Artificial Intelligence for fighting the COVID-19 pandemic

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Abstract With the advent of coronavirus (COVID-19), the pandemic which has created massive chaos around the world, millions of people has been affected and almost a million dead. Numerous studies have been put forth to control and devise a new medicine for the ongoing COVID-19. Artificial intelligence (AI) has been widely applied to perform various tasks in our daily life and has emerged as the most successful player in the recent times. AI has also been used to deal with the pandemic situation and various studies have been presented to analyze and estimate the possible impact of COVID-19 using AI based techniques. AI based models, such as neural networks, can be used for detecting viruses with high sensitivity and speed. Also, forecasting models, such as long short-term memory (LSTM) and auto regressive moving average (ARIMA), as another aspect of AI has played a significant role in combating the COVID-19 pandemic. Also transfer learning based techniques can be used to analyze the possible impact of COVID-19. In this chapter, we will be dealing with the unprecedented role of AI for combating the battle against COVID-19 pandemic. Here a number of different areas have been explored where AI plays a significant role and in an essential component. These include medical imaging, deep learning, natural language processing, computational biology, internet of things, data analytics, time series analysis and others. A detailed case study on the already proposed literature is also presented. Apart from that, research direc-

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tions based on the potential impact of AI and possible measures required to enhance its capabilities for the current scenario has been discussed. It is expected that this study will highlight some background to the AI research community and also to the other wider research areas about the contribution of AI in combating COVID-19 and hence provide prospective aspects in harnessing AI against the global pandemic.

1 Introduction

With more than 25 million confirmed cases and around one-million deaths, the severe acute respiratory syndrome corona virus 2 (SARS-Cov-2) or simply coronavirus disease 2019 (COVID-19), has emerged as a global pandemic and has affected more than 90% countries of the world. What started in December 2019 as a potential threat has taken almost all nations by storm. The rapid contagion of SARS-CoV-2, causing the COVID-19 disease, which is around ten times deadlier than the common cold or the seasonal flu, challenges health care systems across the world [16]. The population is not immune to the novel coronavirus strains and effective therapies are not available, which benefits the enormous pace of the spreading. The World Health Organization (WHO) then declared that a global coronavirus has been identified and isolated. The movement of people across the various provinces in China and to other countries of the world were put under serious scanner and every person reaching from China was investigated at the respective airports [40]. The authorities tried to contain the virus by imposing strict restrictions on travelling and mass gathering by closing airports, state roadways, public transport, local transport and all other services such as public gathering, gaming events, mass events and any other activity where chances of social contacts or public interactions were higher [41]. The Chinese administration started collecting the travel histories and required information of people travelling to and from various provinces across the country, by calculating the infectious disease vulnerability index (IDVI) according to the user data records International Air Transport Association (IATA) [25]. It was further noted that IDVI has a range of [0, 1] and if the valye of IDVI is higher, the risk of transmission and vulnerability is the higher. The data thus collected was used as the primary source of information for analysing the effect of virus outside China.

Despite rigorous efforts, the first case outside China was reported in Thailand on 13 January 2020 [38] and by 19 January 2020 numerous cases were reported in Bangkok, Hong Kong, Japan and Taipei, all having an IDVI greater than o.65 [39]. The virus started escalating toward the third world countries and on 31 January 2020, WHO declared an emergency condition. By 11 March 2020, the virus was declared as a global pandemic with a daily increase in the total number of cases by 25% to 30% in the total number of confirmed cases [29]. As of March 2021, the United States of America (USA) is the most affected country of the world with around 10 million confirmed cases (CC) and a total death count (DC) of more than 500,000 people. The second most affected is India with a total of more than 7 million CC (200,000 DC); and followed by Brazil with more than 4 million CC (100,000

DC) [29]. Thus it can be said that the virus which started from a single human being is currently multiplying as a community level transmission agent. Though numerous efforts have been put into place by the respective governments, the virus is still escalating at a rapid pace.

The pandemic became a game-changer for the health and economic lifestyle of the world's population. Despite rigorous efforts, the exponential spreading burdens the whole medical care system. During this crisis, predominantly developing countries struggle to stabilize their economy and health care system [21]. When nations faced the first contagion wave (around April 2020), most organizations which require face-to-face contact (e.g., hotels, cinemas, restaurants, universities, and others) faced heavy restrictions. As a result this measure caused a significant rise in unemployment. The pandemic forced governments of all countries to deal with such a health economic dilemma (HED) [12]. The pandemic is a frightening example that trade-offs between health and economy are sometimes inevitable and regulators have to come up with appropriate actions to deal with it [12].

