them. Thangasamy and Patikar (2014) described that the main factor that influences the behavior of the consumer is the need for the goods, and the other factor that influences the consumer in purchase is the advertising of the product. The marketer recommendations also play an important role as they try to influence the customers to buy a certain brand and it often helps the marketer and is part of marketing. Hu and Jasper (2018) demonstrated that consumer attention is gained through emotions and feelings, and here the researcher lacks where he did not incorporate the emotional touch towards while buying from shopping malls and did not talk about creating an experienced shopping for the consumers. Stocchi et al. (2017) found that how the usage rate of the brand and the image of the brand are connected to each other. Another objective was to find out which types of apps are appealing to customers and to know that how Apps of any brand can bring in more customers toward the product. Nelson-Field et al. (2012) focused on covered one social media platform, which is Facebook. The research also covers other social media platforms, which are common nowadays to provide a broader picture to the research. Future research can be undertaken in the same area but providing a wider picture to the research by including more social media platforms makes the study more reliable for reference. Farhangmehr et al. (2000) stated that what consumers thought of retail stores and hypermarkets and how these huge markets had an effect on sales of retail stores. In addition, they demonstrated how retail stores have overcome the issues faced because of these hypermarkets taking into account consumer expectations. Durmaz (2014) analyzed the positioning and segmentation of the products as this creates an image of the product in the consumer before buying the product, so there is a need for repositioning of products in the minds of consumers. Future research direction can be in the area of where the marketing strategy STP can be used which can help to better understand consumer minds and wants for effective planning. Niazi et al. (2012) conducted the study to know what impact do ads have on the buying behavior of the consumer and to know which aspect of behavior, whether emotional or environmental, leads the consumer to buy the goods and found that how people react while watching an ad and what they expect after watching the advertisement. Prathiraja and Ariyawardana (2003) conducted the study to know if the consumer were aware of the health labels provided on the product and these nutrition labels induces the consumers to buy the goods Moreover, consumers were benefited by the labels provided on the package of goods. Mehrdad Salehi's (2011) study states that now the internet has become a major source of information to today's generation so the ultimate consumer of the marketer lies online as it has become a new trend in shopping. In today's world, the internet is easily accessible. The internet service provided to customers helped the marketer to sell their products through online platforms. The increasing demand for online marketing encourages the marketer to set up businesses online to attract new demands of people who are changing with time, and according to recent trends people are changing and so are their buying patterns. Meneely et al. (2009) conducted a study to learn about the senior consumer's expectations from goods in Ireland, as well as the advantageous purchasing conditions for this demographic. In their study, Bhaskaran and Hardley (2002) stated that people rely on television and articles to gain knowledge about the health benefits and nutrients needed for a healthy living. People are gaining knowledge about healthy living and eating and becoming more conscious about this (Table 27.1).

27.3 Methodology/Proposed Model of Assessment

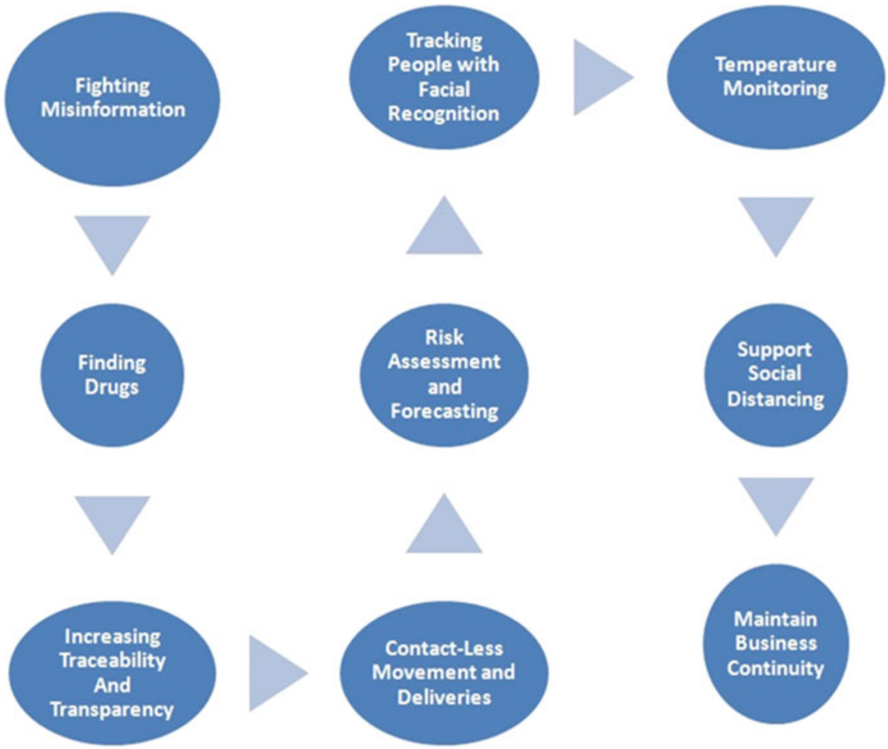

Table 27.1 Summary of related literature

Author/s	Essential commodities
Nevin Sanlier (2010)	Perception Questionnaire Purchasing Consumer behaviour Supermarkets
Thangasamy and Patikar (2014)	Consumer buying behaviour Nagaland Durables Marketing mix Decision-making process Brand preferences
Hu and Jasper (2018)	Browsing Socialization Activity Shopping for fashion products Uniqueness Service Aesthetics Escapism
Lara Stocchi and Carolina Guerini (2017)	Studies Brand image Online advertising Software Smartphones
Karen Nelson-Field, Erica Riebe, and Byron Sharp (2012)	Negative binomial distribution Facebook fan base Fast moving consumer goods Effective advertising
Farhangmehr, Marques, and Silva (2000)	Hypermarkets Traditional retail Buying behaviour Store image
Durmaz (2014)	Consumer Consumer behaviour Cultural factors Culture Subculture Social class
Niazi et al. (2012)	Environmental response Emotional response Consumer buying behaviour
Prathiraja and Ariyawardana (2003)	Consumer's awareness Nutritional label information Local food processors Willingness-to-pay
Mehrdad Salehi (2012)	Online shopping stores Consumers Internet shopping The Internet shop

(continued)

Table 27.1 (continued)

Author/s	Essential commodities
Meneely, Lisa, Strugnell, Chris, Burns, and Amy (2009)	Older consumer Food shopping Access Issues Satisfaction
Bhaskaran and Hardley (2002)	Consumer knowledge Beliefs Health campaigns Consumer needs Attitudes Market potential

The proposed model explains about the customers' need to fight against misinformation so that the appropriate drugs/medicines available can be traceable through different applications and that is how a level of transparency can be maintained. To stop any malfunctioning and misappropriation it is important to adopt Facial Recognition technique so that future risk can be ascertained and plan of action can be determined. The delivery procedure should be planned with contactless movement and temperature monitoring at the entry-level of office/residential zones. Everyone should be encouraged and motivated to maintain social distancing norms as formulated by the government and healthcare agencies.

27.3.1 Experiment Analysis/Results

- **Fighting Misinformation**
  Misinformation about the number of deaths, diagnosis and treatment options, vaccines, medications, government policies, etc., generates more anxiety and panic among the population. The effect could spread chaos, panic buying, hoarding of essential goods, price increases, street violence, conspiracy theories of discrimination, etc. To reduce false information, companies like Google, Facebook and YouTube are working tirelessly to provide the public with correct and verifiable information issued by the government or local authorities. Although the social media provides accurate, transparent information to the public, it is not able to obtain information on what to do next.
- **Finding Drugs**
  When a pandemic occurs, the first question you have in mind is whether there is a drug or a vaccine and seventy others. The world is now desperate to find ways to curb the spread of coronavirus and find effective treatment. Technology becomes a facilitator to speed up the process. AI is playing a significant role, implying an understanding of the structure of vaccines of viral protein components, and medical researchers are requesting the assistance of dozens of research papers,

causing a lot of serious concern at the current rate. The AI for the Allen Institute teams, Google DeepMind, which created the A tools, shared data sets and research results. In January, Google introduced DeepMind AlphaFold, a leading-edge 3D structure of the protein according to the genetic system that the series predicts. Biology is a popular technology used to develop the world's first board-scale 3D nuclear programme that is a portion that binds and infects human cells—the dental protein—which was developed by the University of Texas at Austin and the National Institutes of Health. 19-AI can help scientists find COVID-19 vaccine.

- **Increasing Traceability and Transparency**
  During a pandemic, they must be cleared to transmit communications to the general public, informing and reminding them that precautions must be taken. Smartphones, broken artificial intelligence, 1050, and other popular technologies are being used by various groups to increase visibility for movement: Microsoft Bing released a 19-COVID interactive map at random to deliver a message. To reduce delays, Sixfold has always offered a free live banana border crossing, and the European supply chains are supposed to be familiar with receiving imports. TikTok collaborated with a social platform for the WHO to create roughly 19 COVIDs to help people stay updated about their health, as well as a timely one for a WHO live feed that they can search and track. At 500 Taiwan Central Epidemic Control Center (Cecco), data on travel health information is being combined to create a monitoring system that will deliver real-time notifications.
- **Tracking People with Facial Recognition**
  The scan can assist infected people to swiftly identify and connect with others who have come into touch with the trail, etc., which is the reason for the administrative pandemic. Look closely to see if humans can use information technology to disguise themselves. These technologies can aid in the regulation of human mobility and the tracking of quarantine. It may also assist to establish whether or not a trace of the disease is present, as well as whether or not they have come into contact with an infected individual.
- **Risk Assessment and Forecasting**
  It becomes an important component of the 'artificial intelligence' in today's care. Through artificial intelligence analysis, medical physicians can learn more about the sickness by studying predictive modelling. With the use of AI FH, researchers are able to make more accurate predictions about the spread of disease, medical treatment, and other platforms employed, making it easier for researchers to rapidly find relevant papers, potentially leading to new ideas or approaches to COVID-19 of the outbreaks. Artificial intelligence has assumed a role in the investigation, with societies constructing 'artificial intelligence' to ensure the clarity of tools in an armory based on the possibility of pandemic-related uncertainty. Google is a Chinese multinational technology business that has developed artificial intelligence-based solutions to the massive and on-the-go detection of body temperature changes. Without stopping the flow, this system can analyse

around 200 persons every minute. Such individuals can be implemented in today's technology, which is filled with locations, hospitals, a garrison, airports, and so on, to recognise the weak, speed to the company, and not shut him up, because he will have first infected the majority of mankind.

- **Contactless Movement and Deliveries**
  When a person avoids human interaction, cars, autonomous dastard drones, and robots can assist. The vehicles that are impacted can be utilised in independent leisure and health centers, while the healthy ones can be operated without endangering human life. Robots can carry groceries, cook, run through the streets, and deprive hospitals. Drones, robots, and self-driving vehicles are deployed are deployed in china during this pandemic China during this pandemic.
- **Temperature Monitoring**
  Temperature monitors and other gadgets of similar nature like wireless infrared thermometer are the most essential medical devices used at checkpoints at offices, airports, hotels, train stations, shops, and other public locations for measuring body temperature. These technologies aid in the measurement of a person's body temperature remotely and effectively than other equipment. When combined with automated thermal processing, the result is a more efficient and effective.
- **Support Social Distancing**
  This pandemic has made people learn about the aspect of social distancing. Initiatives have been taken by the government to make citizens aware of maintaining social distance while talking to each other, walking, standing in a queue as well as sitting in the office. These directions have been formulated keeping in mind the spread of this virus rapidly.
- **Maintain Business Continuity**
  Working from home ensures continuity and allows social space in the corporate sector, which is constantly threatened by calamities or pandemics. In the form of television, technologies that offer safe access to data, such as corporate applications, virtual contests, cloud-based conferences, and power/mixed/increased to prevent the problem from being impacted, possibly on top of the deliverable rules, are used to prevent the problem from being impacted. Remote working technology is a boon, and it provides us with solutions to assist us on the most social networks.

27.4 Discussions

The greatest threat of a pandemic now is a worldwide catastrophe caused by a highly contagious virus that is highly damaging yet does not kill many people. In this current COVID-19 situation, we have won the ability to comprehend what a pandemic situation entails. The Premier's ‘It can be, but it must be done, prepared by a private individual and the collective level that we will be dealing with the Premier’ is the second reason. What we need to know to be prepared. Technology has progressed and continues to improve at an exponential rate, but human institutions, enterprises, and adaptation must continue to invest in developing faster technology systems. After the commencement of COVID-19, try not to offer aid, so that the team caused by the epidemic is better because the LORD fought for the future of the public's health in a timely, systematic, and tranquil manner for them now, as it appears from artificial intelligence is robots.

27.5 Conclusions

The study includes the behaviour of consumers before and during COVID-19, and the findings are as follows:

- There exists a shift in the buying mode of the consumers. During COVID-19 people started shopping online for goods which they earlier thought that they may not get quality products and they may end up in fraudulent transactions. Gen Z has influenced family members to change their necessity shopping habits.
- People who were earlier not health conscious and do not take care of hygiene also became health sensitive because of COVID-19.
- People's mobile shopping and comfortable shopping became panic shopping as commodities were stored in quantity.
- Consumers have become more receptive to things that provide them with the assurance of zero contamination and zero interaction.
- There is a change in marketing strategies of people as a whole as now all marketers have designed new marketing plans to capture the attention of consumers.
- It is essential for the marketer to ensure that parcels and goods are sanitized before delivery and the delivery person is not infected. To implement this, it requires extra cost which automatically increases the price of the product. Therefore, the consumer is made to pay more for the same good which was available to them at nominal prices earlier.
- Marketers are now relying on social media and television as the only platforms to advertise their goods since consumers sitting at home are constantly scrolling the Internet and watching television which can make them aware of the recent changes in marketing, whereas formerly marketers could advertise their goods in any way they wanted.
- During this time, the fundamental difficulty encountered by marketers was how to reach out to consumers to purchase things, as opposed to prior times when people themselves approached when the need arose, which impacted the marketing approach as a whole.
- Earlier people would do information research before buying goods and were attracted by different packaging and attributes, but during COVID-19 these strategies of marketers failed to attract consumers as they are no longer looking for these attributes in the goods they buy.
- Governments have also reacted against the same situation and have taken various steps towards providing essential commodities to everyone and for people who cannot afford essentials. For example, the Government of India has cut GST on commodities consumed by the poorer sections as a form of assistance. Various

big organizations are doing the same; a big example of this is Reliance Foundation that provides food to the poor through their mission Anna Seva, provides essentials to truck drivers and also they looked upon not only humans but have taken steps to feed stray dogs as well.

27.6 Future Scope of Work

The future research will go in the direction of discovering what changes customers encountered during COVID-19 and how they are replacing their demands according to the scenario and buying what is readily accessible to avoid making another trip to the store to acquire items. It will state the expectations of consumers from marketers due to this situation. It would also provide how the marketers have moulded their marketing strategies and how they reacted to a major change in their distribution strategy because of the changed market conditions. The study will aid in determining the influence that this circumstance has had on people's purchasing and consumption of essentials. The study will provide a synopsis of how the market conditions have changed pertaining to essential commodities due to COVID-19 as this situation has changed the whole economy of the world and it will provide how marketers and consumers handled the situation.

27.7 Executive Summary

Essential commodities always have a high demand from people at a reasonable price at all times, but due to COVID-19 and associated scenarios there is a sudden rise in demand for essentials goods. Every marketer who was not associated with essential goods tried to reposition their marketing strategy and tried to incorporate essential goods. During this situation, many people have turned towards the essential goods sector for a living and due to high demand and less supply the government had to intervene so that supplies are made available even to the weaker section of the society. The government has made various changes regarding the same. This study provides a synopsis of the market situation experienced by the consumer and marketer before and during this situation. It also includes information on the many types of consumers, as well as their segmentation by social status and purchasing habits. It provides a study of consumer behaviour as to what people expect, how they were attracted through various attributes of goods, and how these attributes changed due to COVID-19.

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Impact of COVID-19 on Manufacturing and Operational Ecosystem in India

28

Surya Kesh and Sukanta Chandra Swain

Abstract

The effect of Covid-19 only on manufacturing and operational ecosystems in India has been severe in many ways. This work includes a variety of topics which have impacted in manufacturing industry. It includes the assessment of the fundamental changes in ways of working. The purpose of study is to understand overall effect, as well as the specific change in the pattern the way these companies are managed and operated. Data has been collected from the Covid-19 worldwide data set as well as various financial and operational data that is available from company websites. Markov chain, which is a good way of predicting the value of a variable independent of past history, is fit for this analysis considering the present system. This along with various forecasting techniques like simple linear regression, multiple linear regressions are used to arrive at the conclusion. Considering the variety of internal and external factors affecting the organization during Covid-19, this chapter will end with a simple model that can be incorporated by any industry and reduce the need to appoint specialist and researchers to get insight. Methodology used in this research has been custom selected because some of the historical data set may have become irrelevant or needs to be reassessed as part of Covid-19 changes. Major assumptions include effect of various international and national events along with the impact of various health factors and unforeseen factors that was beyond the control of the organization. Research methodology would also account for the gaps that have been observed in the operation with regards to business continuity

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management. A major assumption is that the government intervention and decision during Covid-19 had a substantial impact over the entire outcome but this cannot be easily quantified and justified by figures but a subjective assessment has been carried out to arrive at results.

Keywords

Covid-19 · Impact · Manufacturing · Operations · Changes

28.1 Introduction

The Covid-19 infection has been spreading fast and has moved India to the third position. Currently India ranks third after the USA and Brazil in terms of total cases will not be surprising to see India take the first spot in terms of total cases reported in Covid-19. The numbers have not been very alarming in terms of new death as the Covid-19 recovery rate has improved. The current Covid scenario has brought the economy to a near grinding halt or at least it is in a standstill for majority of the cases. The impact has been pretty wide and we try to assess the impact of the Covid-19 scenario in terms of the manufacturing and operational impact in various organizations in India. It is important to know that the impact cannot be assessed in isolation and has to take into consideration the Global perspective as well as various other internal and external factors that have led to the current complex scenario.

It is estimated that the quarterly profits of various industries has nearly been wiped off and there are enough indications that the subsequent quarters will also not be good enough. The study takes a look at various factors under various categories specially economic as well as operational factors which has been impacted the industry. The ripple effect of the impact has led to the decline in the economic output of various industries. As the economy is gloomy people have not been buying and this has led to the decline in sales. This has become a recursive cycle which again has hit Industries very hard.

28.1.1 State of Economy

The GDP numbers for this year has fallen for sure and as of January estimates of the national statistical organization the gross domestic product will be 5% in the year 2019–2020 in real terms. This value may be revised down because the Covid-19 situation has not been improving over time. It is also estimated that recession has started and secondly there has been plenty of bad news all around. Oil prices have hit the historical low during this period which is a very good indicator of the state of the economy.

The economic consumption has been on a steady decline India is estimated to face a GDP decline of 45% in Q2 as per Goldman Sachs latest report. Short- and long-term measures have been announced by the government to revive the economy. India government has declared many economic packages and a stimulus package in fact Atma Nirbhar Yojana packages says the economic package size is 10% of GDP. The cash-strapped India economic plan is unlikely to soften as India's economic package fail to revive the economy and save from disaster. Many economists feel that the economic package was inadequate. Apart from this the Global slowdown has led to the slowdown in goods and services. The demand and consumption pattern has change the curve like never before.

