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Artificial Intelligence for the Novel Corona Virus (COVID-19) Pandemic: Opportunities, Challenges, and Future Directions

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ABSTRACT

The COVID-19 outbreak has created havoc around the world and has brought life to a disturbing halt claiming thousands of lives worldwide with the infected cases rising every day. With technological advancements in artificial intelligence (AI), AI-based platforms can be used to deal with the COVID-19 pandemic and accelerate the processes ranging from crowd surveillance to medical diagnosis. This paper renders a response to battle the virus through various AI techniques by making use of its subsets such as machine learning (ML), deep learning (DL), and natural language processing (NLP). A survey of promising AI methods that could be used in various applications to facilitate the processes in this pandemic along with the potential of AI and challenges imposed are discussed thoroughly. This paper relies on the findings of the most recent research publications and journals on COVID-19 and suggests numerous relevant strategies. A case study on the impact of COVID-19 in various economic sectors is also discussed. The potential research challenges and future directions are also presented in the paper.

KEYWORDS

Artificial Intelligence, COVID-19, Deep Learning, Diagnosis, Machine Learning, Natural Language Processing, SARS-CoV-2, Treatment

INTRODUCTION

The world is facing an exceptional threat from the novel coronavirus, termed as coronavirus disease 2019 (COVID-19) by the world health organization (WHO), a pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) virus. SARS-CoV is alleged to be an animal virus from an as-yet-uncertain animal reservoir, perhaps bats, that eventually spread to other animals (civet cats). The COVID-19 outbreak originated in the Wuhan district of China (Hubei Pro Province) and was declared a pandemic by WHO on March 11, 2020 (Wang L,et al.,2020). Since the outbreak, more than 0.7 million deaths have been reported spanning around 200 countries across the globe as per the statistics of WHO on Aug 2020 (WHO,2020).

Clinical features of this virus range from the asymptomatic state (no symptoms) to multiple organ dysfunction syndromes (MODS) and acute respiratory distress syndrome (ARDS). The primary

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symptoms of COVID-19 include fever, dry cough, fatigue, dyspnea, increased expectoration, muscle pain or joint pain, sore throat, and headache. A small percentage of patients (5%) have shown the symptoms of nausea and vomiting. China CDC detailed the clinical features, outcomes, laboratory and radiologic findings of 44 672 laboratory-confirmed cases on February 14. Among the 965 (2.2%) people under 20 years age group, only one death was recorded (0.1%). The majority of the patients (77.8%) were aged between 30 and 69 years. Patients aged over 80 years had a case fatality rate (CFR) of 14.8%. Among the chronic disorders, patients with cardiovascular, diabetes, chronic respiratory disease, hypertension, and cancer were at increased risk and showed a high CFR (WHO,2020).

The impact of the COVID-19 outbreak has caused extreme distress all over the world. The number of COVID cases has been exponentially increasing, evoking the need for immediate measures to tackle the effects of this virus. The overworked healthcare systems that haven't produced vaccines for this pandemic and the shortage of resources to handle the outbreak have put the majority of the countries in lockdown.

Furthermore, section 2 provides brief details on AI application in COVID-19 and describes the prevalent machine learning and deep learning algorithms; section 3 illustrates a case study on the impact of COVID-19, section 4 discusses the potential research challenges and future directions, and section 5 concludes the paper. The motivation and organization of the paper are depicted in Fig.1. The main contribution of the study is:

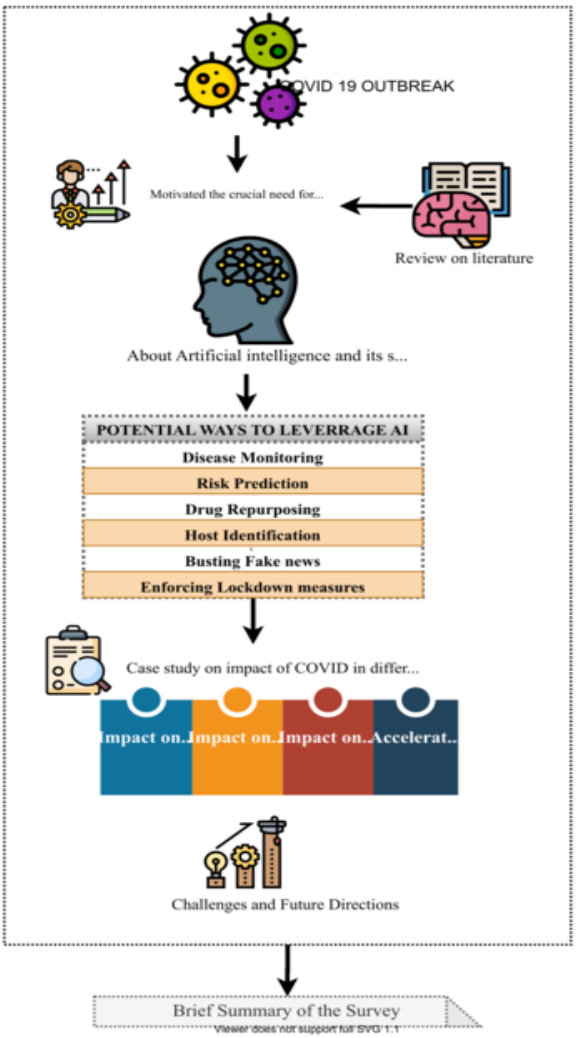
1. Identifying the potential way of leveraging AI during COVID pandemic and its significant impact
2. Presenting the case studies on the impact of COVID in lifestyle, economic sectors, diabetic patients (as they are easily prone to various illness and organ disorders) and accelerating healthcare in AI revolution.
3. The COVID related data are widespread and have not been effectively managed, so a blockchain with edge computing-based secured framework for COVID data management is presented.
4. Identifying various sources of the COVID data for research purpose.
5. The major challenges and future directions for COVID 19 research are highlighted.

1. ARTIFICIAL INTELLIGENCE IN TIMES OF COVID-19

In this paper, we carefully explore the use of Artificial Intelligence in mitigating the impact of COVID-19. From the inception of Artificial Intelligence (AI), it has proved to be a milestone in technological advancement because of its capability to unravel complex problems. AI has contributed to deal with the COVID-19 ranging from screening and tracking the virus to predicting the current and future patients. It has the potential for the development of drugs and vaccines and lessens the workload of healthcare workers. Some of the actual and potential ways in which AI can help the authorities in effectively combating the COVID-19 pandemic are described in Table.1.

The data collected from application-specific sources (COVID related data) for the problem under research will be in a raw format. So data preprocessing techniques are applied to remove unwanted data, missing data to retrieve meaningful information. Furthermore, to improve the AI algorithms' performance, the relevant subset of data is extracted using feature selection methods (data normalization techniques). The relevant subset of features is split into the train and test data (70% and 30%, respectively). The training data is used for constructing the model by applying AI algorithms and learning through the experience from various evaluations. The model is evaluated using test data, and the model is trained based on the experience. The data visualization methods are then applied for viewing the prediction and classification results. The steps involved in AI with various applications of COVID is depicted in Fig. 2.

Figure 1. The motivation and organization of the study.



ML and Deep Learning as Subsets of AI

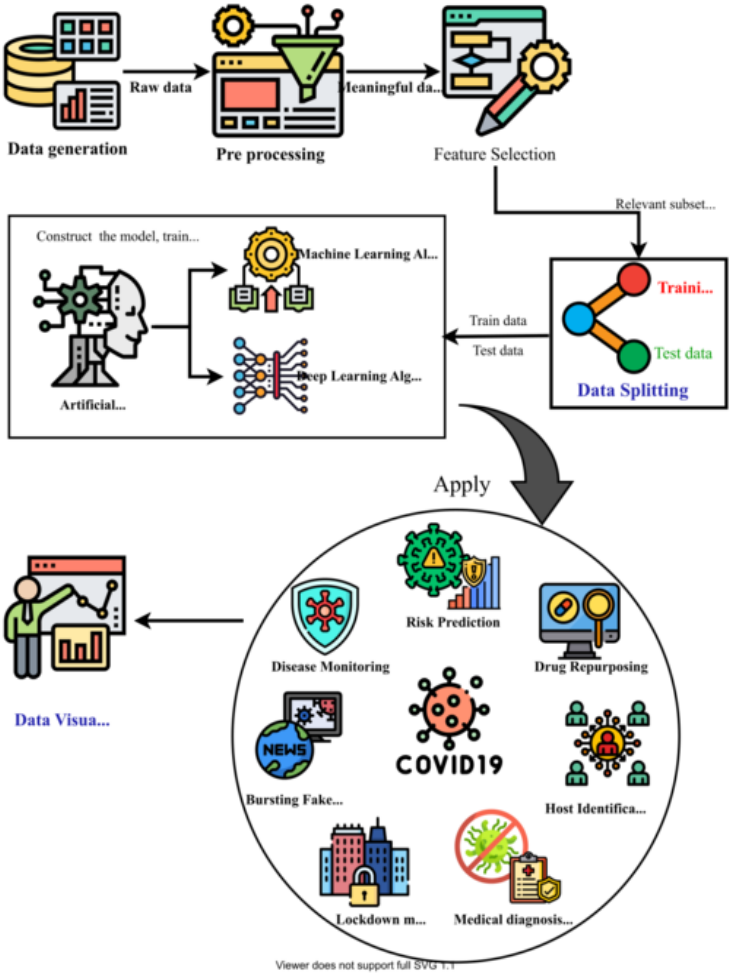
Machine learning, a subset of AI is an alternative to the conventional engineering approach for the design of an algorithmic solution in which the problem of interest is studied in detail. ML has already proved its capability for detecting, diagnosing, containing, and therapeutic monitoring of lot of diseases(Muhammad L. J et al.,2020).