The potential effect of COVID-19 has prompted various studies and numerous articles have been published to analyse the possible impact of the virus and derive potential vaccine and provide solutions to the policy makers for the global pandemic [5]. Figure 1 shows distribution of documents by subject area. As it clear from Figure 1, Medicine has the most contribution in the area (53%) followed by Biochemistry (7%), Social Science (6%), and Immunology (5%) while, for example, Mathematics, Computer Science, and Agricultural Sciences possess the least contribution (1%). Initial studies showed that the virus has a very devastating effect on people of elder age, with heart related aliments, respiratory disorders and other ailments [8], [28]. These studies further predicted that the virus has an incubation period of around 5.1 days and the minimum quarantine time is around 14-21 days [7]. Some other studies showed that the transmission rate ranges from [0.001 2.3] [24], whereas the reproduction number lies in the range of [2.3 3.9] [44]. Apart from these studies, it has also been projected that the transmission of the virus is limited on a global scale with only few hundreds of people getting affected per one million peoples [30], [31]. Some of the recent studies on COVID-19 include Weibull distributed modelling [1], logarithmic distribution [43], exponentially growing patterns [11] and others [20]. While most of the studies predicted that the virus is growing at an exponential rate, some studies predicted that the growth curve is logarithmic which stagnates towards later stages [43, 11]. These studies have provided some basic insight into the initial background of AI and its application to find the exact pattern of COVID-19 and what possible impact it will create in the near future.

In present work, the role of AI based techniques and their possible impact in the battle against COVID-19 pandemic is presented.

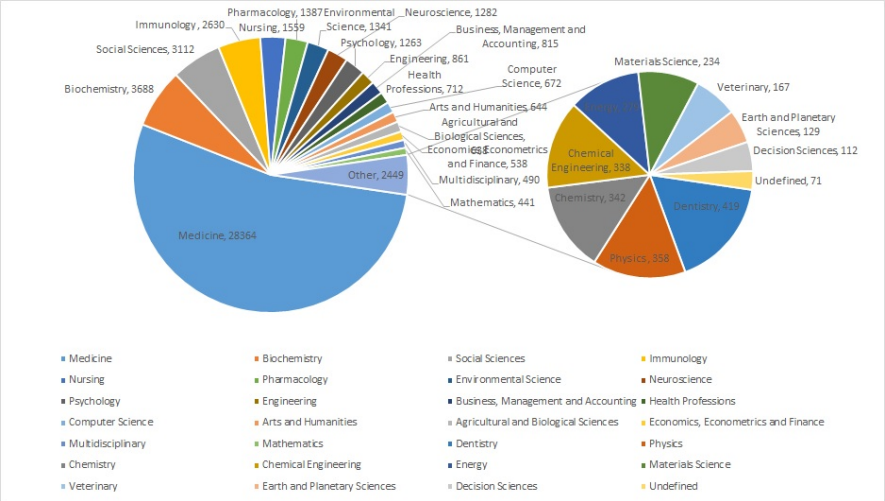


Fig. 1: Distribution of documents by subject areas

2 Can AI solve Real World Problems?

During unprecedented and chaotic times, the science and technology has provided significant contribution for the implementation of government propaganda and policies. This can be understood from the fact that numerous AI based models and approaches are being used to solve real world problems. Figure 2 presents different classes of AI. Although there are several fields in AI, only few studies have been used for dealing with the pandemic. Implementing AI into our lives has been studied for years now and things are getting more real. In the field of data science, useful information is turned into valuable resources and hence new creative business models and strategies are designed. AI based natural language processing has been used for communications with intelligent systems using languages such as English and is required to instruct intelligent systems such as robots for deriving new decisions from certain clinical experts and other major tasks. AI models based on machine learning and deep learning are used to develop computer based programs to learn and adapt as per the user requirements. Apart from that, deep learning which is a sub-field of machine learning, helps in modelling high level abstractions in the available data by using deep graphical models with multiple neural network layers, that are composed of multiple linear and non-linear transformations. Apart from that automatic extraction of data, its analysis and understanding of the useful information from images or simply computer vision is also an important branch of AI which aims at providing better capabilities to machines. A deeper understanding of these concepts is beyond the scope of this chapter.