What can India do to overcome the current economic crisis due to global slowdown for many of its industries and allied Industries especially in the auto spare parts industry and the like switch depend majorly on export import operations are badly hit? The lack of employment in rural areas has adversely affected the rural mass of people and even schemes like mgnrega (Mahatma Gandhi National Rural Employment Guarantee Act) and more food subsidiary coupled with overall government intervention has been inadequate or even suboptimal to contain this scenario and bring about a reversal. The RBI has rates on interest rates and provided Moratorium period of initial 3 months and later it was extended which has led to do a critical scenario where in banks and NBFC (Non Banking Financial Corporation) are not sure of the NPA amount they need to provision as the default risk across various industries is sure to effect the financial sector.

28.1.2 Rationale

As research conditions cannot be fully controlled in the current situation so there is a high degree of reliance on the balance sheet of the companies and the financial data provided by the companies. This data along with commentary by the company are analyzed to provide insight. The results will be inferred from observations, values, rates, trends, changes in Manufacturing and Operational Ecosystem etc. Finally, the recommendations are provided under three categories namely 'Procurement process under various constraints', 'Operational readiness and continuity under drastic situation' and Impact on sales and changes in forecasting techniques.

Based on the findings of this data set, if the companies work upon to annihilate the risk and incorporate the changes, the sales will definitely be improved, and profitability can be maintained. This chapter establishes the various companies leading and showing the way to others on how to remain profitable in pandemic. A wide assessment helps in drawing out the right way ahead which will have high impact because of feasibility of implementing simple suggestions that go a long way and ensure smooth transition from current state to normal state.

28.2 Analyses and Research

Purpose of the analysis was to keep whole process of gap analysis and fundamental analysis simple enough so that it can be effectively applied by company of any scale and yet be effective enough. It has been very challenging get the necessary inputs from all the company members due to various restriction in travel and other activities. What is purpose we have embarked on returning to create a simple and wired Framework which was used during the analysis and can also be extended by the company to create desired outcome.

28.2.1 Methodology

Data collected from various sources like financial data from company and public websites along with Covid-19 data set from public website has been used for this research (Fig. 28.1).

It is important to collect data to determine the cause and effect and also classify the same for which we have come up with a multi-step process in this framework both as a model for this analysis as well as can be applied by companies. First step is to ascertain causes at least two effects. This can be further enhanced to a greater level based on the required for such analysis and the importance of an accurate prediction to solve the particular issue.

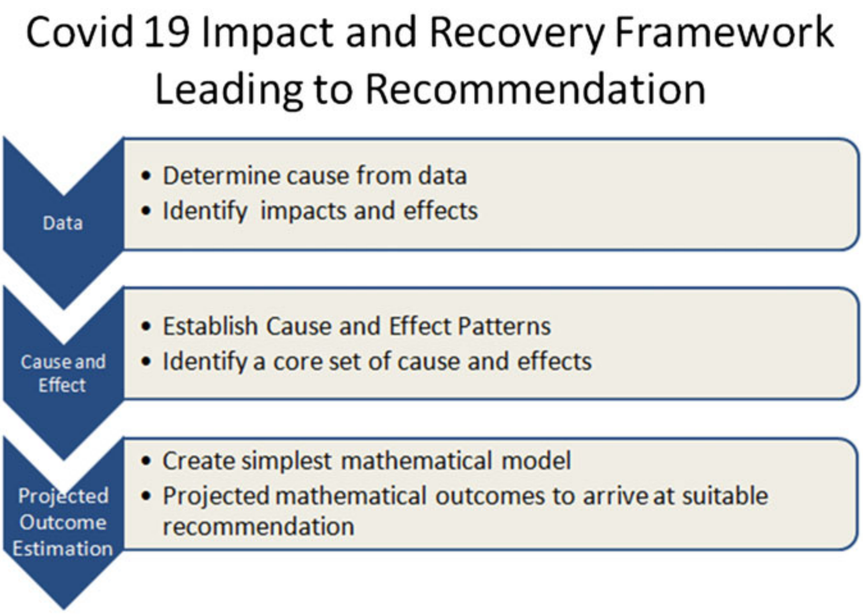

Fig. 28.1 Methodology for this study which can also be used as an assessment framework for industries

Second step is to establish cause and effect pattern. In this we classify the problem into groups. The group form a core set of activities which can easily explain the cause and effect. Once the effect has been understood well, the core set of activity identified takes all our focus.

Third step we create a simple mathematical model. Model should have dependency on previous because a pandemic situation is not a normal one and we cannot rely on previous. What's the mathematical framework has been established the mathematical framework has been deliberately kept simple to find out the cause and effect in a sentence and unified way a across company. The projected mathematical outcomes and the resultant of this particular activity are matched. Result of can be measured in a sequential manner the output is messing with the projected mathematical outcome. Result match help us in validating the cause and effect pattern. The acceptance of the model will be driven by the outcome and if needed the process can be iterated till we get desired output.

28.2.2 Hurdles in Manufacturing Process

There is lot of production hurdles. This also means that the essential goods sector was almost close to a full stop. With 1.3 billion people and a state mandated shutdown there is little hope do quickly move back to normal state. Measures have been announced to ensure that manufacturing sector is least impacted in terms of labors, transportation and delivery. Even after many policy announcements we still see gaps and difficulty. The absence of labor force seems to be a very critical factor in determining the output, but unfortunately most of the labor force has gone to native and it will take a while to bring the labor force back to the place and become productive. Apart from this the sales has been very disappointing which has reply effect in the production space. Most of the factories are reported only running at 40% of their capacity with intermittent closes. Many essential commodities have seen price fluctuation and this means many of the companies which saw a mild increase in profit are not really profitable by end of the day. Thus a new view is needed which has been propounded and will be summarized in the findings.

The major factors are like absence of workers, absence of allied & auxiliary or standard goods and services, non-availability of transportation or licenses and unwillingness of many people to move the goods from source to destination have been identified as major challenges during data collection.

Companies operating across many States have not been able to use the existing business continuity measures which are already in place. A certificate may be required in many circumstances to resume industrial production and this has to be issued by the district Industries Centre or state government and the local police commissioner should allow the same this along with various ways of mobilizing the workers and transportation while maintaining social distance and other Covid safety norms. Safety norms will be critical for smooth supply of essential goods like foods vegetables sugar rise raw materials oil and various other products.

New challenges faced by workers as well for they cannot come out of homes to go to the office. Apart from this the workers need to be protected and screened. Anybody who has got symptoms of Covid-19 needs to be carefully separated and the team should be carefully screened for Covid 19.

28.2.3 Manufacturing

The whole Industrial Psychology needs to change and therefore currently it is a difficult condition to live up to the expectations as well as arrange the ways and means to revive the production and manufacturing process. Current process is unsuitable for a pandemic situation. The companies that are surviving and will survive we learn from the Global best practices to deal with these kinds of situation and achieve a higher PAT/sales ratio.

Manufacturing today on May 13 2020 outlined the impact of Covid-19. Article stated that there has been a lot of strain in the manufacturing industry which contributes to 20% of the GDP.

As far as the purchasing manager's index which stood at 30.8 in May and 47.2 in June it shows a straight fourth month contraction in manufacturing activity followed with little revival. Shrinking demand, the supply side and other parameters also impacted production.

The farm sector source better performance than initially estimated as the government stepped in and allowed the production to carry on with necessary safety measures. A normal monsoon contributed to better production. Ultimately food is the most important high value commodity to the entire society and especially in a pandemic situation. Services PMI recovered from 12.6 in May 2022 to 33.7 in June 2020 as reported by the hindi.com on 4th of August.

28.2.4 Operations

The fragility of the entire system has been exposed which could not cope up with initial lockdown and subsequent intermediate lock downs. Recovery has been fragile and minimum in most cases. Also the purchasing managers index and index of Industrial Production has taken hit.

Top three concerns for management are:

1. Reduction and decrease in productivity
2. Supply chain disruptions
3. Funding

So clearly a cyclic problem exists, which can be visualized like this. Many of the labors have migrated to the hometown specially villagers and it is difficult to resume full scale production in many industries including auto manufacturing and construction. Additional precautions have to be insured to ensure the supply side is intact. The warehouses need to be carefully managed and sanitized. Delivery boys needs to follow new norms while delivering goods and contents to the end clients. The intermediate retail shops if there exist also facing a dilemma for they need to open as well.

28.2.5 Company Overall Performance and Stock Prices

Stock prices have been unpredictable as always. The India market has been unpredictable and has followed the as US market. The chances of a "V" recovery looks almost achieved even though the current quarterly prospects look gloomy. This is the optimistic approach shown by the market which is sure to revive the hopes and make great strides. The market has not given to the bearish moves even when the country went into lockdown the lows were not abysmal. Most people who followed and believed that each pandemic situation has resulted in "V" shaped recovery did stick to it. A lot of new people as new entrants in the market who believed in the revival and the new found fascination in stocks.

While many say no end of the Covid-19 story, it was imperative that these people switched over to gold and silver as the way to investments and thus earning the high rates of returns on invested capital. Unfortunately with the announcement of world's first Covid Vaccine by Russia the Bull Run for gold and silver has come down which is showing up in the steep fall in gold and silver prices.

The graph in Fig. 28.2 is the testament of the tremendous wish of the common people and the optimism and hopes of the masses in the near future revival which has led to the revival of the stock levels to earlier once even with the steady increase in number of cases.

The performance of each sector has dropped but there is a silver lining to each cloud as the saying goes. This can be seen from the electricity consumption data control by energy policy institute at University of Chicago showing striking decline in the case of India when compared to US and EU which was reported by livemint.com on 13th April 2020. The graph shows 18.4% decline in India during the 24th March lockdown period as compared to a 4.97% fall in US and 6.23% fall in electricity consumption related to December 2019. As most of our industrial production is linked to the energy in one way or the other it is very easy to understand the use Fall In the industrial production in terms of energy consumption.

Scanning for the number of companies with "*net profit quarter > TTM net profit > than 1*" results for **423 stock** records. Similarly scan run to ascertain those that don't fit into this criteria returns **1280 stock** records. (This scan was run in chart link on 8th of August 2020 and TTM stands for Trailing 12 months). The above data clearly shows that the country has been worse state in economic terms. Out of this

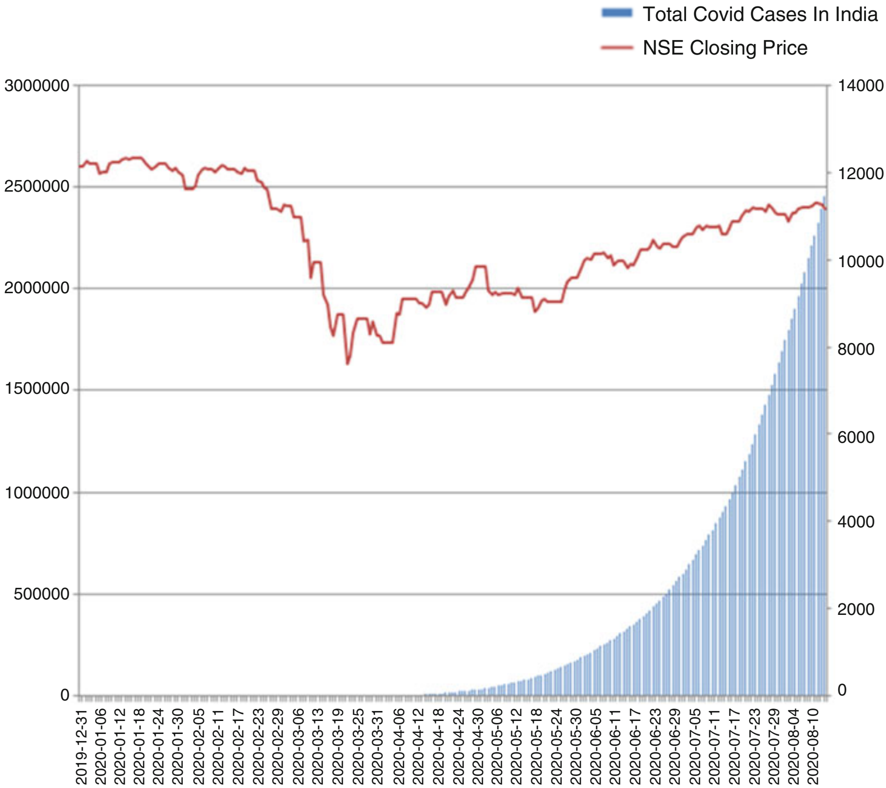

Fig. 28.2 Graph of total Covid cases in India and NSE closing price

the industrial stocks 204 have shown a decline, 188 FMCG stocks have shown a decline, 109 finance stocks have declined, 96 services sector stocks have shown decline, 82 metal stocks have declined, 76 Parma stocks have also shown a decline given the set in Parma stocks have real benefits as they have higher prospects of releasing Covid-related medicines and earn from increased sales. The Other values which show is declining include 72 auto stocks, 68 reality stocks and 64 in textile industry stocks even though textile was supposed to be less impacted initially. From banking perspective 26 banks have shown a decline where in 24 banks have shown a decline in the month of July. So there is slightly better performance expected down the line as banks try to improve the performance and decrease the NPA (Non-Performing Assets) by allocating funds for the NPA. The media seems to be increasingly hit wherein the 38 companies show the initial decline initially which has increased 39 companies in the month of July.

28.2.6 Estimate Next Quarter Performance

Estimated performance for the upcoming quarter is also not very bright as chances of full lockdown and area wise lockdown are high. Our industry is not able to cope up with the changes and this coupled will the fall in the purchasing power of people has made sales extremely difficult. Ultimately the cause and effect has brought down quarterly performance.

28.2.7 Impact of National and International Events

A series of intermittent lockdown across the nation this coupled with the International Slow Down both in terms of demand and supply along with the restriction in the movement of goods and supplies across the borders has resulted in resource crunch, demand falls and contraction in production output. The standard supply chain assessment mechanism, which had traditionally helping to ascertain the demand and fulfill the means of productions in terms of raw material goods and labor are no longer adequate to predict the changes in anyway. A series of job cuts and joblessness has led to increase in demand which is somehow contracting and has made it impossible to determine the optimal quantum of production required during these times.

The increase in demand of tractors is an exception and indicates an emergence of cash rich rural market.

28.2.8 Research Conditions

The research condition will vary due to the uncertainty and surprising new events in the current scenario. Most of the traditional ways of research would find it very difficult to create a module or a method or methodology to address a pandemic situation and ascertain the outcome.

In view of this scenario we have chosen a Markov chain analysis for the research work. The main reason for assessment is the very fact that the subsequent outcomes are not driven by past events but based on the current once. This sounds a very realistic way of analyzing in the pandemic. For this we will create multiple samples in order to ascertain the outcomes at each level of Markov chain. Why Markov chain analysis was chosen to predict the outcome at $t + n$ times.

28.2.9 Markov Chain Analysis

Starting with the high level macroeconomic model we move down to the least granular process wherein we try to find the right set of task groups that needs to be handled in a sequential manner to achieve the outcomes. The macroeconomic factor is very critical at this stage for this gives a view of the contraction in various sectors are not uniforms and while some of the sectors like perfume industry has taken a large hit the agriculture industry is relatively afloat when compared with the others. Pharmaceutical industry emerges as a special case and might have actually benefitted in terms of the overall money circulated, demand surge and heavy spending in search of medicines and vaccines. The INDEX OF INDUSTRIAL PRODUCTION Monthly NIC-2 digit and sectoral indices of industrial production data has been used for this assessment (Fig. 28.3).

In line with the index of industrial production is also important to look at global clues and find if the changes and revivals can be in line with the established market practices. The dea.gov.in site gives the data for various categories out of which the GDP data is quite significant to assess the global impact. The worldwide GDP shows a dent in 2020 as per World Bank and IMF projections as shown below. The business impact of Covid is not known and it will take time to realize the NPA assets for Banks and the number of industries closed during the period. Covid is also known as the urban disease by few as the major impact is perceived by the urban whereas the rural sector has been ok during this period in many terms. The health environment of rural India with full or partly self-sustainable ecosystem of food, cloth and essential items has kept the rural India moving and showing its strength to survive a pandemic situation. The good monsoon has added to this and there seems to be a notzion that the rural India is cash rich which is seeing an increase in demand of tractors.

Haward has a strong footprint in India indirectly in terms of the funding, grants for survey/research and various other activities which has been a great beacon for many foreign universities which may have a similar base in India. This will ultimately lead to the revival of a vibrant education sector that is the key to any revival from pandemic and similar situation. The universities in India have started working in distance learning mode and this trend has picked up to an extent that the trend will be irreversible in the near future. Similarly there are many other avenues that have sprung up during the Covid which was otherwise hard to get the necessary traction and attention of the masses. Education industry is reinventing and so is other industry but the rate of change to the new normal will be the critical and determining factor (Fig. 28.4).

financialexpress.com: At over 322% of GDP, global debt almost 40% more than that seen during 2008 crisis: RBI

A look at the fundamental segments like electricity, manufacturing and mining also shows a trend reversal which is a good indicator for the growth and revival prospects in the economy and has been separately tabulated in the chart below (Fig. 28.5).