There has been a lot of advancements in Machine Learning in recent years. For example, Reinforcement learning has been used by Google's Deep Mind to develop systems that can play games, including video games and board games. It is also used in marketing and advertising lately to target an individual and perform real-time bidding.

Deep Learning

Deep learning, a technique with its base in artificial neural networks, is emerging in recent years as a leading tool for machine learning inspired by the design of the human brain, promising to remodel

Figure 2. The steps involved in AI and its application in COVID



the future of artificial intelligence. Deep neural networks have recently gained attention due to the development of new variants of Convolutional Neural Networks (CNN), which is an excellent tool in analyzing visual imagery. CNN's main strength lies in its deep architecture composed of two main blocks, which lets extracting a set of distinctive features at multiple levels of abstraction (LeCun et al.,2015). Deep CNNs automatically learn mid-level and high-level abstractions obtained from raw data (e.g., images). The striking distinction that Deep Learning makes is its flexibility in the design of neural systems like repetitive neural networks (RNN), CNN, and deep belief networks (DBN). It is the ability to pick up on patterns in the input image like gradients, lines, curves or even eyes that makes CNN extremely useful in object recognition and localization in natural images. It has also paved the way for new frontiers in data analysis with excellent rates of progress not before experienced. Deep learning models like RCNN and YOLO have been proved to be successful in automatic feature extraction in images and videos, paving the way for many business applications that were difficult to be implemented before.

Table 1. Potential ways of leveraging AI in COVID-19

Ref	Potential ways of leveraging AI	Methodology adopted	Challenge
(W Naude,2020)	Disease monitoring	ML and NLP for information extraction, classification, and making prediction models	Although disease prediction using these models yielded results, human interpretation and knowledge remain central to its working. Insufficient data can lead to uneven results.
(E. Strickland,2020)	Risk Prediction	Deep learning algorithms, decision trees, and predictive analysis	Uncertainty of AI model outcomes. Inadequate time-series data
(Joseph J. Titano, Marcus Badgeley,2018)	Medical Diagnosis and Screening	3-dimensional deep learning model, Image analysis	Low-quality datasets due to insufficient medical imaging data.
(fda,2020)	Drug Repurposing	Machine learning, Convolutional Neural Network and Combinatorics	Not available in the short span since candidates go through extensive scientific checks and clinical trials before approval for commercial use.
(J. Wakefield,2020)	Host Identification	ML models, Combinatorics	Dealing with genomic data. Huge computational expenses.
(thewire,2020)	Busting Fake News	SVM, NLP, Deep learning CNN models	Difficult to understand the tone of the article, consider cultural context and then classify.
(Kaliyar,et al.,2020)	Enforcing lockdown measures	AI-based image capturing	The use of AI techniques for crowd monitoring is considered a breach of privacy.