Also when compared to the current pandemic scenario or an emergency condition, the traditional machines learning classifiers require special attention so that

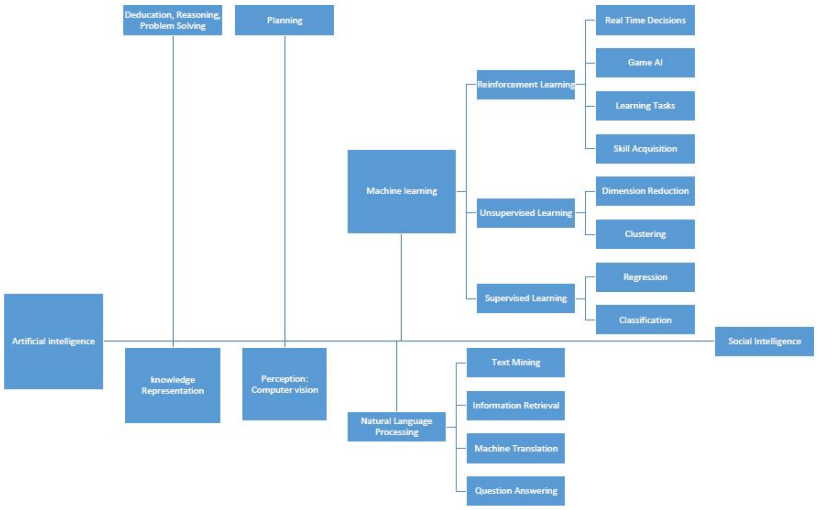


Fig. 2: Different classes of artificial intelligence

decisions can be made consistently without wasting time for training and analysis. This is because the real world data available in the literature won't be available for months or even years for proper analysis and experimentation. This implies that instead of using a traditional or conventional set of data, AI-driven tools can be used to analyse the impact of such emergency conditions by using interactive learning or self-learning over time. The main aim is to learn iteratively over time to adapt and formulate new data without forgetting its existing limited knowledge. While significant changes can be brought over time using Anomaly Detection techniques. These techniques helps to identify rare items, events or observations that may be different from the normal data for that particular condition.

In health care, several important health care facilities such as hospital beds, ventilators, medical masks, capacity and others are very limited and doctors are forced to provide judgement without proper inspection. As a result of that, AI based systems can be used to make such decisions and various AI inspired decision support systems can be actively used to provide clinical support to the patients [17]. Various diseases such as epilepsy [22], heart rhythms [3], nerve and muscle disease [18] have been successfully interpreted by using machine learning classifiers. Deep learning based algorithms have also been used to predict cancer [26], various viruses [4] and other biomedical studies [33]. Apart from that, transfer learning based models can be used for analysing existing literature and provide predictions for other current state of the art.

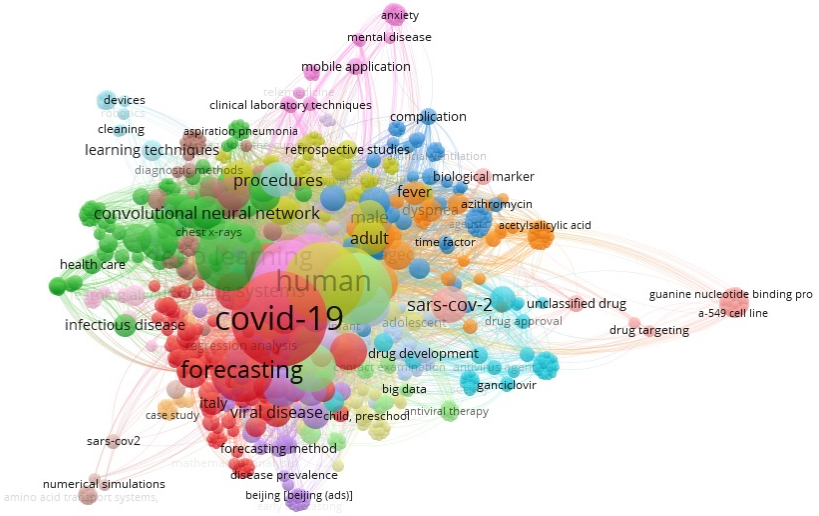
3 AI and COVID-19

The primary purpose of AI based techniques is that they do not require complete datasets for training, testing and validation of models. Instead, these can be implemented from the initial data collection scenario, in conjugation with the experts from the domain research where active learning is required. To achieve higher accuracy level during decision-making, rather than relying on single type of data, several different types of data are employed. Apart from testing, training and validation for prediction analysis, AI based models can be used for detecting viruses with high sensitivity and speed. Neural network based classifiers can be used for screening and monitoring of patients overtime. In this section, a detailed study on the role of AI in tackling the problem of COVID-19 is highlighted with respect to the existing literature. Figure 3(a) present network and figure 3(b) density visualization found by VOSviewer software [35]. From figure 3, it can be seen that forecasting and deep learning are the most interested area of Artificial Intelligence applied to COVID-19. Figure 3 have been provided based on clustering algorithm that 1000 items are distributed in the different clusters (Table 1 shows the top items with the most occurrences in each cluster).