Figure 28.6 clearly reaffirms some of the age old assumptions like the demand of primary goods are not affected hugely by pandemic and is probably the only segment that is relatively untouched while consumer durables are most hit, followed by capital goods segment. The consumer durables and capital goods segment is also

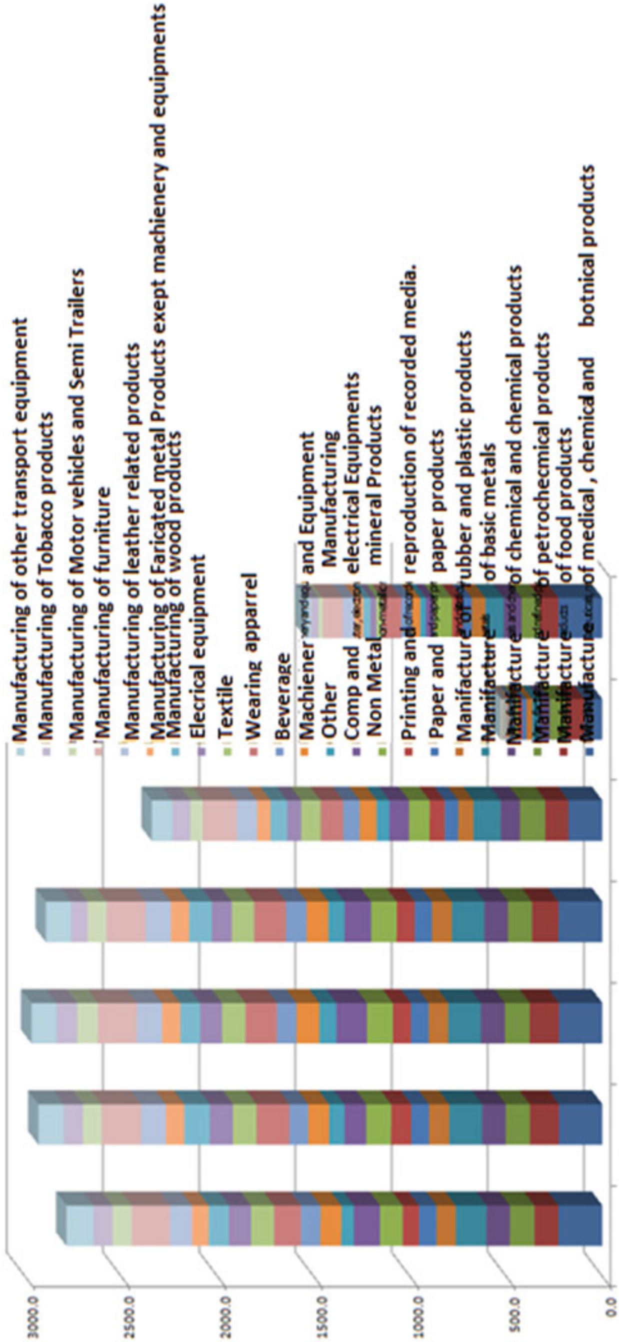

Fig. 28.3 INDEX OF INDUSTRIAL PRODUCTION Monthly NIC-2 digit and sectoral indices of industrial production

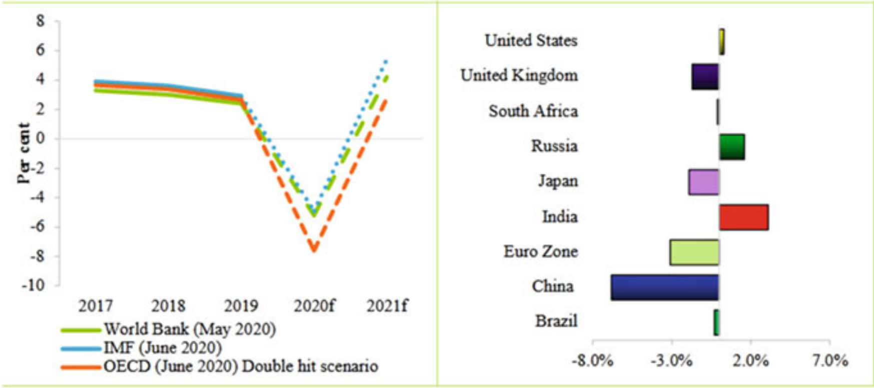

Fig. 28.4 GDP comparison data. Source: https://dea.gov.in/sites/default/files/July%202020.pdf. Data Source: compiled using data from various agencies

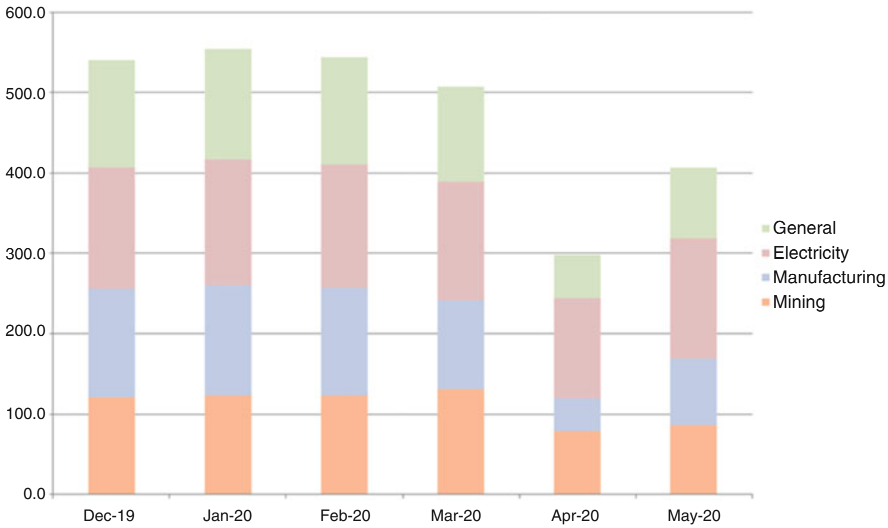

Fig. 28.5 INDEX OF INDUSTRIAL PRODUCTION Monthly NIC-2 digit and sectoral indices of industrial production

growing faster in May 2020 when compared with April 2020. So based on in above classification the industry can be segmented and analyzed to ascertain the need for elaborate arrangements and charting for growth revival. Other industries can grow at a normal pace without much intervention from any government and without elaborate planning as demands surges and Covid vaccination becomes available.

So we arrive at next step after assessing the kind of industry or the kind of industrial process and production process and assessing the need for an elaborate or a relatively small plan for next action.

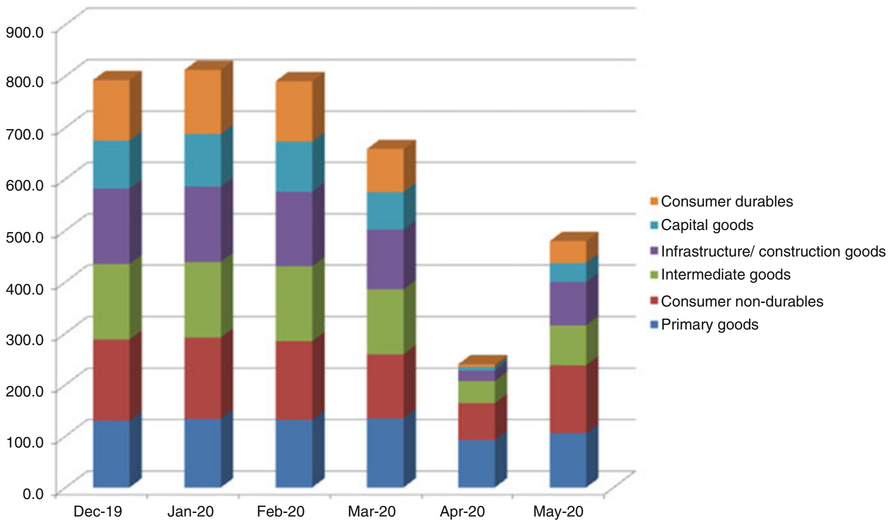

Fig. 28.6 Monthly indices of industrial production as per use-based classification

The next actions will include due diligence to establish the kind of work that can be done and executed in the circumstances and the various cause and effects of unplanned changes. Each such cause and effect can be associated with certain amount of risk and compliance assessment for example Covid readiness and government mandated compliance during the pandemic.

28.2.10 Markov Chain Limitation Under Current Situation

Markov chain analysis depends on current state and does not depend on previous state. The next step is to go from macro view to the micro process view and we outline a possible way out of this current situation.

Create a pandemic risk assessment model for the company and analyze the percentage of the total work that can be done without any contact which can be tabulated as given below (Table 28.1).

For example the percentage change in sales work that can be contactless in after period T calculated by the mathematical model for Sales unit which can be expanded to the other units and then outlined for the company or group by extrapolating the various factors.

The states for sales in matrix form are $[s \;\; 1-s]$

The probabilities of transition of can be depicted by the matrix

$$P = \begin{bmatrix} Ps & v \\ w & P(1-s) \end{bmatrix}$$

Table 28.1 Estimating the current AS-IS contactless or distance work as percentage of total work

Categories	Contactless or safe distance work as percentage of total task	Current exposure
Sales	s	1 − s
Procurement	p	1 − p
Operation	o	1 − o
Management	m	1 − m
Distribution	d	1 − d

$Ps/P(1 - s)$ is the probability of staying in state $s/(1 - s)$ and v/w is the probability of transition to next state. The matrix P represents the various transition probability modes between states.

$(P)i\ j$ is the probability that, if a given state is of type i, it will be followed after T days the type will be j and the sum of all probabilities is 1 for this stochastic matrix.

28.2.11 Predicting the Next State

The state of the next day can be predicted using this model to access the next state and of all the functions the one with the least output will create the bottleneck.

The calculation can also be applied if the company is currently not working in contactless way and following covid19 operational readiness. Calculations above show the possibility of changes over time for different probability to next state.

From the above it is clear that even if the company spends sufficient push to ensure that 30% chances exists to move a relatively low contactless or distance work process, there is a change from 10 to 36% in terms of state after duration T. This is relatively good number to get started so the research recommends that if the company is assessed at 10–20% then the company should be aiming for a 30% chance of going to contactless and achieve a viable way of working in contactless model. For various assessment the Table 28.2 can be used to develop a minimum viable plan.

The table also shows that for companies which are 70% or more of the processes driven in contactless manner but they have to push the agenda for supporting contactless or distance work else the percentage of work done remotely or in contactless manner decreases over time even if we assume that the chances of moving from one state of mostly contactless to non-contactless is low.

The metrics raises hopes that with relatively low effort the companies can still get into a minimum viable model and continue with the operations.

28.2.12 Linear Regression

From the earlier table we observed the following and considering a simple scenario where the industry is mostly not prepared for Covid pandemic and only 10% work is

Table 28.2 Data shows the outcome of series of efforts leads to a higher percentage of work that can be done in Contactless manner. It enables working from safe distance and creating contactless working environments

Percentage of work done as contactless of the total work	Probability to next state	Optimistic probability matrix	Percentage of work done as contactless of the total work in period *T*
	Chances of increase in T period by pushing harder the contactless or distance working *Assuming that the push should be harder if the current value is low*		
10	30	$\begin{bmatrix} 0.95 & 0.05 \\ 0.3 & 0.7 \end{bmatrix}$	36.5
20	30	$\begin{bmatrix} 0.95 & 0.05 \\ 0.3 & 0.7 \end{bmatrix}$	43
30	20	$\begin{bmatrix} 0.95 & 0.05 \\ 0.2 & 0.8 \end{bmatrix}$	42.5
40	20	$\begin{bmatrix} 0.95 & 0.05 \\ 0.2 & 0.8 \end{bmatrix}$	50
50	10	$\begin{bmatrix} 0.95 & 0.05 \\ 0.1 & 0.9 \end{bmatrix}$	52.5
	Companies already equipped to handle will lose the edge over time if the BPC agenda is not pushed		
60	5	$\begin{bmatrix} 0.95 & 0.05 \\ 0.05 & 0.95 \end{bmatrix}$	59
70	5	$\begin{bmatrix} 0.95 & 0.05 \\ 0.05 & 0.95 \end{bmatrix}$	68
80	5	$\begin{bmatrix} 0.95 & 0.05 \\ 0.05 & 0.95 \end{bmatrix}$	77
90	1	$\begin{bmatrix} 0.95 & 0.05 \\ 0.01 & 0.99 \end{bmatrix}$	85.6

contactless, and is trying move to the next stage by pushing it very hard with 30% probability is likely to do 36.5% of the work in contactless manner over time period *T*.

Thus in order to calculate the total impact the simplified linear equation can be arrived at for each section of work

$$P_{\mathrm{A}}(\text{Increase in automation probability}) \cong (1/\mathrm{PT}\ (\text{Probability to next state})) + c(\text{constant})$$

28.2.13 Multiple Linear Regressions

Gathering the functions over time and a multiple linear regression can be arrived at that will be able to assess the next outcome over $T - n$ periods.

The value across the organization can be roughly estimated as follows.

$$f(x) \cong a_0 + 1/\sum_{n=1}^{n} (\mathrm{PT}(\text{Probability to next state}))$$

a_0 can be taken as a constant.

While assessing via multiple linear regression with various factors can lead to better results of analysis but we consider the primary factors like probability of government mandated lockout to change the predicted value.

So the output can be increased or decreased by the probably of lockout and other uncontrolled factors.

$$f(l) = c_0 + l_0 * f(x)$$

28.2.14 Limitation

There are various limitations as this research is based on available data only and cannot be an extensive study due to various limitations on movement and other restrictions at this point.

28.2.15 Balance Sheet Impact Assessment

Balance sheet impact assessment across the industry helps every company learn something from the similar and dissimilar lines of business (Fig. 28.7).

The sales and Pat has been affected during the Covid and the relative rate of decline has been higher when we exclude banks in the accounting process to arrive at the value. The same is available in the data above. The earning snapshot is showing a large decrease in sales of 28.43% which means that the upcoming quarters will also be stressed. We would like to change the structure of the company slightly so that there is a decent mix of opportunities both online and offline that can help the companies viable during any pandemic situation.

We take a look at the various categories of companies and the companies have been categorized into four quadrants based on revenue and profits as shown in Fig. 28.8. The changes in revenue and profit have been positive for 117 companies which are listed in quadrant 2 and the top names are listed in the same place as shown in Fig. 28.9. These companies which have outperformed and have remained profitable in covid are in Q2 quadrant and there are many points that can be an inspiring story for many. Similarly the other inspiring companies which have been able to

Fig. 28.7 Shows data from Source https://economictimes.indiatimes.com/markets/stocks/earnings showing the snapshot of earnings

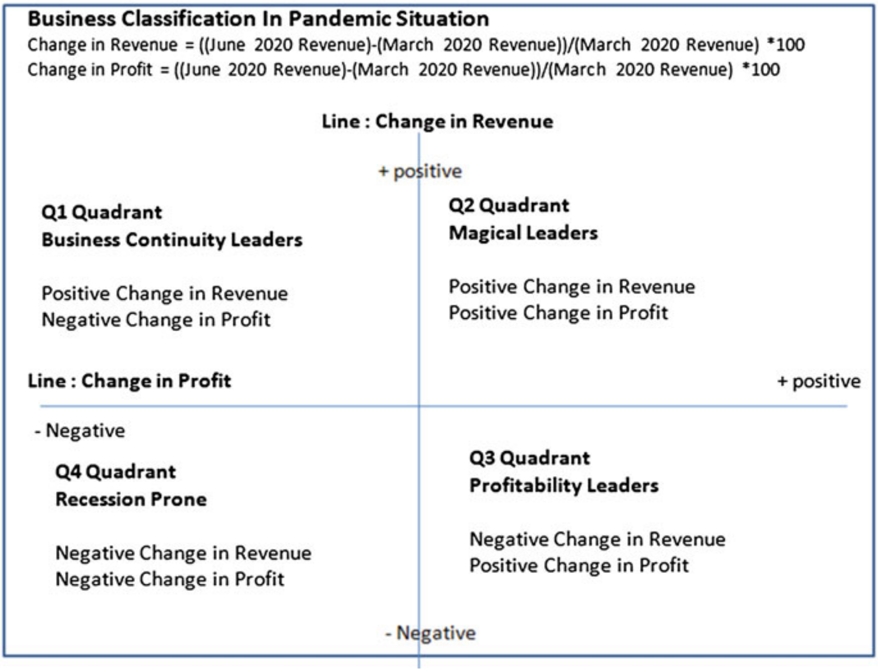

Fig. 28.8 Companies classified into various categories based on profit and revenue

maintain positive revenue are grouped in Q1 quadrant and are Business continuity leaders and the companies which could maintain positive profit margins are in Q3 and are profitability leaders.

The sum total of companies in the inspiring companies are thus grouped into Q1, Q2 and Q3 and the number of such companies are lesser than Q4 quadrant which constitutes the companies that have not been able to remain profitable and show a healthy probability of survival.

To sum up the companies have leaders and success stories that can be replicated in one way or another as each of these groups are mostly heterogenous set of companies from various segments and each company can learn the way the operations have been morphed from companies in Q1, Q2 and Q3 Quadrants, some of the top names have been listed in Fig. 28.9 to depict the outcome of the exercise..

28.2.16 Observations Values Rates Trends

Next it is important to also revamp the processes or group of task one at a time and identify the bottlenecks via assessment which results in the identification of the

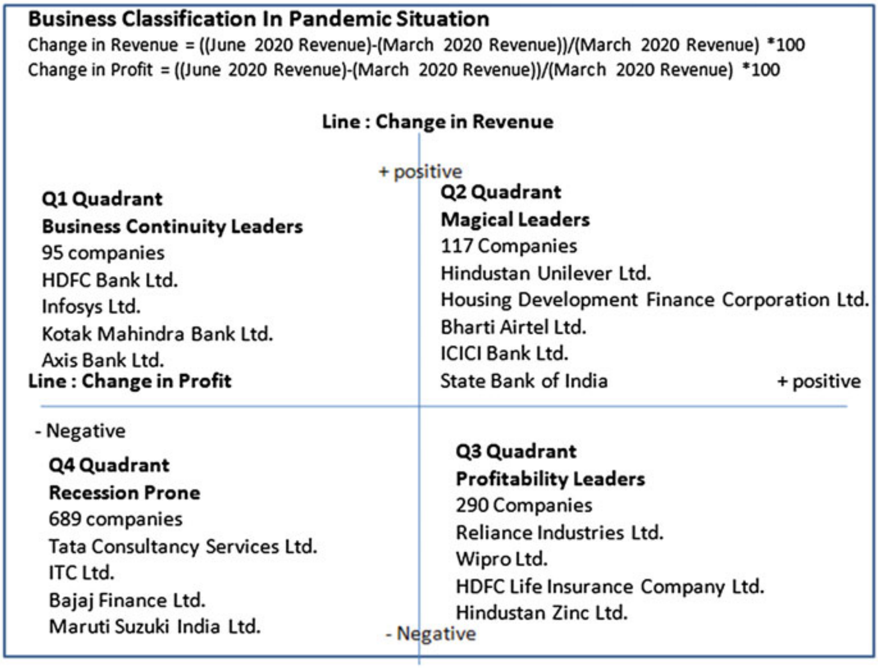

Fig. 28.9 Few top companies grouped into various categories based on profit and revenue

weakest link in the chain as well as helps in prioritizing the task that leads to the removal of issues one at a time or removal of a set of issues at a time.

As shown in Fig. 28.10 shows that the bottleneck 3 will be an impediment and must be removed as step e has the least efficiency in terms of output in the whole supply chain that means that we will have to be updated and much more push is required to dive the factor. Combining the leanings from Markov chain analysis it can be mentioned that there can be relative difference in the amount of work done to remove the bottleneck at each steps where the least once should be modeled in a way to give a 30% probability to move from the current state to the next higher desirable state.

28.2.17 Growth and Availability of Funds

Probability of survival for diversified companies is evident from the growth indicators during pandemic. A particular story that is most inspiring during the pandemic situation is the JIO story as the company has been able to gather huge capital by divesting the state thus making reliance company unit practically debt-free.

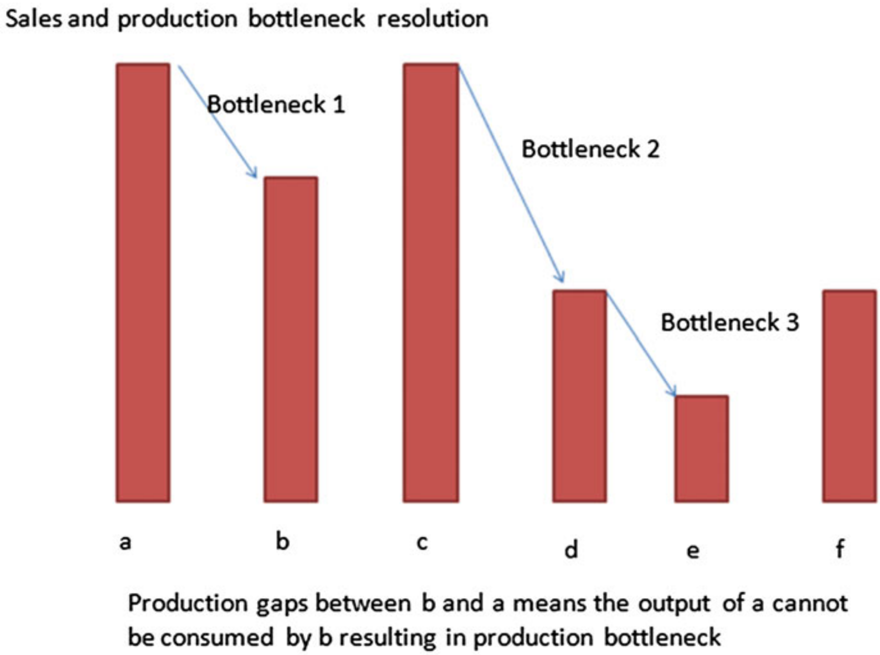

Fig. 28.10 Process bottleneck visualization, identification and prioritization

From NDTV.com

The sale of more than 25% in Jio Platforms along with a rights issue worth over 53,000 crore have helped Reliance Industries become net debt-free much earlier than its target of March 2021.