THE POTENTIAL WAYS OF AI LEVERAGING

Disease Monitoring

It is crucial to anticipate and keep tabs on the outbreak and spread of diseases. On December 31, 2019, a Toronto-based health surveillance company, BlueDot that uses a platform built on AI and ML was successfully spotted the impending outbreak of coronavirus, nine days before the WHO and other epidemiologists(M. Hollister,2020). BlueDot's AI model utilizes several ML and natural language processing (NLP) tools to track and forecast the spread of several infectious diseases. In addition to this, they also leverage big data which helped them identify the cities where the SARS-CoV-2 was likely to spread using things like global airline ticketing data to anticipate where the infected might be traveling. Although the AI model of BlueDot proved to be a powerful tool in giving predictions regarding the outbreak, it can't be denied that human interpretation was central in evaluating the output(W Naude,2020) . Other virus-fighting technical initiatives like BlueDot have adopted the use of AI to estimate the risks associated with emerging infections.

The Global Virome Project (GVP) is an endeavor that uses technologies capable of identifying potentially zoonotic viruses. The GVP aims to make a genetic and ecological database of microorganisms in various animal species that could infect humans. The vast amount of data that they collect on viruses could also be used to train AI technologies to predict which zoonotic viruses have the potential to be transferred to the human species. Programs like GVP can be effectively used for the proactive development of drugs, vaccines, and preventive measures (Garza,2020) .

Risk Prediction

AI tools, specifically machine learning, can prove to be an effective intervention strategy against COVID-19 in risk prediction. Risk prediction involves identifying the vulnerable group, predicting the risk of getting infected, the course of illness, and the risk of carrying on a specific treatment for a person.

Identifying the Vulnerable Group

A study of people who contracted COVID-19 in Wuhan suggests that the risk of severe complications from COVID-19 is more significant for specific vulnerable populations, specifically immune-compromised people, elderly, weak, or people with multiple chronic conditions (Zhou, 2020). The most susceptible group can be identified by collecting their age, medical and travel history, and doing a comprehensive analysis of the data coupled with AI techniques. Based on that and ML algorithms, a vulnerability index can be built for individuals to prioritize the outreach for the most vulnerable members (DeCaprio, et al.,2020) .

For contact tracing purposes, automated digital tracing using IoT has been proved efficient. The IoT Model uses the block chain's trustworthy decentralization for on-chain data logging and retrieval (Lalit, et al.,2020).

Predicting the Course of Illness

The authors of (E. Strickland,2020) have detailed on retooling AI-enabled systems via machine learning to predict the course of a patient's illness. These AI-based systems offer clinical decision support by identifying patterns of illness in patients through data ingestion and predict specific COVID-19 outcomes like intubation. In another effort, physicians at the University of Chicago have come up with an upgraded version of their earlier launched product named eCART to an AI System. The upgraded version will collect data from the patient's electronic medical records and predict which patient's conditions are likely to deteriorate and who needs intensive care or intubation. The most striking feature of this version is to accurately predict the patient's health using the respiratory rate, which in turn is calculated by finding the amount of supplementary oxygen required to keep the patient's blood-oxygen level up. Predictive analysis, a form of AI, can be leveraged to identify from among the many mild cases the few that will progress to critical illness. It uses deep learning algorithms and decision trees to determine the best subset, which comprises the least number of dimensions that contribute the most to the accuracy of predicting ARDS. This approach allows for making pragmatic responses early in an epidemic more than waiting for large, complete datasets (Jiang, et al.,2020). Hence iteratively developed AI tools along with the involvement of clinicians in their development can strengthen the power of accurate predictions and help in closer clinical attention.

Medical Diagnosis and Screening

In this crisis, it has become a herculean task for authorities to conduct large-scale diagnostic testing due to the shortage of testing kits. Rapid medical diagnosis and screening could be a solution for authorities in controlling the spread of the virus. Deep learning which has shown promising results in medical diagnosis due to improved image acquisition and interpretation, could be used to achieve this (Sweta, et al.,2020). Image acquisition has improved considerably over recent years, with devices

acquiring data at faster rates and increased resolution. Computerized AI tools have facilitated image analysis and support workflow (LeCun,et al.,2020).

Following the COVID-19 outbreak, various authorities have started using facial recognition and thermal cameras in public places to detect people with fever. To reduce the need for a human operator, cameras carrying AI-based multisensory technology have been deployed in airports, hospitals, textiles etc. to detect people with high temperatures automatically and tracks their movements after face recognition (Obeidat, 2020).