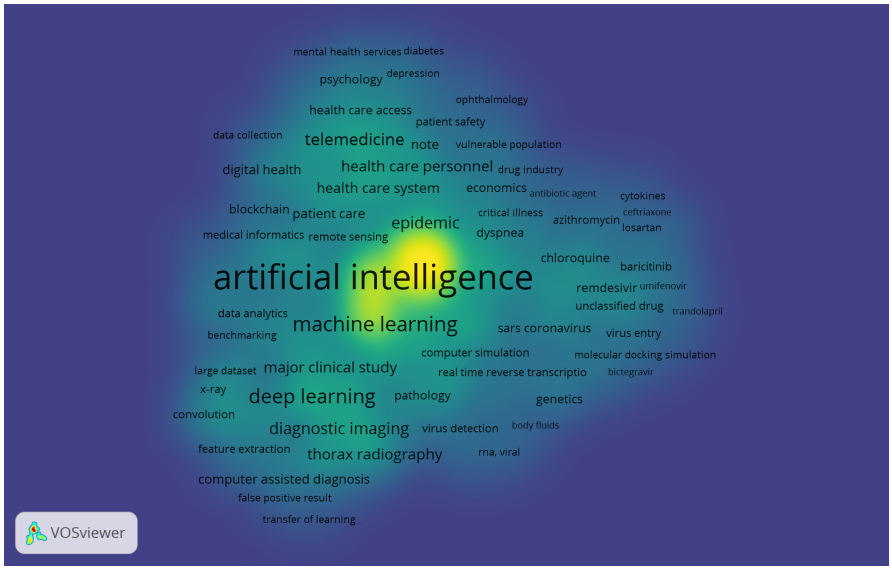
Table 1: Top keywords in each cluster

Clusters	**1**	**2**	**3**
Item 1	Accuracy	Automation	Artificial Ventilation
Item 2	ARIMA	Chest CT	Consensus
Clusters	**4**	**5**	**6**
Item 1	Body Temperature	China	Analysis
Item 2	2019 Novel Coronavirus	Coronavirus	Biotechnology
Clusters	**7**	**8**	**9**
Item 1	Anorexia	Case Series	Anxiety
Item 2	Case Series	Chest X-ray Image	Artificial Intelligence
Clusters	**10**	**11**	**12**
Item 1	Drug Targeting	Big Data	AI Applications
Item 2	Gen Ontology	Clinical Feature	Computer Scientist
Clusters	**13**	**14**	**15**
Item 1	Climate	Metabolism	Deep Learning
Item 2	Environment	Molecular Dynamics	Medical Imaging
Clusters	**16**	**17**	**18**
Item 1	Climate	Metabolism	Chest CT
Item 2	Environment	Molecular Dynamics	Image Recognition

Various efforts have been made to develop novel diagnostic approaches using deep learning, neural networks and machine learning algorithms. Transfer learning based SARS-CoV-2 assay design for screening of patients has been designed



(a) Network visualization



(b) Density visualization

Fig. 3: Visualization found by VOSviewer software

using CRISPR-based virus detection system [23]. In an enhanced version, neural network based classifiers were developed for screening on large-scale. This type of system is based on the respiratory patterns of the patients [37]. Deep learning based enhancements have also been proposed for automatic detection and monitoring of COVID affected patients by analysing systematic thoracic CT-scanned images [15]. It has already been known that the hallmark of COVID-19 are patchy shadows and opaque ground glasses distributed bilaterally with in the respiratory system. So deep learning based methods were used to extract the radio-logical graphical features for diagnosing the coronavirus [36]. Similarly chest images classification using multi-objective differential evolution-based convolution neural networks has also been done [34]. These studies not only pave way for increased accuracy and speed but can also help in reducing the total number of health care workers required to complete the same task. Apart from that, contact-less health care system will minimize or reduce the chances of disease transmission to the health care workers.