For companies which are unable to move ahead without the necessary funding they will have to explore the options like debt financing and in some cases public listing or any other means of raising equity capital. During Covid, it's mostly equity that has given the most money out of which JIO is clearly the market leader.

28.2.18 Manufacturing and Operations

A closer study of the various risk assessment and gap analysis of various companies shows the humane side of workforce management wherein, many company have tried to retain the workforce and remain investible by conserving the funds and growth prospects. Apart from the financial sector the biotech and tech cluster, gamification and healthcare sectors are mostly doing better than expected due to the problems with men, money and labor force management (Fig. 28.11).

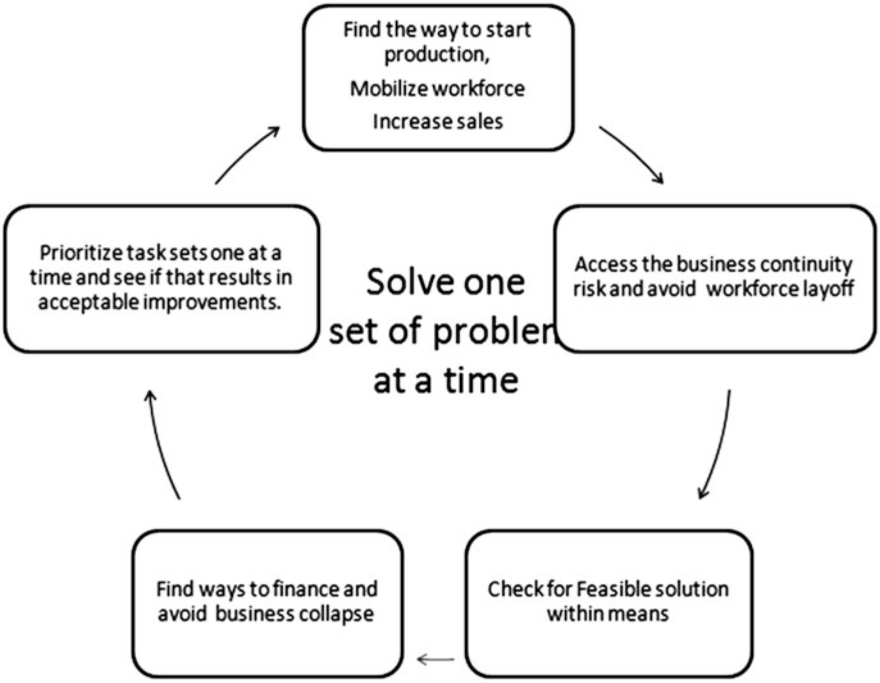

Fig. 28.11 Recommended ways of solving the problem or a set of problem one at a time

28.2.19 Sales

The most striking story that was seen during this research is the zero sales for a company like Maruti Suzuki during the beginning of the lockdown period.

> Businesstoday.in reported "Coronavirus lockdown: Maruti Suzuki reports zero sales in April"

While more and more companies like the construction sectors are highlighting various options like the low interest rates to attract home buyers, there are other innovations across the industries which serve as a great learning to the rest of the companies in the segment.

28.3 Results and Recommendations

As analyzed above the various activities can be grouped under three primary categories for the manufacturing segment.

28.3.1 Procurement Process Under Various Limitations

The inevitable shift is observed in the procurement process including changes in government sector procurement processes which has been the most difficult to change historically. In an article in Haryana times dated August 4, 2020 it has been mentioned that Haryana plans to switch over to machine driven procurement As per the article published in Hindi Haryana, before the paddy harvesting season the government has embarked upon a process to allow for procurement of food grains in a different way by shifting from manual to machine driven procurement during Covid-19. Such steps to automate the procurement process even by government so clearly the nature of changes in the procurement process. Write from government to the other industries the procurement process must change like the hardware procurement process which got impacted for it system of GSTN.

Also Industries observing few new Trends being picked up like crowd procurement which is relative new. Assembler function has been observed to change over time as they now need to adapt to the changes in the service and supply chain process.

Reinventing the procurement process is one of the ways to deliver during the pandemic times and should cover various business continuity measures after learning from the industry pears. This can be facilitated by learning the best practices from the segment leaders which fall under the Q1, Q2 and Q3 quadrants and are leaders in one way or another.

28.3.2 Operational Readiness and Business Continuity Under Drastic Situation

Operational readiness means to empower the sector to work at optimal levels of efficiency even during the pandemic situation and during the revival period. It also considers the way to manage the operating assets in a way that best utilizes the workforce and enables continuous efforts to enhance the process via improvement that allows virtual workforce management along with virtual assets and industrial production management. This can reduce the exposure to virus and close proximity off people can be avoided thus limiting the downside in production manufacturing space during this pandemic situation. This requires a close observation of various values and trends as given in Sect. 28.2.16 above and constantly improving the process by removing the bottlenecks.

28.3.3 Impact of Changes in Sales and Forecasting Techniques

Safeguarding long-term business is contingent on a solid plan during such pandemic. It is not possible to drive sustainable profit which is unaffected by the movement uncertainty during a pandemic. So industry is at a cross-section wherein most of industry and Technology helping each other to achieve the best out both and for the betterment of all.

28.3.4 Incorporate the New Normal, Drastic Changes and Improved Profitability

The new normal for improve profitability would include accelerated adoption of cloud infrastructure. Automation is the way to fuel growth in the future and there is no other way out. Our Industries would largely remain heavily dependent on workforce but it is equally important to have a mobile workforce which can trigger industrial production from any part of the globe by automating the means of production and using IOT (Internet of things) along with the other tools to gain access to this production system from remote. The human machine interaction should not only be in close proximity but also driven via latest technology. This also means operating agility and remote workforce management would be the way to go because higher automation would require higher capital which is not available with majority of the industrial production setups.

The manufacturing should also be resonating with the sales were then the sales team have to cater to be digitally enabled and we should be able to reach out to customers both in digital as well. It would be little far-fetched Idea initially to go for complete digitization immediately because of practical and financial reasons but can be a top priority for the coming years. Digitization is not possible in most company due to Limited capital driven Enterprises which would not be able to cope up with the funding requirements and reinvent process. Changes are a given and it will drive the way we operate our production and the way we sell goods.

28.4 Conclusion

These are exceptional circumstances and set of events that have impacted all the aspects of manufacturing and operation process. The impact is not isolated but far and wide. The demands of the near future may be changing for good and each company is advised to reinvent the processes. It also means starting out on an un known journey against all odds but must be started. To help companies adopt to the new ways, learning's from the macroeconomic variables along with the segment leading companies which has shown the way ahead one way or another will be the first thing that each company should refer followed with the bottleneck assessment and also ascertain the set of processes that needs the most push. Once a group of activities have been identified to be improved during the next period of time, the company must also approximately estimate the amount of effort to arrive at an approximate value whereby calculating the probability to move to the next desirable state. The sum of impact over subsequent time periods can also be estimated and during the execution, the companies must follow a iterative assessment to identify the impact of the last change thus continuously filling the gaps identified in the gap assessment. The probability of moving to a decent level of operations is high as per the analysis which intern means that each and every company can hope to revive following a simple assessment, planning and action driven working model.

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Conflict of Interest The author(s) declare that they have no conflicts of interest to report regarding this study.

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29 Impact of Repatriated Migrants on the Production Possibility of Agricultural Sector Owing to Covid: A Study on the Basis of Inferential Statistics

Sanjaya Kumar Sahoo and Sukanta Chandra Swain

Abstract

An inherent trait of Indian agriculture is prevalent of disguised unemployment. However, uncertainties in agriculture, mind set of rural masses towards farming and lifestyle of rural youth have succeeded persuading rural youth to migrate and get engaged in non-agricultural activities; thereby releasing the disguised unemployed for employment transparently. Covid-19 pandemic has reversed the trend and the fear of recurrence of disguised unemployment in agriculture is very much there owing to repatriated workforce from their migrated places. Considering the would-be challenge of managing huge workforce, emerged due to addition of returnee migrants with already existing workforce in agricultural sector, this chapter aims at unfolding the problems to be cropped up in rural India, particularly in Banpur Block of Odisha State and devising the way out to address those problems. The study has used primary data collected from the households of 40 returnee migrants that are selected by snowball sampling method and used ANOVA and Regression Coefficients for inference.

Keywords

Returnee migrants · Agriculture · Disguised unemployment · Productivity · Rural economy

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29.1 Introduction

Agriculture is the backbone of India's economy. It provides direct and indirect employment to nearly 50% of all the labour force and provides food security to all the people of our country. But the matter of regret is that it has been facing so many problems. One of the major problems in Indian agriculture is the small size of land and labour productivity. It occurs due to dependence of large number of people on available small holdings of the family. This leads to division and fragmentation of land. Because of dependence of large number of people on small land, agriculture has been failing to provide employment to all the labour force of the family. Due to paucity of employment opportunity and to avoid disguised unemployment in agriculture, some rural people prefer to migrate for adding income to the family income. At present, pandemic owing to Covid-19 has changed the dimension of economic development not only in India but also the whole world. Almost all the migrant workers in India have lost their job due to shut down and lock down across the country and are forced to back to their native places just to save their lives. Realizing the difficulty faced by the migrant workers, Government of India liaising with every State Government has adopted a standard operating procedure for returning them to their own states. Now to put emphasis on both the lives and livelihoods of the returnee migrants, Government of India and Government of Odisha has taken so many steps. However, all the steps taken are insufficient to absorb all the returnee migrants. Most of them are now completely dependent on their family agricultural land as their main occupation by raising the dependency ratio on the same land. Total production from an agricultural field depends on the productivity of all the factors involved, particularly major factors like land and labour. As returnee migrants are added to the existing family labour force in the agricultural land, this may lead to the following three consequences.

1. Employment of all the returnee migrants and increase in agricultural productivity considerably, provided the existing workforce in the family is much less than what is required to optimally utilize the available agricultural land of the family. In such a situation, all returnee migrants of the family may be engaged in farming effectively with a considerable increase in total production and productivity.
2. Temporary or seasonal employment of the returnee migrants and increase in agricultural productivity marginally, provided the existing workforce in the family is almost enough to optimally utilize the available agricultural land of the family except during peak seasons like sowing or harvesting. In such a situation, may be, the existing workforce in the family is doing most of the farming activities efficiently by its own, but it needs some additional workers to supplement for activities like harvesting and sowing that require more workers in a stipulated time frame. This requirement may be fulfilled by the returnee migrant workers of the family by which the expenses of the family that are to be incurred on hired workers could be saved, and
3. Unemployment or disguised unemployment of the returnee migrants and no change in agricultural productivity with given natural conditions, provided the

existing workforce in the family is enough to optimally utilize the available agricultural land of the family. In such a situation, if the returnee migrant workers get engaged in agricultural activities that will lead to disguised unemployment as there won't be any upgradation in productivity. Otherwise, they will be unemployed.

If the returnee migrants get engaged in agricultural sector completely and efficiently as mentioned at point (1) and partly or seasonally as mentioned at point (2) above, the contribution provided by the additional labour force in the agricultural field to increase the family income may not be the same as whatever they were earning as a migrant labour outside the native place. The potential threat that may occur in the agricultural sector due to the return of migrant workers is the increasing disguised unemployment by reducing the productivity of the labour force. So the Government, experts think about the remedial measures for saving the economy from this type of problem.

29.2 Review of Literature

Arumugam et al. (2020) shows that Pandemic Covid-19 generated from china disrupts the every activity of the economy in general and farming activity in particular. As lock down imposed it becomes difficult in the transportation of the agricultural commodity from the producer to the consumer. So the growth rate in this sector falls. Similarly many perishable products are wasted due to the lack of available labour supply.

Siche (2020) finds that agriculture and food supply chain severely affected due to pandemic Covid-19. This reduced the purchasing power of the people. So Government is taking so many steps to control the spread of corona virus. The study shows that people demand less food grain due to reduced purchasing capacity.

Hajra and Ghosh (2018) studies the relationship among agricultural productivity reduction, poverty and the out-migration in the Sunderbans area. The findings show a positive relationship between agricultural productivity reduction and out-migration. Further study finds the negative relationship between poverty and out-migration.

Maharjan et al. (2013) finds that even though Nepal is one of the agrarian-based economy, still migration is the main livelihood in the economy. The study shows that people generally neglect subsistence farming whenever there is alternative source of income is available. And people show more keenness towards livestock farming rather than crop farming whenever their household income is low. The chapter highlights increasing female participation in the agricultural activity.

Krishnaveni et al. (2020) shows that pandemic corona virus brings the social and economic life all over the world to a standstill. The lock down imposed by the Government affects negatively to the agricultural sector. Different primary activities like dairy, floriculture, poultry, etc. witness loss. Farmers are facing difficulty like labour shortage and transport problem.

Malanski et al. (2019) finds that agriculture issue is divided into six domains like labour market and rural employment, occupational health and safety, agricultural policy and agrarian changes, work organization, labour and family farms and labour and farm sustainability. These domains are analysed through five scientific communities. The study shows that USA, France and China is the leader in the scientific landscape. The chapter suggests a collaborative work is necessary for the sustainable development in agriculture.

Tomich et al. (2019) in their research establish that structural transformation can reduce poverty and they cite how the number of countries which were dominated by agriculture with respect to their employment and GDP has been reduced due to structural transformation.

Whether additional workforce by way of return of migrant workers in rural sector puts pressure on productivity of agricultural sector has not been the focal point of any of the existing literature. This gap is the base of our chapter.

29.3 Objectives and Methodology

The objectives of the chapter are as follows.

- To explore the potential threat to the productivity of the labour force in the primary sector due to the pandemic caused by Covid-19 in the Banpur block of Odisha.
- To suggest the way out to mitigate the risk associated in the agricultural sector owing to repatriated migrants.

To address the above objectives following methodology is followed.

- To explore the potential threat to the productivity of the labour force in the primary sector due to the Covid-19 pandemic situation in the Banpur block of Odisha, a structured questionnaire is administered. As per the questionnaire 40 returnee migrants and their household heads are interviewed telegraphically to ascertain how they have engaged or going to engage their returnee migrants in the agricultural field. Here snowball sampling method is followed to trace the family whether returnee migrants are engaged in their own agricultural field. On the basis of their response we can conclude that whether returnee migrants are responsible for increasing or decreasing the productivity of the labour force in the agricultural sector.
- To suggest the way out that could mitigate the risk associated in the agricultural sector due to returnee migrants, besides the responses of returnee migrants and their household heads, suggestions from the experts are taken into account.

29.4 Potential Threat to the Productivity of the Labour Force in the Primary Sector Owing to Repatriated Migrants

Before ascertaining whether the returnee migrants pose pressure on productivity of the rural sector, relevant demographic traits are to be presented.

29.4.1 Demography of the Family of the Returnee Migrants

Figure 29.1 shows the family size of the sample families taken in the study. There are eight number of families with four members in each of the families. Further, six number of families have family size each of five members. Similarly, the family size of six, seven, eight, nine and ten are there respectively in number of families of eight, two, eight, four and four in the sample.

Figure 29.2 represents the acre of land owned by the sample households. It is found that eight number of families are landless farmers. Similarly, there are eight families owned less than one acre of land. Further, there are twelve, six, two and four families which own respectively one acre, two acres, three acres, and five acres of land. This indicates that maximum families of the study area belongs to land less, marginal and small farmers.

Figure 29.3 highlights the acres of land cultivated by the sample families. It shows that there are six families that are cultivating less than one acre of land. Similarly, there are one, two, three and five acres of land cultivated by two, sixteen, twelve and four number of families respectively.