Harnessing the power of AI has been used to detect disease in CT scans in a matter of 1.2 seconds which is faster than radiologists. Such a system could preprocess an image and alert the physicians to a critical finding when an issue is detected. This deep learning-based system can be extended to detecting pneumonia from analysis of CT scan, which is a common complication of COVID- 19((Josephet al., 2018).

In a study by authors of (Li, et al.,2020), chest CT could be used as a reliable and rapid approach to screening COVID-19. A three-dimensional deep learning model referred to as the COVID-19 detection neural network (COVNet) is designed for detecting coronavirus disease 2019 (COVID-19) from chest CT scans. The lung region is extracted from the preprocessed image using the segmentation method and is sent to COVNet, a convolutional neural network that uses ResNet50 as the backbone. A classification prediction of the CT image is generated after a series of CT slices are taken as input. A max-pooling operation is combined with the convolutional neural network features from each slice of the CT series, and the feature map is fed to a fully connected layer to generate a probability score for each class. On an independent testing data set, it was seen that this model was able to accomplish high sensitivity (90% [95% confidence interval [CI]: 83%, 94%]) and high specificity (96% [95% CI: 93%, 98%]) in COVID-19 detection. However, the study has tiny limitations since the CT findings of COVID-19 may have similarities in image characteristics as that of pneumonia caused by other viruses. Also, several radiologists have expressed issues concerning the lack of unbiased data, which impedes AI models' performance. The use of medical imaging techniques can also possibly contaminate the equipment used, which, in turn, causes the disease to spread further (Naude, 2020).

Voice detection platforms can act as a screening measure to identify potential COVID-19 patients when testing kits are inadequate. Several voice-detection apps have been developed for COVID-19 screening during these difficult times. According to (R. Staines, 2020) a project by Cambridge University is trying to develop a software that leverages machine learning and listens to coughs and voices of users to predict if the user has COVID-19. Similarly, a COVID Voice Detector built by a team at Pittsburgh University asks the users to cough, recite an alphabet, and a vowel loudly, which aids the app in determining the user's lung capacity and indicates the probability of the users having COVID-19. Although one can rely on these voice-based platforms, it should be noted that this software does not compensate for the need for other medical tests, which can produce a more accurate and efficient diagnosis.

In (Chouhan et al.,2020), authors discuss using the Image Augmentation technique, two different image augmentation techniques (rotation and translation), to train deep networks in classifying normal and viral images to make COVID-19 training images.

The above instances indicate that AI devices and algorithms have immense potential to assist COVID-19 screening and facilitate clinical procedures.

Drug Repositioning

Drug "repositioning" is a strategy which uses existing approved, shelved or investigational drugs for the treatment of a never-considered therapeutic indication - in this case, COVID-19 (XueH, et al.,2018). Conventional drug development usually proceeds through five stages over many years, which are:

1) Drug discovery and development: This is where research for a new drug kicks off in the laboratory.
2) Pre-clinical research: Drugs undergo laboratory testing in this stage to ensure the drug is safe.

3) Clinical research: Qualified people are tested with a drug to check the effectiveness of the drug.
4) FDA review: The FDA review team conducts a review in 6-10 months to decide if the drug can be approved or not.
5) FDA post-market safety monitoring: This stage monitors all drug and device safety and can agree to add restraints to the dosage or treatment information (FDA, 2020).

However, a repositioned drug omits the initial stages mentioned above and goes straight to pre-clinical testing and clinical trials, thus reducing the costs and development time. An antiviral drug Remdesivir, which is adenosine used in the treatment of Ebola virus clinical studies, has been shown to inhibit replication against COVID-19 (Gautret, et al., 2020). Tocilizumab, a humanized monoclonal antibody, was also used in the treatment of COVID-19 patients in China. This is recommended to aid rheumatoid arthritis tested in COVID-19 patients (Chan, et al., 2013).

With technological advancements in Artificial Intelligence (AI) combined with increased computational power, the AI-enabled drug repurposing has proved its effectiveness in the COVID-19 scenario. Given the similarities between the COVID-19 virus and the 2003 SARS Virus, AI, and ML-enabled models can be generated to envisage drug structures to treat COVID -19 (GNS, et al.,2018).

Atazanavir, an antiviral medicine used to treat HIV/AIDS, is used by a group of researchers from the Republic of Korea and the USA to treat COVID-19 using deep learning that can embed a network connecting drugs, targets, and diseases (Wakefield, 2020).