A second aspect where AI has played a significant role in combating the COVID-19 pandemic, is the prediction and forecasting of expected rise in the number of cases in any particular region. Inital studies included adaptive neuro-fuzzy inference system using flower pollination algorithm and salp swarm algorithm for forecasting total new cases in mainland China [2]. Deep learning based long short-term memory (LSTM) networks were used to predict ending point of outbreak without using loosing temporal components [9] . Wide range of mathematical and statistical models such as auto regressive moving average (ARIMA), moving average and others have also been used to model the transmission dynamics of COVID-19 pandemic [10]. Genetic programming based models have also been proposed to analyse and forecast the impact of virus in different countries of the world [30, 31]. Also, along with epidemiological data, environmental factors have also been studied to analyse and forecast the possible effect of temperature, humidity and other factors on the increase in COVID-19 cases [24]. Apart from that various other algorithms such as krill herd [13] and naked mole rat [5] can be used for analysis and prediction of COVID-19 case. These studies have helped to predict and forecast, the possible effect of COVID-19 in coming days and helped the authorities to come up with certain solutions such as imposing lock down, strict travel restrictions, limiting mass events and others. Also transfer learning based techniques can be used to analyse the possible impact of COVID-19. As an example, the possible impact of COVID-19 in China, Italy, USA, Brazil and India can be used and extended to analyse and predict the effect in other countries. It means a model trained in Italy or China or India can be used to automatically detect coronavirus in Singapore or Australia. In other words, for a respiratory syndrome such as COVID-19, cross-population training and testing based AI models must be designed so that automated detection can be processed. In parallel, the COVID datasets generated by AI based models can be used for decision based training without the formal requirement of whole data. In the next section, a detailed study of AI based techniques with respect to COVID-19 is presented.

Instead of diagnostic, monitoring and forecasting studies, there is a need of effective therapeutic strategy to treat COVID-19 affected patients at a rapid pace. As

clinical trials for various drugs are under way, there is an urgent need to analyse previous potential drug candidates against the deadly virus. A machine learning based positioning and purposing strategy has been designed to prioritize existing drugs against COVID-19 for clinical trials [14]. Also, novel drug like compounds have been discovered by using deep learning based drug discovery pipelines [42]. Google platform DeepMind has also come up with the protein structure associated with the COVID-19, which if done by traditional experimental formulations, may take months to compile [33]. A reverse vaccination tool using integrated technology and machine learning has also been proposed in [27] to tackle the ongoing scenario. Molecular transformer drug target interaction based deep learning model has been used to identify commercially available antiviral drugs to potentially reduce or disrupt the effect of viral component such as proteinase, polymerase and helicase from the SARS-CoV-2 viral component [6]. Thus tremendous efforts are being carried out to produce a potential vaccine for COVID-19 as the earliest possible and AI is playing a very significant role to subsequently transform minimal available information into useful resources for easy access and implementation. Figure 4 shows the citation network based on authors. The minimum number of documents and citation of an author has been set 1 resulted in 422 authors selected. Selda- Enriquez G., Sola Ortigosa J., Ruiz- Villaverde R., Roncero Riesco M. are among top cited authors in the field. AI also plays significant role in helping humanity on a whole by provid-