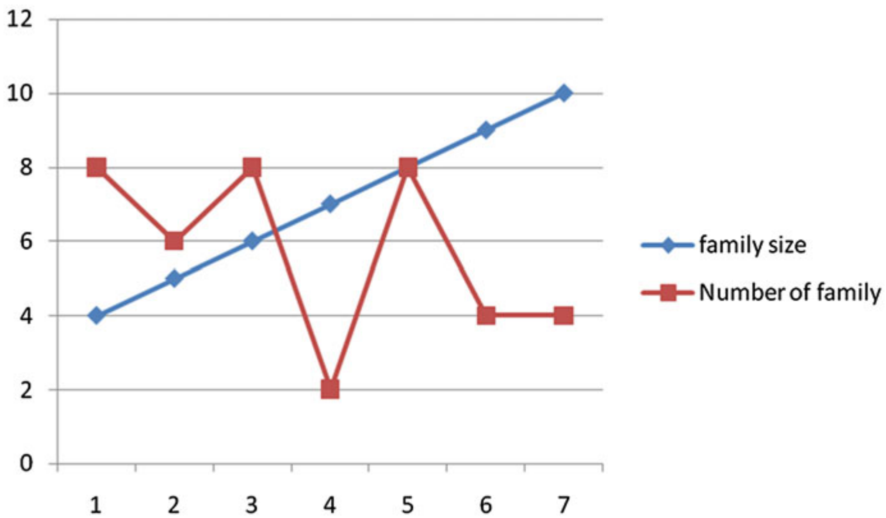

Fig. 29.1 Size of the family members

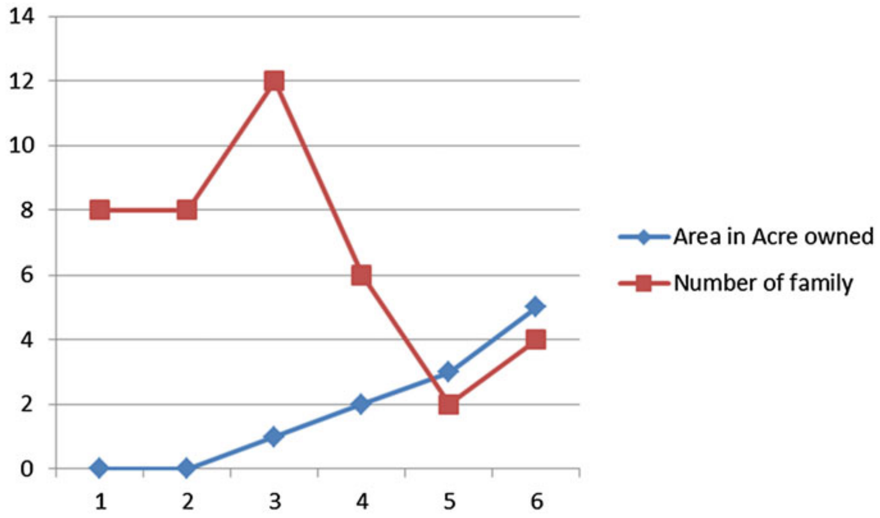

Fig. 29.2 Acres of land owned

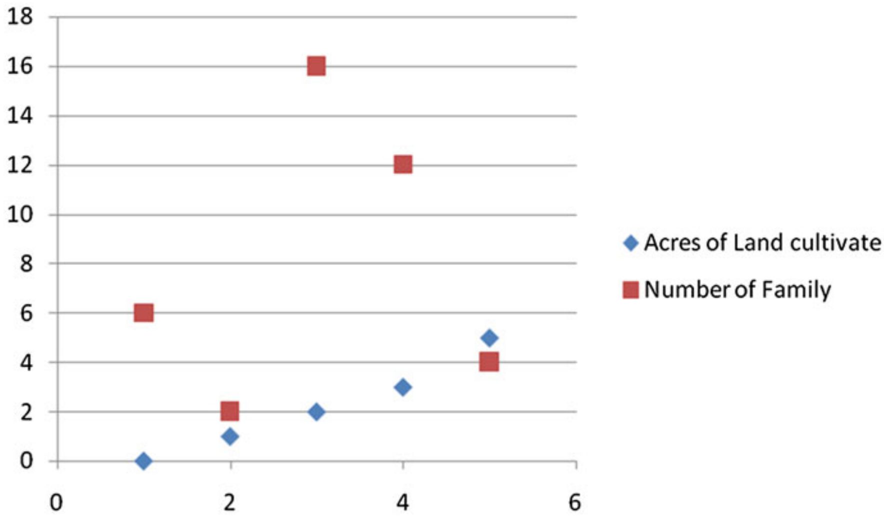

Fig. 29.3 Acres of land cultivated

In Fig. 29.4, number of families is taken in the *Y*-axis and total paddy production in the financial year 2019–2020 is taken in the *X*-axis. This shows that there are six agricultural families that had not produced paddy in the previous year. There are two families that had produced 2000 kg of paddy in the same year. Similarly, there are four, two, ten, six, two, four, two, two and six families that had produced 3000,

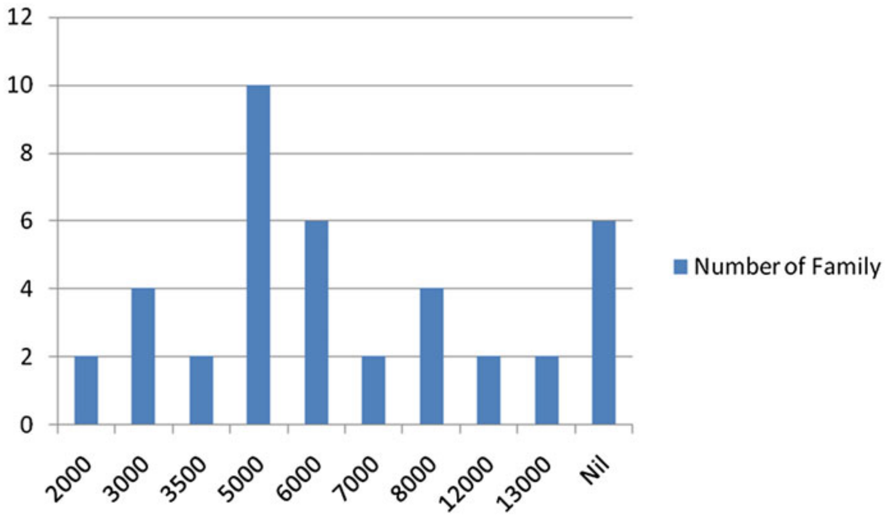

Fig. 29.4 Total paddy production in the previous year

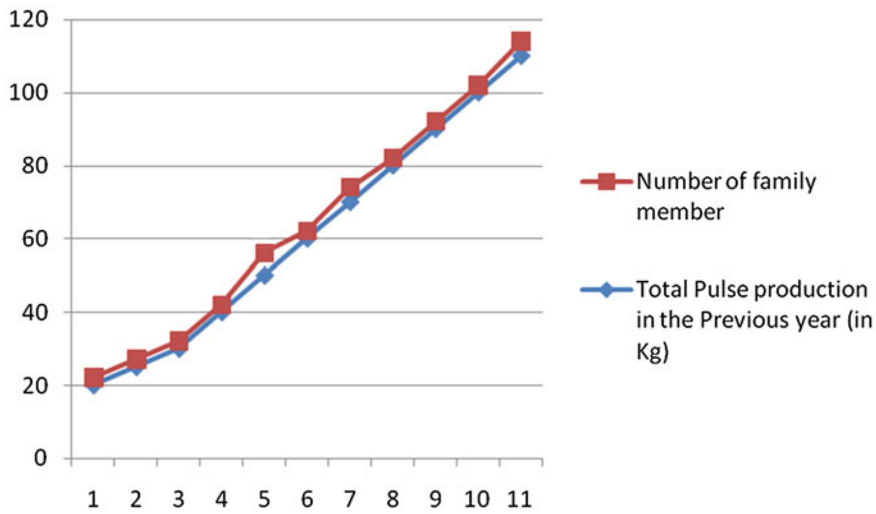

Fig. 29.5 Total pulse production in the previous year

3500, 5000, 6000, 7000, 8000, 12,000 and 13,000 kg of paddy respectively in the year 2019–2020.

Figure 29.5 shows the total pulse produced by the sample farmers where 20, 25, 30, 40, 60, 80, 90 and 100 kg of pulses produced by two different types of families in the financial year 2019–2020. Similarly, 50 kg of pulses are produced by six families

Table 29.1 Hiring workers

Hiring workers	Frequency
No	8
Yes	32

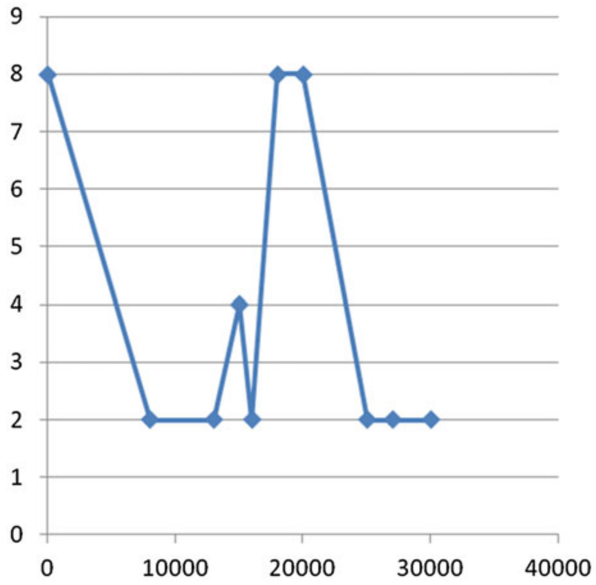

Fig. 29.6 Expenditure on hiring workers in the previous years

and 70 kg of pulse are produced by four number of families in the previous year. Further, 110 quintals of pulses are produced by four families in the same year.

Besides paddy and pulse production, there are some members who are engaged in the production of mango, cashew, vegetables, flowers, etc. Further, there are some families who are engaged in rearing the goat for commercial purpose.

Table 29.1 shows that 32 sample families hire agricultural workers while cultivating and only eight families don't hire any labour at the time of cultivation. It indicates that there is scope of accommodating some returnee migrants in agriculture particularly in the families who keeps on depending hired workers for cultivation.

Figure 29.6 shows sample agricultural farmers' total spending on hiring agricultural workers in the previous year. The Graph highlights that there are eight families who did not hire any agricultural labour in the previous year. There are two families who spent Rs. 8000 towards hiring agricultural labour. Similarly there are two, four, two, eight, eight, two, two and two families who spent respectively Rs. 13,000/-, Rs. 15,000/-, Rs. 16,000/-, Rs. 18,000/-, Rs. 20,000/-, Rs. 25,000/-, Rs. 27,000/- and Rs. 30,000/- on hiring agricultural labour.

Table 29.2 shows that there are 32 families from where only one member from each family is out-migrant. Similarly, two members are out-migrated from each of

Table 29.2 Number of out-migrants from sample families

Number of out-migrants from your family	Frequency
1	32
2	4
3	4

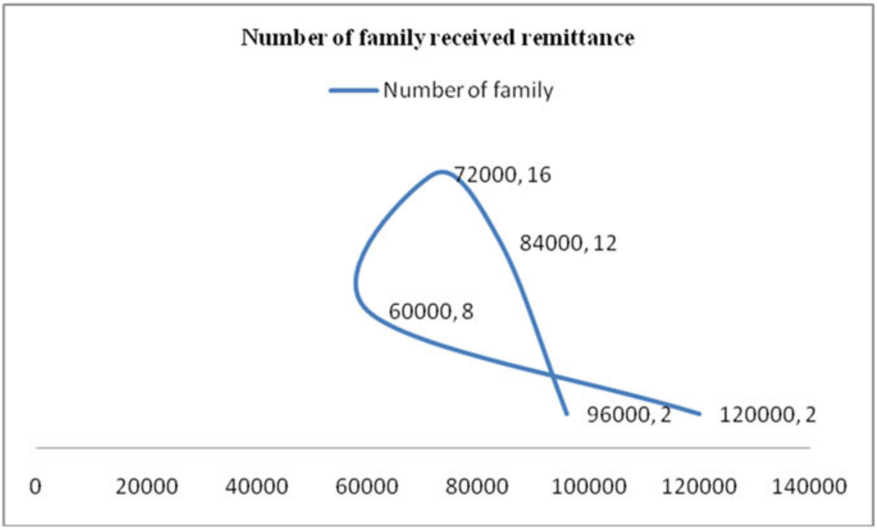

Fig. 29.7 Amount of remittance from each out-migrated family member (per annum)

the four families. There are three members from each of the four families that are out-migrated.

Figure 29.7 shows sample family members that received remittance in the previous year. it shows that there are two families which received remittance from out-migrants to the tune of Rs. 120,000/- in the previous year. Similarly, there are other two, eight, sixteen and twelve families which received the remittance to the extent Rs. 96,000/-, Rs. 60,000/-, Rs. 72,000/- and Rs. 84,000/- in the same period respectively.

Most of the people said that they prefer to out migrate due for lack of employment opportunities locally, poverty in the family, pressure of debt ridden, marriage of the sister and education of their children.

Most of the migrant workers come back to their native land. So most of them have planned to engage themselves sometimes in the agricultural sector and other times in the non-agricultural sector. Further some of them planned to diversify the agricultural productivity. So that maximum time they can be engaged in the agricultural sector. More over some of them have planned to sell the agricultural production during the lean season. Some of the returnee migrants planned to be engaged in the painting work. Some of them planned to work sometime in their own agricultural land and other time to be engaged as daily wage labour in the non-agricultural sector. Further some have planned to be self-employed like opening saloon, etc.

29.4.2 What Heads of the Households of Returnee Migrants Do Feel on Productivity Threat?

To explore the potential threat to the productivity of the labour force in the primary sector due to pandemic caused by Covid-19 from the point of view of the head of the household of the returnee migrants, variables identified are:

- Returnee migrant family member prefers to work in agricultural sector throughout the year (v1),
- Returnee migrant family member prefers to work less than 3 months in the agricultural field (v2),
- Returnee migrant family member prefers to work for sometime in the agricultural activity and some other time in the non-agricultural activity (v3),
- Returnee migrant family member prefers to sell the agricultural output when there is lean phase in agricultural field work (v4),
- Returnee migrant family member prefers to diversify the agricultural field to make it commercialized throughout the year (v5),
- Returnee migrant family member has a plan for self-employment related to agricultural sector but not directly engaged in cultivation (v6),
- Returnee migrant family member prefer to work only in the non-agricultural activity (v7),
- Due to paucity of land, returnee migrant family member not interested to work in agricultural activity (v8),
- Returnee migrant family member won't be a burden for agricultural productivity as he will be engaged in agriculture efficiently or will do some productive job that will promote agricultural productivity (v9).

Here V1, V2, V3. . .. . and V8 are taken as independent variable and V9 taken as dependent variable. Data is collected from the heads of the households of the returnee migrants through a 5-point rating (Likert) scale and regression technique is applied to know the significance influence of the independent variables on dependent variable. The collected data put in the SPSS to check the reliability and we found the Cronbach's Alpha as 0.697 as mentioned in the Table 29.3. Since sample size is less with the Cronbach's Alpha value of 0.697, we can settle down that the variables identified and data collected are accepted as reliable for exploring the potential threat to the productivity of the labour force in the primary sector due to the pandemic caused by Covid-19 from the point of view of the household of the returnee migrant.

Table 29.3 Reliability statistics

Cronbach's alpha	No of items
0.697	9

Table 29.4 ANOVA

Model		Sum of squares	*df*	Mean square	*F*	Sig.
1	Regression	9.337	8	1.167	4.864	0.001
	Residual	7.438	31	0.240		
	Total	16.775	39			

Table 29.5 Regression coefficients

Model		Unstandardized coefficients		Standardized coefficients		
		B	Std. error	Beta	*T*	Sig.
1	(Constant)	2.220	0.844		2.630	0.013
	V1	−0.075	0.097	−0.104	−0.767	0.449
	V2	0.541	0.184	0.996	2.947	0.006
	V3	−0.199	0.207	−0.328	−0.962	0.344
	V4	−0.077	0.132	−0.077	−0.582	0.565
	V5	0.014	0.110	0.021	0.126	0.900
	V6	0.153	0.125	0.190	1.225	0.230
	V7	0.133	0.184	0.103	0.726	0.474
	V8	−0.146	0.152	−0.135	−0.959	0.345

Dependent variable: V9

Null Hypothesis: Returnee migrants won't be productively engaged in the primary sector and hence will be a burden.

Table 29.4 shows that the level of significance is less than 0.05 and hence null hypothesis is rejected. So returnee migrants can be productively engaged in the agricultural sector and they cannot be considered as a burden from the point of view of the heads of the households.

Table 29.5 shows that out of the total eight independent variables, the only one variable, i.e. V2 significantly influence the dependent variable. Here the calculated significance value of v2 is 0.006 which is less than the presumed level of significance i.e. 0.05. Other independent variables don't have significant influence on the dependent variable. So as per the statement of the heads of the households of the returnee migrants, the repatriated migrants can work less than 3 months in the agricultural field which can effectively accommodate during peak seasons. If the returnee migrants depend on agriculture more than 3 months in a year, it may put pressure on productivity. Thus, to engage the returnee migrants throughout the year, some other heads of employment in rural sector needs to be created.

29.4.3 What Returnee Migrants Do Feel on Productivity Threat?

To explore the potential threat to the productivity of the labour force in the primary sector due to inflow of returnee migrants to the rural sector, as returnee migrants feel, variables identified are:

Table 29.6 Reliability statistics

Cronbach's alpha	No of items
0.671	9

Table 29.7 ANOVA output

Model		Sum of squares	d*f*	Mean square	*F*	Sig.
1	Regression	11.090	8	1.386	6.219	0.000
	Residual	6.910	31	0.223		
	Total	18.000	39			

- I prefer to work in agricultural sector throughout the year (v1),
- I prefer to work less than 3 months in the agricultural field (v2),
- I prefer to work for sometime in the agricultural activity and some other time in the non-agricultural activity (v3),
- I prefer to sell the agricultural output when there is lean phase in agricultural field work (v4),
- I prefer to diversify the agricultural field to make it commercialized throughout the year (v5),
- I have a plan for self-employment related to agricultural sector but not directly engaged in cultivation (v6),
- I prefer to work only in the non-agricultural activity (v7),
- Due to paucity of land, I am not interested to work in agricultural activity (v8),
- I won't be a burden for agricultural productivity as I will be engaged in agriculture efficiently or I will do some productive job that will promote agricultural productivity (v9).

Here V1, V2, V3. . .. . and V8 are taken as independent variable and V9 taken as dependent variable. Data is collected from the returnee migrants through a 5-point rating (Likert) scale and regression technique is applied to know the significance influence of the independent variable on dependent variable.

The collected data put in the SPSS to check the reliability and we found that the Cronbach's Alpha as 0.671 as mentioned in the Table 29.6. Since sample size is less with the Cronbach's Alpha value of 0.671, we can settle down that the variables identified and data collected are accepted as reliable for exploring the potential threat to the productivity of the labour force in the primary sector due to the pandemic caused by Covid-19 from the point of view of the returnee migrants.

Null Hypothesis: Returnee migrants won't be productively engaged in the primary sector and hence will be a burden.

Table 29.7 shows that the level of significance is less than 0.05 and hence null hypothesis is rejected. So returnee migrants can be productively engaged in the agricultural sector and they cannot be considered as a burden from the point of view of the returnee migrants.

Table 29.8 shows that out of the total eight independent variables, the variables V2, V4, V5, V6, V7 and V8 significantly influence the dependent variable. Here the

Table 29.8 Regression output coefficient

Model		Unstandardized coefficients		Standardized coefficients		
		B	Std. error	Beta	*T*	Sig.
1	(Constant)	2.045	0.828		2.471	0.019
	V1	0.055	0.106	0.074	0.517	0.609
	V2	0.328	0.101	0.541	3.233	0.003
	V3	−0.234	0.207	−0.189	−1.133	0.266
	V4	0.396	0.097	0.538	4.081	0.000
	V5	−0.387	0.128	−0.412	−3.031	0.005
	V6	0.307	0.122	0.332	2.523	0.017
	V7	0.438	0.167	0.326	2.626	0.013
	V8	−0.393	0.147	−0.370	−2.682	0.012

calculated significance value of V2, V4, V5, V6, V7 and V8 are 0.003, 0.000, 0.005, 0.017, 0.013 and 0.012, respectively which are less than the presumed level of significance i.e. 0.05. Other independent variables, i.e. V1 and V3 don't have significant influence on the dependent variable. So as per the statement of the returnee migrants, they can work less than 3 month in the agricultural field. They can sell the agricultural output when there is lean phase in agricultural field work. Further they will diversify the agricultural field to make it commercialized throughout the year. Moreover, they can be self-employed related to agricultural sector but not directly engaged in cultivation. Similarly, they don't have hesitation to work only in the non-agricultural activity. However, most of them are not interested to work in agricultural activity due to the paucity of land and nature of job.

The finding shows that as per statement of the heads of the household, the returnee migrant can be productively engaged in the primary sector by working only for 3 months in the agricultural sector and other time in other activities. But from the point of view of the returnee migrants, they can be productively engaged in the primary sector in a several way like working less than 3 months in the agricultural sector, by selling the agricultural output in the lean season, by diversifying the agricultural output, by creating atmosphere of self-employment in the agricultural sector etc. Further they can be engaged in the non-agricultural sector of the economy. Moreover, due to the paucity of land most of them are not interested to work in the agricultural sector throughout the year.

29.5 Way Out to Mitigate the Risk Associated in the Agricultural Sector Due to Returnee Migrants

To devise a set of suggestions for mitigating the risk associated in the agricultural sector due to returnee migrants, besides the responses of 40 household heads, suggestions from the experts are taken into account. Accordingly, following suggestions are put forth.