Various ML techniques can accelerate drug repurposing and also identify drug candidates by predicting drug-target interactions (DTIs) between the virus's protein sequences and existing drugs. A deep learning Deeper-Feature CNN is built (Zhang, et al., 2020). The system can classify protein-ligand interactions with accuracies up to 92%. In another effort by the authors of (Beck et al.,2020), a deep learning-based drug-target interaction model, Molecule Transformer-Drug Target Interaction (MT-DTI) has been developed, which is imperative to narrow down the number of potential drug candidates and identify commercially available drugs that can act on SARS-CoV-2 viral proteins.

Host Identification

In a study by the authors of (Eng et al.,2014), computational models for 11 influenza proteins were created using the machine learning algorithm random forest to identify the hosts. The results were highly accurate prediction models with an accuracy of over 96 per cent hence proving that these models could act as an early warning of the host range capability of the virus. From the study, it can be learned that these kinds of models could be extended to include the SARS-CoV-2 as well, which is a member of corona Miridae.

Busting Fake News

Following the outbreak of the COVID-19, social media platforms have been struggling to contain misinformation and myths. To find a solution for the same, MetaFact, a local start-up by a group of youngsters in India, has used Natural Language Processing (NLP), an AI tool that uses linguistics and computer science for fake news detection. The product's fact-checking tool has used NLP to curb the propagation of these fake news and phoney stories. Firstly, the MetaFact fact-checker analyses the context of information in prominent news stories and social media posts on various websites. The tool then detects misleading content by identifying disputable sentences via the tone of the sentence. Hence, these tools can be trained using AI to effectively bust fake news and screen the content (thewire,2020).

In another effort by the authors of (Kaliyar, et al.,2020), a tensor comprising the correlation between various user-profiles and news articles on social media is constructed and tested on a real-world dataset, namely BuzzFeed. Echo-chambers, a community on social media with identical opinions, is exploited for acquiring the latent representation of the news article. The content of the news is fused with the tensor, followed by a matrix-tensor factorization to get a community enhanced

representation of the same. This representation is later used for fake news classification and DeepFake, a deep neural network model in AI that applies deep learning to combine news and social media context.

CIMTDetect is also a matrix-tensor factorization based method that jointly models the content information and the community-infused tensor information. The generic embedding of the news articles and social media users generated are subsequently fed into a Support Vector Machine classifier for the final classification, which will help discriminate fake news from genuine news(Gupta,2018).

Tracking news propagation on social media can also be used to detect fake news. A news cascade can be used to present news propagation, which is a tree structure comprising post-repost correlation for every news posted on the social media platform. RNN and CNN is also incorporated into the news cascade to identify the similarity between news cascades and draw conclusions regarding the genuinity of news (Ruchansky et al.,2017).

Google has partnered with an Ireland-based start-up called Storyful as part of Google's news initiative to analyze content across digital platforms with the motive of identifying dated, inaccurate, or modified images. The app makes use of the AI technology of Google to filter out fake information. Therefore, it can help journalists in verifying the authenticity of an image, thus making the app a solution to fight misinformation

Enforcing the Lockdown Measures

An AI-based computer vision camera system is used in the UK to ensure citizens obey social-distancing measures imposed by the government. The system has adopted an AI-based computer vision camera to track individuals who violated the rules (Naude,2020). Countries like China and the USA are also using infrared cameras to scan public places to ensure social distancing protocols are maintained. Apart from facial recognition, these cameras notice individuals who are violating rules and identify people with high body temperatures.

Recurrent YOLO is another method to predict an object's type and location by capturing the spatiotemporal features. Recurrent YOLO's architecture is such that it combines the detections from YOLO with feature vector from CNN feature extractor hence giving major improvements for challenges in tracking (Redmon et al.,2016).

Deepsort, a deep learning-based approach for object tracking in a video, is used in several places to track individuals present in the surveillance footage by making use of patterns learned via detected objects in the images and utilizing Kalman filter, Hungarian algorithm, and feature extractor to identify the associated trajectories of the custom object. The object under consideration can be kept track of by mapping unique identifiers for additional statistical analysis (Wojke et al.,2017). Deepsort can also handle associated challenges such as identifying the same person in different frames, non-stationary cameras, variation in viewpoints, and annotating training data set.