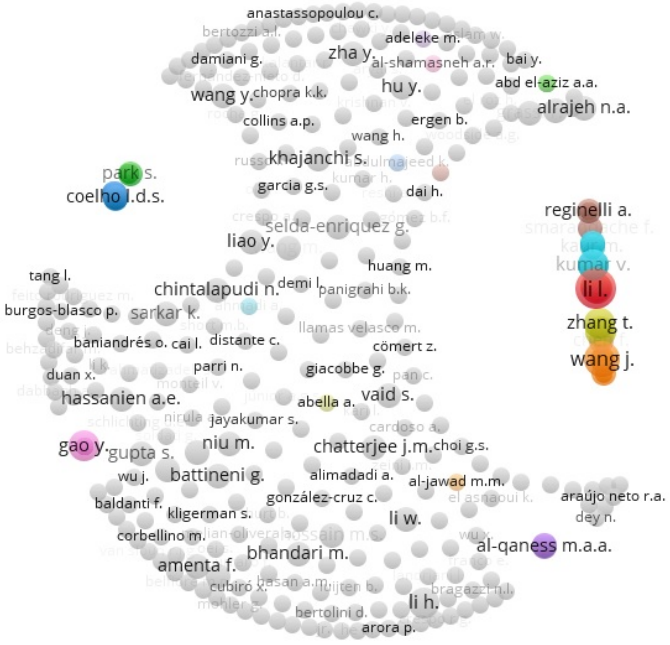


Fig. 4: Citation network

ing a general framework for health, economy and policy making in order to deal with the pandemic. This can be better understood from the fact that AI is considered as the major non-pharmaceutical interventions and the most effective tool to contain pandemic. This can help the whole population to reach herd immunity. These containment measures have a prominent effect on reducing the spreading speed of the virus, although it is necessary to find an optimal strategy to implement them [32]. Generally, there are two tactics: a restrictive one, using a protective approach to handle the population by imposing lockdowns and self-isolation (e.g., Japan or South Korea), and a relaxed approach, for not taking any precautions at all to reach herd immunity faster (e.g., Sweden or the United Kingdom in the early phase of the pandemic). A protective strategy prevents health care systems from collapsing while putting large pressure on the economy. Contrary, the second approach helps to provide a stable economy. However, the number of case fatalities would rise dramatically. Thus, the top priority is to not over strain the capacity of the health care system and simultaneously keeping the economy going. This shows a need for a trade-off strategy between the containment of the pandemic and economic health [19]. Overall in this scenario also, AI can be used to find optimal trade off between both health as well as economic constraints [21].

Apart from the above discussed advantages of AI in handling the COVID-19 pandemic, there are some points that need to be dealt with, and in most of the cases, human needs to be in the loop to make final decisions. This can be better understood from the health economic dilemma problem which is highlighted by the fact that whatever the scenario is, policy makers and involved persons work in collaboration to deal with the pandemic. For example, the AI based models can provide numerous possible solutions to deal with the health and economic aspect of pandemic. Based on these solutions, the policy makers can decide how to deal with the whole scenario in an organized manner.

4 Insightful Implications & Future Direction

Healthcare organizations are in urgent need of decision-making or more precisely multi-criteria decision making to handle the coronavirus and get proper suggestions to limit its spread. AI plays a very significant and vital role in an efficient way to mimic human like intelligence. It may also provide possible understanding of the basic protein structure of COVID-19 and hence suggesting the development of a potential vaccine. Overall, important conclusions and some insightful implications can be drawn as:

- For forecasting prediction analysis, various models can be integrated including ARIMA models, Weibull function, evolutionary approaches and others. These models have already been used for analysis of various diseases and integration of these into one another can make the system more convenient and reliable.
- Predicting protein structure of COVID-19, and their interaction with host human proteins and the cellular environment is another important aspect which can be

dealt by using AI based techniques. This may help to analyse the basic structure of the virus and hence potential vaccine can be derived.
- Incorporating indicators such as population density, age distribution, individual and community movements, health care facilities available, can be included in regression or computational models to enhance prediction accuracy.
- AI based Real time forecasting, wireless sensors, camera for surveillance, visual tracking of symptoms from the affected persons and using apps such as Arogya Setu, worldometer and others to keep a check on the number of infected cases.
- Analysis of social media data sets from platforms such as Twitter, Facebook and others for real time collection of epidemiological data.
- Contact-less treatment using AI based robots, for drug delivery, treating patients at remote locations without the involvement and direct contact of medical staff.
- Risk assessment with different age grouped person can be analysed and predicted. This will help to find which section of the population is most vulnerable and needs to be given more intensive care.

Overall, there are numerous factors where AI plays a significant role in keeping a check on the spread of the virus, providing primary care to patients and searching a potential vaccine for curing the disease. The research is still on and as compared to traditional testing mechanisms, AI has contributed significantly towards its advancements. Research data from diseases such as pneumonia and others has been used as basic preliminaries to formulate new hypothesis for COVID-19 pandemic and analyse its effect. Apart from that, models have been made to make a possible vaccine using deep learning epidemiological data. Thus we can say that, with the advent of AI, even diseases such as COVID-19 can be brought under scanner and possible solutions can be obtained.

5 Conclusion

In this study, we analyse the overall significance of AI based techniques in order to fight with the COVID-19 pandemic. Typically AI based tools can assist mankind in various forms from detection of various infections to treating infected patients, and from forecasting of the total number infections to keeping track of the various advances for proper policy making. Detailed discussed study shows that AI can track the COVID-19 crisis under various constraints such as medical, climatic conditions, and others. AI can also be used to facilitate research by analyzing already available literature. Apart from that, it can serve as the basis for providing proper treatment to patients, prevention, vaccine development, policy making and other tasks for humans to make the final decision.

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