- More funds need to be provided to the agricultural sector.
- Proper training is to be given to the migrant workers for the beneficial use of the agricultural sector.
- Plan must be made for the improvement in modern technology in the agricultural sector.
- Emphasis should be given for the diversification of the use of productivity in the agricultural sector.
- Government needs to establish data centres for providing information related to the agricultural sector.
- We know that agriculture is a state subject. So every state needs to coordinate while formulating any policy by which it will not affect the interest of the other states.
- Government needs to provide more institutional credit to the all the farmers including small and land less farmers and workers.
- There are so many small scale and cottage industries that use agricultural output as raw materials. So priority needs to be given to promote those industries so that the demand side distortions of agricultural produce won't be there.
- For the larger interest of the society, Government needs to link the MNREGA with the development of the agricultural sector.
- For enlarging the market of the agricultural sector, e-commerce facility should be extended to the agricultural sector.
- Government needs to establish an Agricultural Infrastructural Fund.
- Farmers need to supply proper seed, fertilizers and modern instruments to the farmers.
- More Research and Development should be done on agricultural sector.
- Government needs to organize camp to train the farmers the modern way of cultivation so that returnee migrant workers can be engaged effectively.
- Government needs to prioritize the security of the farmers.
- Public investment needs to be increased in the agricultural sector.
- Minimum Support Price needs to be redefined in the favour of the farmers.

29.6 Conclusion

It is obvious that as additional workforce gets injected to the existing set up, distortions in labour market is natural. It encounters immediate hiccup in the form of imbalance in two market forces of demand and supply of workforce. Ultimately, pressure on productivity comes into picture if the issue of inflow of workforce is not managed properly. However, channelizing the excess workforce in all possible effective ways may turn the situation around and convert the threats to strength. In our comprehensive study, we could find that the existing manpower in the agricultural sector is of the feeling that the existing facilities cannot accommodate additional workforce in agriculture effectively. Maybe, some of them can be engaged effectively for a short period of time in a year as some of the existing farmers are depending on hired workers for cultivation seasonally. If the repatriated migrants get engaged in agriculture for longer period in a year, it may put pressure on productivity and thus give rise to disguised unemployment. Thus, to engage the excess workforce in the form of repatriated migrants throughout the year, some other heads of employment in rural sector needs to be created.

As felt by the repatriated migrants, besides cultivation which can be a very short arrangement for their accommodation, there must be skill mapping and appropriate training to them so that they can be engaged throughout the year effectively with rural endowments. If allied activities that depend on agricultural output or cater to agricultural inputs are promoted, repatriated migrants can have positive impact on production possibility of agricultural sector. On the contrary, if injection of extra workforce to rural sector is not properly handled, there will be massive disguised unemployment and production possibility of the agricultural sector will be hampered greatly. Thus, skill mapping and relevant training to returnee migrants coupled with facilitation from government in promoting new ventures or adoption of modern technology can go a long way in turning around the rural sector.

Acknowledgment We acknowledge the cooperation of the selected returnee migrants, the heads of their households and experts whose enlightened responses have been the foundation of this chapter.

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Conflict of Interest We declare that we have no conflict of interest to report regarding the present study.

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Nicotine in COVID-19: "Friend or Foe"? 30

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Abstract

Corona virus disease 2019 that was initially observed in the Wuhan province of China is now a pandemic situation and whole world is looking toward the solution to combat the disease. Since the virus is new and its associated pathogenesis is still not well understood, thereby numerous researches are going on to find out the promising therapeutic intervention. In current scenario, quickest and effective approach is desirable to find out the potential candidate against COVID-19. Computational modeling is considered to be the only solution which can pace up the identification of desired candidate. A recent French study has reported that smokers are less likely to be affected by COVID-19 than non-smokers signifying that nicotine may be playing a role for the same. In this regard, it becomes mandatory to explore the scientific background behind it at least by initial computational modeling studies. Through comprehensive understanding of the molecular targets involved in COVID-19, we have selected few important targets and performed docking studies of these targets with nicotine. Also, other computational *in-silico* approaches were used for target analysis and ADMET prediction. Nicotine was found to have interaction with SARS-CoV-2 and ACE-2

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receptors through docking studies. The other computational approaches used predict nicotine to have good solubility, target accuracy and pharmacodynamics. Nicotine follows druglikeness factor rules, suggesting it as a potential candidate to track further cell based and biochemical assays to investigate potential of nicotine for use against COVID-19. It may be concluded that nicotine may be a potential agent for various target proteins of SARS-CoV-2.

Keywords

SARS-CoV-2 · In-silico · COVID-19 · Virtual screening · Toxicity · Nicotine

30.1 Introduction

Worldwide pervasiveness of Corona virus disease 2019 (COVID-19), caused by the SARS-CoV-2 is increasing day by day. COVID-19 is not only a reason for mortality and morbidity but also knocking the social and economic fronts too (Satpathy et al., 2021). As per WHO, till date COVID-19 has affected 216 countries & territories around the world. Rising number of evidences suggests that viral infection is not only restricted to respiratory illness but this virus eventually spreads out and triggering neuronal and cardiac complications (Geng et al. 2020; Wu et al. 2020). All over the world researchers are considering this pandemic as a war and doing restless efforts to fight against it. Numerous efforts have been made to understand the structure and target sites for COVID-19. These findings argue that numerous proteins of SARS-CoV-2 such as fusion proteins, proteases, nucleocapsid proteins, ribose phosphatases, endoribonuclease and other free enzymes are involved during the course of this disease (Zhou et al. 2020; Prajapat et al. 2020). However, during this clinical scenario it is very challenging for practitioner to use nicotine without proper scientific background, especially when interaction with ACE2 is in question. Thereby, the virtual studies are only solution to explore the nicotine interaction against the molecular target sites of COVID-19 as well as ACE2.

Thereby, the present study was designed to conduct the virtually screening of nicotine against SARS-CoV-2 target proteins, ADMET prediction and target prediction (Enmozhi et al. 2020; Zhang et al. 2020).

30.2 Literature Survey

Currently Plasma therapy, hydroxychloroquine, and azithromycin are main therapeutic option against COVID-19. Unfortunately, till date no promising therapeutic intervention is available for clinical use. To develop ground-breaking therapeutic concepts to prevent the progression of this disease, a comprehensive understanding of the molecular targets involved and exploration of their modulators are need of time. In this regard, an extensive literature survey to identify the potential candidate and exploration of therapeutic potential of that candidate using Computer-aided docking seems to be rational. It is worthwhile to note that SARS-CoV-2 has been noted to interact with the ACE2 receptor present on the surface of host cells through spike protein (S protein) to invade into epithelial cells of the host, suggesting ACE2 as a key molecule for COVID-19 infection. Studies reveal that affinity of S2 toward ACE2 receptor leads to its down-regulation followed by lung injury during the course of SARS-CoV infection (Li et al. 2020). Conversely, over-expression of ACE2 may accelerate the access into the host of COVID-19, and potentiate the clinical manifestations (Verdecchia et al. 2020). Thus, targeting ACE-2 to prevent interaction between SARS-CoV-2 with ACE2 could be precedence. It would be the fortunate if we could identify an agent that could target the interaction between ACE2 and SARS-CoV-2. A very recent published French report that states smokers are less likely to be affected with COVID-19. In regard evaluation of beneficial effect of nicotine against COVID-19, French researchers are preparing themselves to conduct human trial for the same.

30.3 Methodology

30.3.1 Docking of Nicotine on SARS-CoV-2 and ACE-2 Proteins

30.3.1.1 Receptor Preparation

The SARS-CoV-2 proteins (nucleocapsid, proteases, post fusion core, phosphatase, and endoribonuclease) and ACE-2 protein were selected based on comprehensive understanding of the mechanism of entry and replication of virus. Protein sequence data was collected from protein data bank. Selected protein data along with their PDB ID are tabulated in Table 30.1.

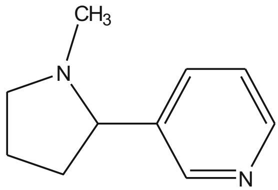
30.3.1.2 Ligand Preparation

The 2D structure of nicotine was drawn using ChemDraw 14.0 and saved in .cdx format (Fig. 30.1). The ligand file was then opened in open babel. Hydrogen was added to the ligand using Add hydrogen option and pH was set to standard physiological pH. Mol2 format was used to save ligand files.

Table 30.1 Targeted proteins of SARS-CoV-2

Sr. no.	RCSB-PDP ID	Name of protein
1	6M3M	SARS-CoV-2 nucleocapsid protein N-terminal RNA binding domain
2	6YB7	Protease
3	6W9C	Papain-like protease of SARS CoV-2
4	6LXT	Post fusion core of 2019-nCoV S2 subunit
5	6VXS	ADP ribose phosphatase of NSP3 from SARS CoV-2
6	6M0J	SARS-CoV-2 spike receptor-binding domain bound with ACE2
7	6VWW	NSP15 Endoribonuclease from SARS CoV-2
8	6Y2E	Free enzyme of the SARS-CoV-2 (2019-nCoV) main protease
9	1R42	Native Human Angiotensin Converting Enzyme-Related Carboxypeptidase (ACE2)

Fig. 30.1 Structure of nicotine



30.3.1.3 Docking

Docking is a molecular modeling technique that is used to predict how a protein interacts with ligands. Swissdock is a website where user can dock their respective ligand with protein. Swissdock is able to compute complete morphology and geometry, site and energy of ligands which interacts with proteins. Predictions from Swissdock were analyzed by using UCSF Chimera. Chimera is used for visualization of interactions and for molecular structural analysis.

The results were analyzed using two parameters full fitness energy and ΔG. Various energy of binding sites can be expressed by following equation:

$$\Delta G = \Delta G_{\text{sol}} + \Delta G_{\text{conf}} + \Delta G_{\text{int}} + \Delta G_{\text{roi}} + \Delta G_{\text{t/t}} + \Delta G_{\text{vib}} \tag{30.1}$$

The elements contain solvent effects, variation in ligand and protein interaction, internal rotation, energy due to ligand-protein binding, complex formation due to ligand and receptor interaction and variations in vibration modes results in free energy formation. A potential interactions and stable system is based on low (negative) energy.

Full fitness energy is the estimation of docking accuracy to estimate the fitness of a docking program by predicting the right ligand to bind with receptor. Low energy conformations are chosen where the score of each pose acts as the fitness function.

30.3.2 ADME Prediction

ADME studies are very significant in order to analyze the pharmacodynamics property of ligand. SwissADME is a website which allows the user to predict ADME properties of ligand. The server permits the user to enter SMILES information from PubChemor draw their ligand. The structure of nicotine was drawn, converted to SMILES and various parameters such as drug likeness rules (Ghose, Muegge, Lipinski, Egan and Veber), lipophilicity (iLOGP, WLOGP, XLOGP3, SILICOS-IT, MPLOGP, log P_0/w), water solubility—log S (SILICOS-IT, ESOL, Ali) and medicinal chemistry methods (Synthetic accessibility, Lead-likeness, Brenk, PAINS) were analyzed (Daina et al. 2017).

30.3.3 Target Prediction

The presence of cross reactivity or phenotypical side effects attributed by the action of small biomolecules was determined by molecular target studies. Swiss Target Prediction website was used to study target prediction of nicotine. Structure of nicotine was drawn, then converted to SMILES and analysis was done (Keiser et al. 2007; Gfeller et al. 2014).

30.3.4 Toxicity prediction

Tolerance power of small molecules before clinical studies in animals as well as human model were predicted by toxicological prediction of small molecules. Toxicological effects such as AMES toxicity, LOAEL, *T. pyriformis* toxicity, skin toxicity, hERG-II inhibitor, Minnow toxicity, hERG-I inhibitor, LD50, hepatotoxicity and human maximum tolerance dose were obtained from online database, pkCSM.

30.4 Results

30.4.1 Docking

The output of the docking investigation of nicotine with SARS-CoV-2 and ACE-2 proteins was the estimated ΔG (kcal/mol) and full fitness energy (kcal/mol) with which the ligand binds to the pocket of receptor protein. The results obtained are summarized in Table 30.2 and the active receptor binding of nicotine are shown in Figs. 30.2 and 30.3.

Table 30.2 Full fitness and estimated ΔG values predicted for Nicotine docked with target proteins by SwissDock

Ligand Name	Protein	Full fitness energy (kcal/mol)	Estimated ΔG (kcal/mol)
Nicotine	6M3M	−2993.056	−6.368318
	6YB7	−1237.363	−7.529965
	6W9C	−1557.825	−7.420591
	6LXT	**−5347.014**	−6.768288
	6VXS	−1662.630	−6.564621
	ACE2-1R42	−3033.52	−7.694256
	6M0J	−3371.881	−7.505898
	6VWW	**−3788.451**	−6.806345
	6Y2E	−1192.792	−6.609647

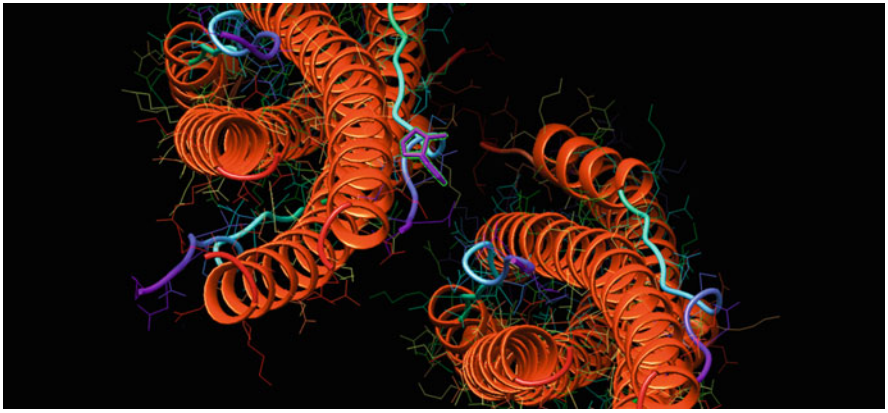


Fig. 30.2 Docking of 6LXT with nicotine (N4)

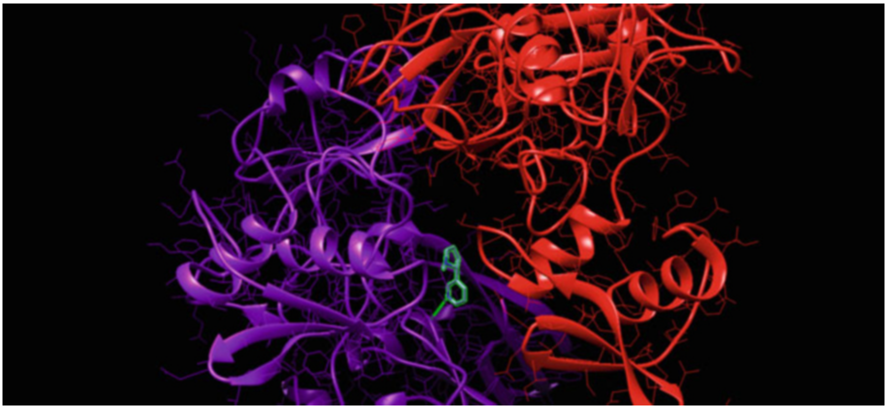


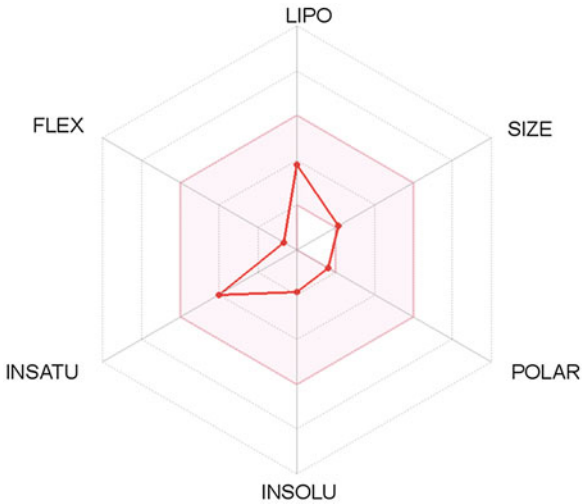
Fig. 30.3 Docking of 6VWW with nicotine (N8)

30.4.2 ADME Prediction

SWISSADME database was used for ADME prediction. The physicochemical characteristics of the drug molecule are 12 no. of heavy atoms, 0 H bond donors, 2 H bond acceptors, molar refractivity of 53.13 and TPSA parameter of the molecule is predicted 16.13 Å. Molecular lipophilicity values, iLOGP is 2.14, XLOGP3 1.17, WLOGP is 1.14, MLOGP is 1.17, SILICOS-IT is 1.89 and Consensus P_0/w is 1.50.

The calculated water properties are ESOL-1.89, solubility of $7.87e^{-02}$ mol/L and the drug belongs to soluble class. Pharmacokinetic data have predicted that the drug has high GI absorption penetrate BBB, does not act as P-gp substrate, and does not interact with cytochromes CYP1A2, CYP2D6, CYP2C19, CYP3A4 and CYP2C9. log K_p value that reflects skin permeation kinetic was noted to be -6.46 cm/s.

Fig. 30.4 ADME prediction of nicotine



The investigated compound complies with the Lipinski's Rules to justify its potentiality as drug like compounds. In addition, it too follows druglikeness score rules for example, Veber, Muegge and Egan. It does not obey Muegge score rule and has one violation of molecular weight less than 200. Its bioavailability score is 0.55. Further, medicinal chemistry parameters support its leadlikeness and its synthetic accessibility is found to be 2.05 (Fig. 30.4).

30.4.3 Target Prediction

Observations of Target prediction study as shown on the web page were given in Fig. 30.5. The pie chart predicts 44% of ligand gated ion channel, 28% of Family-A G protein-coupled receptor, 8% of Electrochemical transporter, 4% of Membrane receptor, 4% Cytochrome P450, 4% of Enzymes, 4% of protease. The output table for both Nicotine consisting of Target, its Common Name, Uniport ID, Target Class, ChEMBL-ID, Probability and recognized actives in 2D/3D are specified in Supplementary file. The probable binding sites where compound easily binds with targets were screened using computational softwares and predicted probability score was found to be very less (Pires et al. 2015).

30.4.4 Toxicity Prediction

Toxicity prediction study reveals that maximum tolerated human dose of nicotine is 0.62 log mg/kg/day and also shows that this is not associated with AMES toxicity and the ligand don't have any inhibitory action on hERG-I and II, LOAEL of Nicotine was noted to be 1.646 log mg/kg-bw/day and $LD_{50}$was noted to be

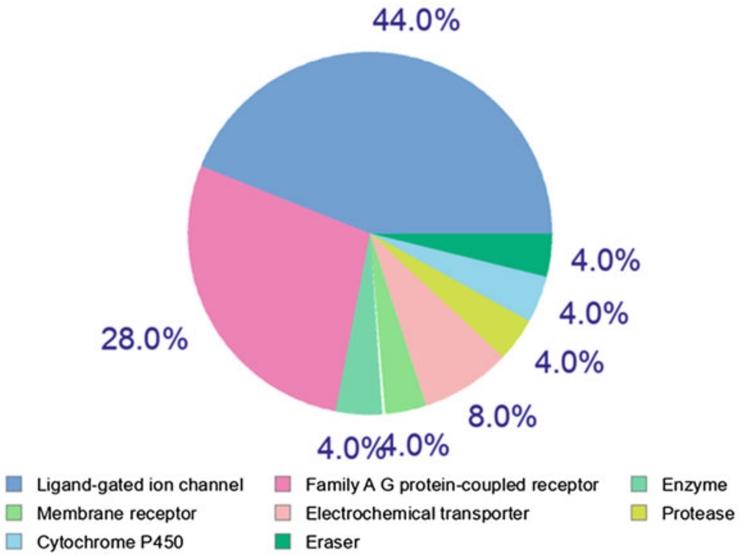


Fig. 30.5 Target prediction of nicotine

2.432 mol/kg, predicted to have hepatotoxicity, causes skin sensitization, T. *pyriformis* toxicity was found to be 0.347 log μg/L and Minnow toxicity was found to be 1.777 log mM.

30.5 Discussion

The need of the hour is to trace out an effective drug against SARS-CoV-2 virus. Though many drugs are under trial but none is found to be effective. So, the interest is to find a drug which interact with the targets of SARS-CoV-2 The output of the docking carried out by Swiss Dock was the full fitness energy (kcal/mol) and the estimated Δ*G* (kcal/mol) with which the ligand binds to the pocket of receptor protein. The results are summarized in Table 30.2.

It is well reported that affinity of S2 toward ACE2 receptor results in its down-regulation followed by lung injury during the course of SARS-CoV infection.

As after initial step SARS-CoV spike (S) protein S2 subunit recognized as crucial for virus fusion with and access into the host cell. Thus, 6LXT (post fusion core of 2019-nCoV S2 subunit) is another target site for preventing the infection. We performed the docking study of nicotine with 6LXT. Free fitness energy was found to be −5347.014 kcal/mol and Δ*G* was found to be −6.76828 kcal/mol. The results indicate nicotine to be potential candidate against 6LXT.

Among nonstructural proteins, NSP15 has been noted to be accountable for the protein interference related to the innate immune response and NSP15 play a role for viral RNA to escape it from the host defenses. Thus, it is biggest challenge for immune component to combat the virus. NSP15 Endoribonuclease from SARS CoV-2 (6VWW) was selected and docking study revealed full fitness energy −3788.451 and free energy −6.806345 suggesting nicotine to be prospective agent against COVID-19.

In order to assess the permeability of compounds through particular membranes and for their steadiness in the midst of weak/strong solute-solvent and also for solvent to solvent interactions, molar refractivity is considered as a gold standard. TPSA signifies transport properties of molecule. The value 16.13 Å suggests it to have great transport properties. The water solubility properties predict nicotine is freely soluble. Nicotine is found to have no inhibitory action on CYP1A2 and CYP2C19, thus are not associated with liver metabolism of drug and also drugs used in the treatment of malaria, ulcer, convulsant and as anesthetic and sedatives. It is also observed that both the compounds do not interfere with CYP2D6 and thus will not inhibit the metabolism of β-blockers, anti-hypertensive, anti-depressants and anti-arrhythmic. In addition, there is no interaction with NSAIDs, anti-hypertensive, type2 diabetes, anti-clotting and anti-seizure because the enzyme CYP2D9 which is associated with the metabolism of these drugs has no any interaction with. Further, nicotine does not inhibit CYP3A4 which is responsible for the metabolism of xenobiotics, fatty acids, steroidal drugs and hormonal metabolism. Taken together nicotine does not interfere with the metabolism of commonly used drugs.

Druglikeness factor rules were also obeyed with only one violation of molecular weight less than 200. It shows that molecule can act as drug in the biological system. As per the medicinal chemistry assessment of both the compound, zero value of PAINS clearly signifies that nicotine is progressive compounds worthy of testing for biological assays. The toxicity data and several lines of evidence suggest that nicotine is not quite safe for systemic administration. Thus, it is recommended novel pulmonary drug delivery system is required to prevent the systemic toxicity associated with nicotine.

30.6 Conclusion

Since the pervasiveness of COVID-19 is increasing day by day, there is urgent need to identify a potential therapeutic agent to manage this disease. On the basis of full fitness energy and estimated ΔG values from docking study of nicotine with selected SARS-CoV-2 target proteins, we remark about the possible therapeutic efficacy of nicotine in the management of COVID-19. Also, on the basis of in-silico ADME and toxicity predictions, it is concluded that nicotine can be used as drug. But due to pandemic situation and lockdown period, the further rigorous studies were not continued in wet lab.

30.7 Future Scope of the Work

Further *in-vitro* experiments investigations are required to justify the role of these compounds against SARS-CoV-2 and novel formulation for pulmonary targeted drug delivery system will add value to currently available dosage forms for COVID-19.

30.8 Executive Summary

Interaction of nicotine with SAR-CoV-2 target site suggest the potentiality of nicotine against COVID-19. However, interaction of nicotine with ACE-2 suggest its detrimental role. Thus, further studies are required to answer that nicotine is a friend or foe for COVID-19.

Conflict of Interest The authors have no conflict of interest.

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Artificial Intelligence in Covid-19: Application and Legal Conundrums

31

Lipsa Dash and Sambhabi Patnaik

Abstract

The current healthcare system needs strong support from new technology support systems like Artificial Intelligence (AI), Internet of Things (IoT), machine learning devices to help diagnose, analyze, assist, and prevent new diseases that are spreading in our world. The current international crisis that the world is suffering and witnessing is a virus contaminating and the spread which initiated as an epidemic but later declared by WHO to be a pandemic Covid-19. Corona virus has triggered a global challenge and has crossed boundaries in dismantling mental and physical health of people. AI technologies have seen to be introduced to help management of patients real time monitoring of its outbreaks and helping update the patients data, improve treatment outcome by prioritizing patients, diagnosis and recording of minute fluctuations in patients, assisting medical practitioners and giving productive solutions. The researchers will show the paradigm shift in the number of patents filed every year in the field of AI specific to healthcare sector from diagnosis to recovery of patients. The chapter includes how all the above applications lead to legal conundrums and the imminent need of bringing amendments to existing legislations or drafting new policies and encouraging government to bring up initiatives for innovations and research and development on the same. The Constitution of India has incorporated provisions which guarantees everyone the 'right for the highest attainable standard of physical and mental health'(Article 19, Internet intermediaries: dilemma of liability, https://www.article19.org/data/files/Intermediaries_ENGLISH.pdf, 2013). With the growth in usage of AI-induced systems in the healthcare sector, it has invited some unwanted issues. Protection of sensitive personal information

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and the impact assessment is however a major concern and is dealt by different International and national legislations and bills. AIs will soon lead the national security of India and economy (Barak, Proportionality: constitutional rights and their limitations, Cambridge University Press, Cambridge, 2012). An analysis on the existing data, application of AI in healthcare and there legal implications shows the expected outcome in a few years. The consequence mainly technical and legal is discussed by the researchers.

Keywords

Artificial Intelligence · Healthcare · Pandemics · Legislations · Covid-19

31.1 Introduction

Artificial Intelligence (AI) is taking over humans as computers did a while back. The dependency proportionality is direct with time. Countries are making rapid growth in AI-based research and its usage in daily life. India however has been a little reluctant as it considers AI to be a threat to national security. However, with the rapid growth worldwide, it is to be expected that India starts adopting a few AI technologies to be in par globally (Vempati 2016). Victory of machines over human has been coming up for a while although not fully perceived. The AI technologies are being subtly incorporated into our lives by private companies and the implications are impactful enough to be noticed by the government policy makers. AI has been crucial in our lives simply starting from browsing internet to performing the most complex unimaginable tasks in our everyday lives. Few AI softwares collect our data and processes it, like Bixby, Alexa, Google Assistant help us in completing tasks without physical touch with the phones and tablets. Creating an AI is now the new competition in the emerging industry. Few countries have started adopting AI which has helped them in boosting economy too. For India to get maximum benefit from this AI revolution it should be open to the idea of adopting a deliberate policy to drive AI innovation, adaptation, and proliferation in sectors beyond merely consumer goods and information technology (IT) services (Vempati 2016). The future of Indian economy as well as national security of India will be very soon dominated by AI technologies.

Covid-19 pandemic, involving the widespread transmission requires innovative and path-breaking strategies and solutions. Artificial Intelligence (AI) with its multifarious applications can prove to be an effective technology against the COVID-19 pandemic.AI can be instrumental for proper screening, tracking and anticipating the current and future patients. Some of the major applications of AI for this pandemic can be utilized by driving new dynamic approaches in discovery of drug, development of vaccine, public awareness, and reduction of workload for healthcare workers also. The optimistic power and potential of AI must be harnessed in the combat against the spread of Covid-19 in order to save lives and limit the economic mayhem of the deadly disease. But at the same time, there can be some major legal issues involved with the application of AI in different spheres which cannot be ignored. Therefore, the researchers have taken up this study to explore and trace the consequences of diverse legal issues that can arise with the usage of AI in the fight toward Covid-19. The objectives of researchers are to find the legal issues involved with AI and analyze their consequences by poring over different available legislation, guidelines and judicial decision in India.

31.2 Approach/Methodology to Accomplishment of the Objective

The review of the literature is done on the database of Pubmed, Scopus, Manupatra, JSTOR, HeinOnline, and Google Scholar and Google Patents using the keyword of Pandemics, COVID-19, Coronavirus, Artificial Intelligence or AI and Patents related to it. Primarily, the study is focused on the functional predicaments associated with Artificial Intelligence in pandemics. The researcher employed historical, analytical and comparative methods to accomplishing the research. The data has been collected from IP India website, Vigyanprasar.gov.in, COVID-19 Technology Access Pool (C-TAP) and different patent databases to study the shift and growth of patent filing due to need of Covid-19 vaccine and research undergoing to acquire new acumen from failures and success of other countries and apply it to Indian circumstances.

31.3 The Outreach of Artificial Intelligence

AI in India in the field of healthcare is one of the growing areas as there increase in new diseases. The efficiency of doctors will be elevated with the introduction of AI technologies to the work environment. Nowadays, companies are keen to offer a wide range of solutions including automation of medical diagnosis, automated analysis of medical tests, detection and screening of diseases, wearable sensor based medical devices and monitoring equipment, patient management systems, predictive healthcare diagnosis and disease prevention (Paul 2018). The use of AI in healthcare industry and the impact on the existing industry and its development, implementation and regulation is much needed. The AI used in healthcare are created using natural language processing, machine learning, voice recognitions, visions etc that are equally as good as a doctor and can potentially be used to replace them. The healthcare ecosystem has different levels as discussed in the chapter starting from prescription, diagnosis, therapies, maintaining health records to surgeries. Few AI could also detect minor changes which might be difficult to notice or might have escaped the attention of the medical professional. The AI is intelligently created to prioritize each medical case helping in management of cases beforehand, for instance, in a few hospitals it has been helping in identifying persons affected with Corona as we are under the Pandemic Covid-19 right now.

There are innovations that predict heart attacks beforehand giving real time heart beat reports and monitoring health. There is an increase in shift of smart watch like FitBits to keep a track on their health and it calculates the number of steps, keeps a record of the sleep schedule, the number of calories burned. There are softwares where you can update the food and protein intake and it calculates and tell you exactly how much to work out for a healthy body. With all the substitutions for real life physically present human AI can prove to be very effective health management systems. Identification of a disease and taking precautionary measures proves efficacy of the AI technologies. There are monitoring devices for patients of different mental health issues too. The systematically handling of the patients is a part of the creation of AI and they act accordingly. The pattern is stored, detected, and reported and taken care as required. Healthcare industry covers a large part of economy and receives high funding for research and development. Few states also support AI-based start-ups and policies.

Few tech companies apprehend that AI has the potential to contribute to India's economy by 15% of the current value and recommends different policy makers, business leaders to utilize the time and opportunity. In the upcoming years, the intelligent technologies with support of human will lead to numerous opportunities. However, the development of AI technologies is the key to such development which is lagging in India for time being. There is boost in the use of intelligent machines in the healthcare industry as it has significantly helped in better diagnosis because of its intelligence. Academicians and students, considered to be the key players, in different research institutes too have researched and come up with devices that can pre-diagnose an upcoming cardiac arrest, disorders and other complexities. Few AI can even screen the retina and identify if the person is diabetic. So the stakeholders starting from start-ups, universities, companies and policy makers are well aware of the AI industry taking over in a few years. They create AI keeping in mind the language and usage in mind. They are categorically created for people who are differently abled so that they don't lag behind. The IT Ministry, along with different private companies are hiring vibrant experts and setting of innovation labs for the same.

AI in Medicine has extended in the pharmaceutical industry starting from keeping a tab on the materials, manufacturing, processing, purification of chemicals and their packaging. Drug development, health monitoring, managing medical data, digital consultation, personalized treatments, health plans analysis, surgical treatments, and other medical treatments are few areas where AI has thrived as assistance in the medical industry (Amisha 2019). The industry is booming and they are proved to have given solutions fit for humans and animals consumption. The most common use in pharmaceutical is in discovery of drugs which was manually impossible (Paul 2018). AI have given high tech solutions and boosted the R&D activity. The robots test millions of compounds helping increase in efficiency (Reuters n.d.). Among a lot of other diseases diagnosis of chronic diseases in the early stage is a complex mechanism, which an AI can prove effective in early diagnosis. Analysis of biometrics, using deep learning techniques to diagnose a disease or symptom using the data stored largely in the computer via different algorithms is among the few projects (Lakshmanaprabu S.K, 2019). AI techniques assist doctors and paramedicals to find the most appropriate imaging procedure, to image interpretation and computer-assisted diagnosis, and lastly results reporting and the extraction of information from radiologist reports (Kahn 1994). Radiologists can find substantial aid from AI by not only labeling abnormal exams but also by identifying quick negative exams in computed tomographies, X-rays, magnetic resonance images especially in high volume settings, and in hospitals with less available human resources(Amisha 2019). Looking into AI industry being used as a therapy there are few data available in the field of psychiatry. Neuro based guidance in treatment by an AI gives insights as to how virtually they assist.

AI assisting in therapeutic sessions even through online has recently been a helpful platform as the humans feel more comfortable for not being judged. Over thinking, anxiety issues, mental disorders, cognitive human behavior are a few areas where an AI is trained to communicate with the humans and assist as relievers. There is an increase in number of start-ups providing platform for self-guided treatments, robots trained for providing therapy sessions, virtual reality therapies, and other web-based treatments available in the click of a mouse. The behavioral pattern is stored and according to the indicators AI systems identify the depression, trauma stress, predict disorders like schizophrenia and bipolar disorders. *Paro,* robotic seal (Paro-Therapeutic Robot n.d.) is one of the therapeutic robots created as it has been proven time and again that animals can be great caregivers. Few AI could also be used to provide spiritual care understanding how the human brain works or wants it. There are chatbots, software for guiding and providing tools for physical and mental health associated problems to humans. They help in reducing stress, paranoid behavior and help the patients in relaxing and motivate them for socializing. Storing, collecting and processing of personal data of the patients comes with a risk attached of being hacked and prone to different vulnerabilities of the human as that sensitive personal information in the form of medical records could be misused and tampered. These platforms being the service providers are considered as Intermediaries resulting in announcing liability according Section 79 of the Information Technology Act.2000. There is an international concept of ***Transhumanism*** (McNamee 2006) which deals with the system of availability of high end technologies is helping enhance the human intellectual abilities, physical abilities, and psychological capacities. There are concerns of it having a short ranged future. It is considered to be quasi-medical mechanism that promotes a variety of therapeutic and human-enhancing aims. However, this study has not yet been prevalent in India.

31.4 Artificial Intelligence in Pandemics

Recently, with the ***outbreak of COVID-19*** which was first declared to be an epidemic and then shifted to be a pandemic has highlighted situations where different hospitals have tried to incorporate many AI to decrease human interactions with patients as it is transmitting through physical interactions. The vaccine is yet not found, however the testing kits and diagnosis are done by a few robots at different hospitals. The virus identified to cause illness has a variety of symptoms between common cold to severe respiratory syndromes and few are identified asymptomatic. The rise is inevitable despite the rigorous trial by all the countries to get an antiviral effective drug for medication. Presently, chloroquine and hydroxychloroquine are under investigation by the US Food and Drug Administration (FDA) as a treatment for COVID-19 (El-Aziz and Stockand 2020).

The Indian government, also tapped into the potential of AI to mitigate the risks of corona virus transmission and launched the ‘Arogya Setu’ app. The app was launched on 2 April 2020 to trace ad track potential patient and their locations and alert public and government officials to take necessary precaution. The app uses artificial intelligence along with bluetooth, location tracking with GPS. The AI used in COVID-19 pandemic starts from detection and diagnosis of the infection by scanning the faces to check temperatures, monitoring the treatment to control spread of the virus, tracing the contact of the individuals, developing drugs and vaccines and analyzing the data (Data Security Council of India n.d.). The increasing number of patients will soon need AI assisting the doctors to decrease workload in quarantine centers and hospitals. The resemblance of the AI to their creators is significant whether or not to treat them as legal personalities as incorrect decisions induced by the AI system may lead to consequences and liabilities as discussed further to make them indistinguishable in a true sense (Fig. 31.1).

The Telemedicine Practice Guideline (BOARD OF GOVERNORS, MCI, NITI Ayog) issued by the Government especially for the Covid-19 pandemic is to be enabling the medical practitioners to practice telemedicine to reduce physical interactions. It provides guidelines regarding the nature and manner of care to be provided to the affected patients.

31.5 Legal Conundrums Around Artificial Intelligence in Healthcare Sector of India

The Indian government has taken initiatives for the promotion of AI in healthcare sector. Ministry of Health and Family Welfare (MHFW) has developed NeHA (National e-Health Authority n.d.) as a regulatory for making India’s dream of e-Health into reality. The authority will develop an integrated health information system, by taking into its fold all integral stakeholders of healthcare sector in India. NeHA will be responsible for setting up the state health record repositories, health information exchanges to facilitate interoperability, health records of patients along with compliance of laws, privacy and security policies of patient’s data. Biotechnology Ignition Grant Scheme was created in 2012 under the Biotechnology Industry Research Assistance Council, to mitigate the prolonged waiting periods faced by start-ups in the sphere of biotechnology and medical devices, making it less bumpy for the commercialization of technological ideas (Vignesh 2017). In 2017, the Karnataka government, in collaboration with NASSCOM, established Centre of Excellence for Data Science and AI on a public-private partnership model for coupling of investing technological infrastructure with industry-oriented research

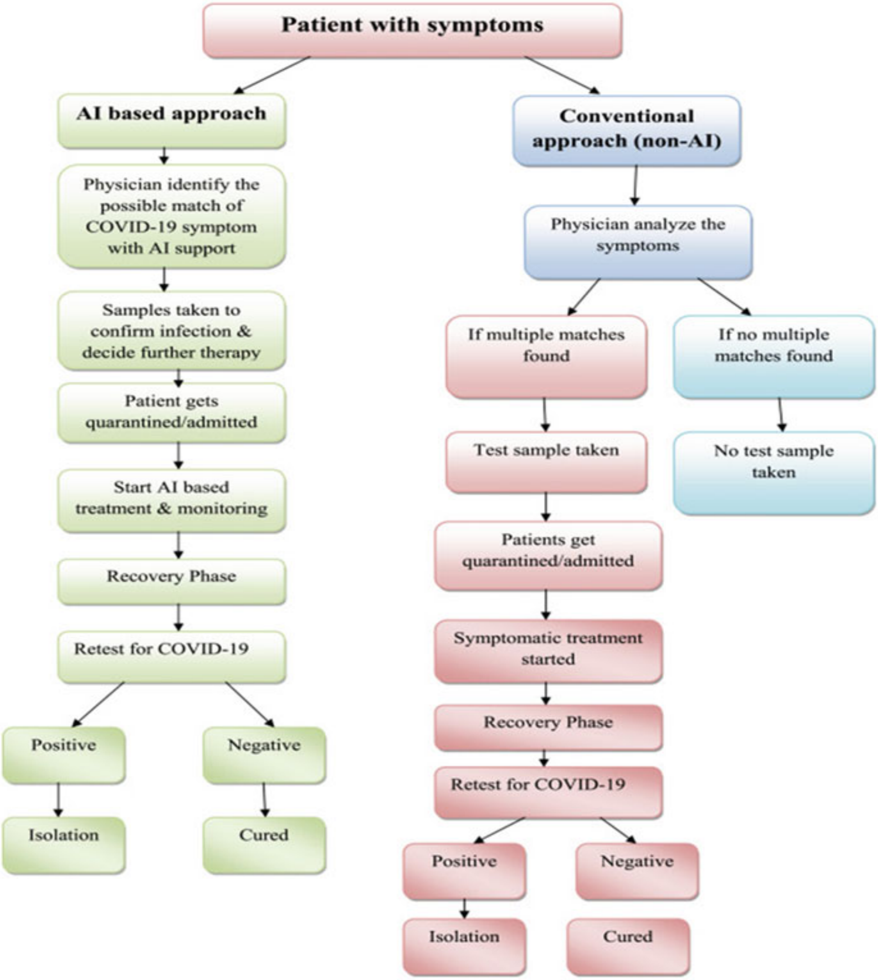

Fig. 31.1 General procedure of AI and non-AI-based applications that help general physicians to identify the COVID-19 symptoms (Raju Vaishya 2020)

which will promote AI in every sphere. The Indian government (Department of Science & Technology) has collaborated with of the United States of America (Department of State) for establishing the United States—India Science & Technology Endowment Fund. The fund can accelerate promotion of entrepreneurship and innovation with special focus on curative and preventive measures which can improve health standards. The Cognitive Science Research Initiative, an initiative of 2008, promotes AI for dealing with cognitive disorders. The Ministry of Electronics and Information Technology has formed a 'policy group' consisting of people from academia and NASSCOM for an industry perspective to study aspects of AI technology and formulate policy framework (NASSCOM 2017). The Ministry of Commerce and Industry in 2017 established the 'Task Force on AI for India's Economic Transformation' consisting of experts from different government organizations which can explore possibilities of development of AI across various fields. Along with the above mentioned initiatives, different legislations of India are expected to be amended to incorporate AI technologies in the near future.

Intellectual Property Rights and AI are inseparable as AI-induced softwares are progressively being utilized by medical clinic systems for patient data analysis and extensive medical prognosis. It is expected that AI systems in healthcare would be valued at 6.6 billion US dollars by end of 2021. Today implementation of AI in the healthcare can be seen in all spheres-diagnosis, treatment, discovery of drug, AI assisted surgery as well as patient data management. Just few years back, during 2013–2017, technology giants, Google (186), Microsoft (73), Apple (54) have filed together more than 300 patent applications related to healthcare (Read n.d.).As reported by World Intellectual Property Organization, technology trends of 2019 indicate exponential increase in AI-based inventions. Patent office records show France, Germany, the Republic of Korea and the U.K as champions in AI-induced patent applications, leaving behind India to tenth position worldwide (Singh and Tiku n.d.).

Presently many healthcare centers are utilizing AI-induced systems. To cite a few examples from India, Manipal hospitals, is utilizing IBM's 'Watson for oncology' for customized malignancy treatment. Similarly, Cardiotrack, an AI-based start-up, have created hand-held gadgets that is capable to examine a patient's ECG scans to diagnose cardiac health issue utilizing AI-based programming and available curated database of scans. The start-up has teamed up with Paras Hospital in Delhi NCR, Star hospital in Ahmedabad and Columbia Asia in Bengaluru. Then again, software giants like Microsoft India have developed 'healthcare next' and 'Microsoft intelligent network for eyecare' for visual screening to avoid blindness in children and is working together with the Telangana state (Singh and Tiku n.d.). The Philips Innovation Campus in Bengaluru have created software-'Mobile Obstetrics Monitoring' to identify and control complicated pregnancies. Philips have also come up AI-based software for TB detection from chest X-rays. It has partnered with Fortis Escorts Heart Institute, Delhi to set up Philips 'IntelliSpaceConsultative Critical Care', where hospitals would now be able to screen multiple ICUs from a centrally located headquarter center that might be situated in a geographically-distanced area (D'Monte n.d.).

National IPR Policy of 2016 themed '*Creative India; Innovative India*' highlights on creating awareness on the value of IPR as an effective economic tool and financial asset. The policy recognizes the potential for innovation in emerging technologies (specially AI) to ensure increased access to affordable medicines and other healthcare solution (Industry n.d.).Tata Consultancy Services (one of India's largest software export), in association with Confederation of Indian Industry, published a report which state that 'Current patent laws treat AI software inventions as logical algorithms implemented on the computer. While patent eligibility of algorithms is valid, there is little about how to deal with inventions that are heuristic in nature' (Chandrashekhar 2019). The very idea that an AI machine is capable of conceiving a patentable idea and can claim ownership over it is a legal conundrum which raises a whole new world of possibilities. Currently, Indian Patents Act, 1970 makes algorithms and computer programmes per se not patentable under section 3(k), except with attached hardware component giving a technical effect (The Patents Act, 1970). India has always largely relied on patent for protection and commercialization of its innovations. But the inherent statutory restrictions are handicapping India to achieve its full potential of AI. For instance, patenting of AI applications that can provide customized disease treatment by analyzing patient's data will be considered as methods to treat a disease which is non-patentable subject matter in India. Copyright of software, design protection, and innovations as trade secrets are of little use. India, being a developing nation, revised its Patent Act 1970, in 2005 to comply with Trade-Related Aspects of Intellectual Property Rights agreement which led to a shift (from patenting of procedure of manufacture to patenting of drug) in its pharmaceutical sector and prevented ever greening of patent which could have made drugs expensive for the mass (Aggarwal n.d.). But still India's pharma companies have to outsource its R&D activities because of lack of robust open medical data sets and its laws which allow making of cheaper generic drugs. Therefore, India needs to revamp its inadequate and outdated IP laws for inclusion of AI-based innovations.

With growth of technology we definitely counter ***Data Protection & Privacy issues*** as AI technologies constantly engage the patient for collection of information at several stages, without proper notice and consent, which can have huge repercussion to data security of individuals (Duraiswami 2017). Following the global practice, hospitals across the country have started using electronic medical records (EMRs) for maintaining patient information. Recent rules notified in 2012 under the Clinical Establishments (Registration and Regulation) Act 2010, makes it mandatory to maintain EMR of each patient for registration/ continuance of all clinical establishment. The Indian Medical Council (Professional Conduct, Etiquette and Ethics) Regulations, 2002, also requires physicians to protect confidentiality of patients and their information at all times (Deo n.d.). Section 43A of the Information Technology Act 2000 (IT Act 2000) and Information Technology (Reasonable Security Practices and Procedures and Sensitive Personal Data or Information) Rules, 2011 sets certain guidelines for body corporate to follow while handling, dealing and processing of any Sensitive Personal Data/Information (Data Protection Bill, 2019).The person whose data is being collected must be informed about the purpose of data collection, while obtaining their consent for the same. The body corporate must publish its privacy policies and contact details of grievance officer, while ensuring to have implemented reasonable security practices and procedures. These rules are also applicable to hospital and similar institutions because patient's medical history, data, scans, and physiological conditions are considered Sensitive Personal Information. However, NGOs and public hospitals are out of the radar under section 43A of the IT Act 2000, because they do not come under the umbrella of body corporate as defined under the same section.

Ministry of Health and Family Welfare (MHFW) has formulated uniform Electronic Health Record Standards 2016 to be followed by all healthcare providers for data protection of health records in India (Electronic Health Record Standards for

India n.d.). The Ministry is also drafting Healthcare Data Privacy and Security Act which will have provisions of civil and criminal remedies for breach of data along with the principles for data collection and its usage (Khatri n.d.). In lines MHFW's NeHA, Digital Information Security in Healthcare Act (DISHA n.d.) has been drafted with a focus of securing the healthcare data in India and making people to have absolute ownership of their health data (Draft of Digital lnformation Security in Healthcare, act (DISHA n.d.)).

Hacking of a database maintained by a diagnostic lab based in Mumbai was reported in 2016 which leaked medical records of patients across the country (which also included some HIV reports) of over 35,000 patients. It was reported that the lab did not take action to secure the data, even after such serious breach, because no law makes it a mandate to inform such breach to an authority (Express New Service 2016). As we have witness that these rules are only in pen & paper with no or minimal compliance due to lack of awareness and effective enforcement. The present regulations also have inherent flaws which do not help in fulfilling the purpose for which it was enacted. However, the recent apex court's path-breaking judgment in *K.S Puttaswamy&Anr. v. Union of India &Ors* (Writ Petition (Civil) No 494 of 2012 (Supreme Court of India) which recognizes the Right to Privacy in India and the Data Protection Bill 2019 showing great potential for the future ahead.

As AI is not yet recognized as a legal person definitely brings up the question of ***Fixing of Liability*** incurred for the actions by the machine. Some of the provisions of Indian Penal Code, 1860 are applicable to medical practitioners if they have been grossly negligent in discharging their duties and have caused serious injury or death of the patient, for instance, Section 304-A (Causing death by negligence), 336 (Act endangering life or personal safety of others), 337 (Causing hurt by act endangering life or personal safety of others), 338 (Causing grievous hurt by act endangering life or personal safety of others) of the IPC. However, Supreme Court decisions have suggested for leniency while criminally prosecuting doctors for medical negligence.

Healthcare service providers might face civil liability and be liable to pay compensation if there is any breach in the contract as there exists a contractual relationship between the digital health service provider and the patient/user (Suneeta Satpathy et al. 2021). Consumer Protection Act 1986 has been persistently used for prosecution of medical negligence in India after the apex court's decision in *Indian Medical Association v. V. P. Shantha and Ors* (AIR 1996 SC 550), which clarified that hospital and medical services, would fall within the ambit of the Act. The employer might also be prosecuted under the principle of vicarious liability under the law of torts which makes the employer liable for employee's act and omission, during the course of employment. Lastly, a patient has recourse under the relevant state medical council against a doctor for professional misconduct, which will attract disciplinary action and even cancellation of medical licenses.

However, when it comes to deciding the liability in cases of AI-based systems, the traditional notions of liability will be difficult to impose. For instance, when there is an error in diagnosis, malfunction of the system, or the exercise of inaccurate procedure, then the liability should be imposed on whom-the system, the software developer or the doctor? If ever robots and other AI systems are provided with the status of a legal person, *lifting of corporate veil doctrine and alter ego principles* can be considered to fix the liability. We do not have a clearly defined law, regulation and guideline for any misconduct by the AI-based solution for healthcare which gives rise to liability.

31.6 Patent Filing and Trends of AIs in Pandemics

The pandemic brought us to a phase where there was a dire need of accelerating process and discovery of vaccines, medicines and technologies and with it came technologies, innovations and windows for open innovations to be patented. There were initiatives taken to make public disclosure of few gene sequences to initiate and fastrack research activities. Sharing the results of clinical trials was a setback for few researchers but the government funded the innovators and pharmaceutical companies to encourage and make the research process affordable.

A patent pool was created to license any potential treatment, diagnosis, vaccine, or related health technologies to backup public health and facilitate the access to medicines in developed and developing countries including India (Kannan et al. 2020). There was a promotion for open innovation and technology transfer to increase partnership and global access to live-saving or equivalent preventative drugs. Each individual life has been of critical importance lately and impact of patent would be huge as it is monopoly right given to the inventor(s), preventing others from using the same to develop similar element even for research purposes. The entity/person could hold on to the patent and not license it or it could have multiple right holders and a chaotic situation for the right holders. The most significant issue is related to the managing of Intellectual Property as according to IP laws, any vital medicine, vaccine, treatment or cure will not face barrier of any sort for public policy.

There is a significant increase in the number of patents filed in the healthcare sector in general over the last decade as researched by Patsheer Database (Fig. 31.2).

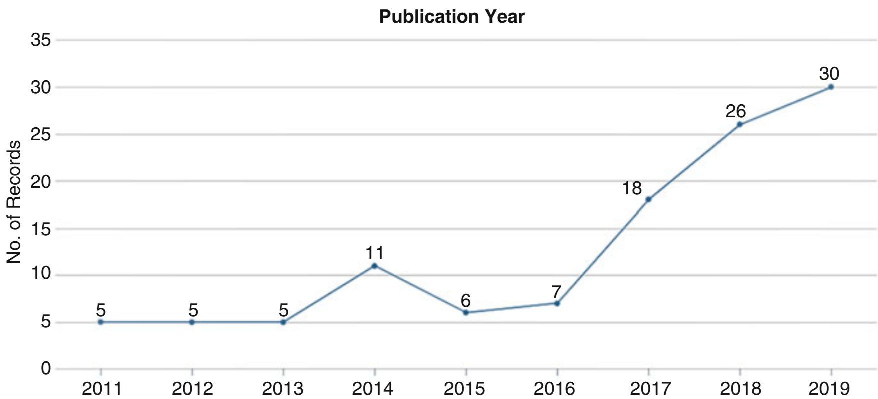

Fig. 31.2 Worldwide Published Patents on AI and healthcare. Source—PatSeer Patent Database

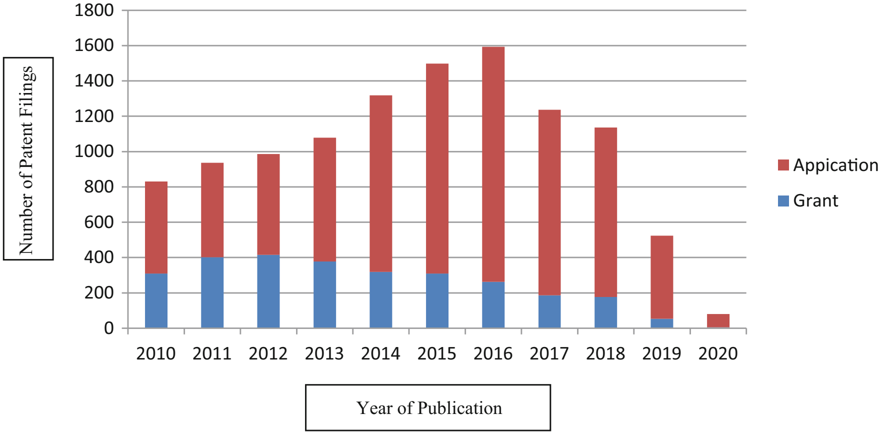

Fig. 31.3 Analysis of Patent Filing (Application and Grant) in the last decade

The below table displays the trend of patent applications filed and granted in the last 10 years in the area of AI in Pandemics which gives a analysis that the research now is made more accessible to the public. This table is created using Google Patents to reach the objective (Fig. 31.3).

31.7 Conclusion

The above study have helped the authors realize that usage of AI in healthcare industry has proven to have a cutting edge in increasing efficiency, accuracy, precision, decreasing workload of the doctors and increasing continuous monitoring of patients without actually being physically present and prioritizing the critical cases. Health is an important indicator to measure human, social and economic development of any country. The Constitution of India has incorporated provisions which guarantee everyone the ‘right for the highest attainable standard of physical and mental health’. In a country like that of ours, access to affordable healthcare is a far away dream, which makes progress of Artificial Intelligence in healthcare even more essential. AI-based applications and systems will definitely come with its own challenges and risks. Therefore, there is a need to balance the possibilities and risks associated with it. India, in its attempt to catch up with the AI revolution across globe, has come up with many initiatives specifically aimed at adopting AI in all sectors. Still, the authors could identify few barriers which will impend its far-flung adoption and implementation. To make digital healthcare a reality, India will need effective and robust legal framework along with impressive government initiatives. The legal framework should be able to mitigate all issues identified with AI-induced systems such as privacy, data integrity and liability, keeping the future of healthcare in mind. The regulatory framework which can ascertain transparency and accountability is the need of the hour for the success of AI healthcare system in India. The successful implementation of AI system in healthcare by many hospitals in India has lay down the foundation for a great future and proves that how helpful will be these systems in pandemic situations like the present COVID 19. Machine learning has advanced in different fields and have time and again proven that it is a necessity to flourish in the future. Soon enough the major players will be having the policies in place and entering into international negotiations and technology transfer agreements, blueprints for manufacturing after being licensed blueprints and other necessary arrangements will be of prime importance in the near future. AI as a tool has high potential of assisting and helping in fighting cases of Covid-19 and other pandemics. The state of the art methods can be analyzed to deal with the global menace with help of AI creations like computers and robots. The present pandemic has created havoc and has left everyone wondering about the future. The authors have come to the conclusion that proper implementation of AI in healthcare with clarity and precise mechanism will help answer those unanswered questions and give a way for smooth transition to the after-pandemic world.

31.8 Future Scope of the Work

Covid-19 is an eye opener for the world and the research is still going on for a vaccine. The invention, use, outreach to public, research processes and products are yet to see the light of the day as a cure to combat pandemic. Using AIs would also help us control the spread among humans as it will lead to a decrease in interaction. The issue further will always revolve around behind creation of AI-based inventions and simultaneously the need of public disclosure. The granting of patent requires complete satisfactory disclosure of the invention, which must be sufficient for an ordinary person skilled in the art to practice the invention. But when it comes to patent for AI-based invention, fulfillment of this requirement can be very challenging because of the nature of the invention. The ownership issue with AI inventions is still blurry and there is no existing legal framework which explicitly makes the stand clear as to who will own the IP rights in any content created by AI systems. The position for the near future will therefore depend on how our existing and future framework is evolved to meet this challenge, as AI systems are not considered legal persons. The liability and accountability of an AI can either be civil or criminal also depends on the category of AI-soft/hard and autonomous/semi-autonomous in nature. The gravity of the mishaps will help us determine the liability or punishment. The debate of whether AI should be considered as a legal person and under which model they will be tried in the court of law is an ongoing battle of giving them status of citizen, constitutional rights, and nationality rights having its own ramification (Arun 2014). India legal framework is still at a very nascent stage when it comes to regulating artificial intelligence and there is a very pressing need for Indian legislature to fill up the gaps and create a robust mechanism. During this global pandemic AIs are used in the field of medicine, therapies, and expected to help in complex operations. However, there is an apprehension that it might result in loss of job, lack of the human touch, empathy and emotional intelligence which may outweigh the million pros of replacing humans with machines. The present pandemic has created havoc with an uncertain future and making predictions impossible. Covid-19 has impacted lives and technologies are expected to make the task easier.

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