CASE STUDY

This section presents the various case studies of COVID-19.

I. Impact of COVID-19 on Different Economic Sectors

The pandemic has made us witness the most significant economic shock in years due to the impact it has had on the global economy. As per the report of Global Economic prospects on June 2020, the pandemic has created long-term damage as the forecast predicts a 5.2 percent decrease in GDP, which seems to the worst recession the world has witnessed in decades. Lower investment, the decline in human capital due to loss of employment for around billions of people, and disruption in global supply linkages are the major factors for causing long-lasting scars on the economy. The inevitable need for social distancing protocols since it is considered the best mechanism to combat viruses and lockdowns have forced governments to limit the trade of goods across country borders, paralyzing international trade and industrial sectors. The pandemic can put the global economy on the verge of

collapse with an approximate loss of 5.5 trillion US dollars in the upcoming 18-24 months, as per the report of JPMorgan Chase & Co (Huang, et al.,2020).

The impact of COVID-19 on different economic sectors is discussed below.

Construction Industry

Due to the social-distancing guidelines and quarantine protocols, the majority of the construction firms have paused existing projection, and site works have come to a halt, which can lead to significant losses for the construction industry. The unavailability of labourers, coupled with financial difficulties, has led to a decline in real estate demand. This will likely result in the large-scale re-scheduling of existing projects, which might lead to severe losses for the industry. According to studies, between January and February in 2020, fixed asset investment in China had dropped by 30.3%, and new construction starts measured by floor area had also dropped by 44.9 percent. As per Global data, the growth in the construction sector has plummeted from 3.1% to 0.5% (D. Goodman et al.,2020).

Aviation Industry

It can't be denied that the aviation industry has been hit very badly since the pandemic. With international and domestic travel closed for a long duration to prevent the spread of the virus, the aviation industry has witnessed a huge loss of employment. Since almost all countries are affected by the pandemic, domestic passenger and international flights have been under the travel ban. According to the Indian Association of Tour operators (IATO), Hotel, Travel, and Aviation are together estimated to hit a loss of 85 Bn rupees. As per a report published by the International Air Transport Association (IATA), the major disruption in the global air travel demand was recorded between 24 and 30 March 2020, when a huge downfall was reported as the number of operational flights went down from 7,80,000 flights in the same period in 2019 to 2,80,000 in 2020 (globaldata.com,2020).

Due to the pandemic, the number of aircraft orders has also plummeted to 235 in 2020 from a figure of 1858 in 2018 (Patel,2020).

Oil Industry

With the outbreak of the virus, there has been a drastic decline in the demand for aviation fuel due to the plummeting number of operational flights with the travel restrictions. Similarly, on the ground, corona-driven restrictions have stalled traffic, causing a sharp decline in the global oil demand. With the sharp decline in crude oil prices and the lasting impact on petrochemical along with an uncertain domestic and global demand, there is a decrease in the investments in this sector (Kenkel and Cyient.,2020).

The Brent crude oil benchmark collapsed over 65% in the first 4 months of 2020, while the West Texas Intermediate (WTI) benchmark saw a drop of around 66% (Ovaska et al.,2020). The upstream sector in the global oil industry will struggle in the long run for efficient survival.

Although oil-consuming nations will not have to struggle much due to the import of oil at a lower price, the oil-exporting nations will go bankrupt unless they find an alternative revenue mechanism. Oil and Gas companies should begin to implement flexible organizational processes and foresee the implications with respect to the external environment to take necessary steps.

Food Industry

The pandemic's impact has not been drastic on the food industry even though food service providers like restaurants, hotels, and cafés have been shut down. According to the United Nations (UN) and the Food and Agriculture Organization (FAO), the demand for packaged food has increased considerably since the outbreak of the pandemic(Meredith,2020).

Moreover, in markets at the local level, specifically in countries badly affected by the crisis, some of the food commodity prices have risen due to import difficulties and logistic issues. As per FAO, the pandemic has severely affected seafood markets since fishing fleets are empty on the supply side.

COVID-19 has badly affected shrimp and salmon production on a global level, especially in India, where the production of farmed shrimp is expected to plummet by 40 percent.

It cannot be denied that the pandemic has reminded us how sustainable our food system should be to cope with pandemics like COVID-19. There has been a lot of disruptions in the supply chain distributions since the outbreak. The Committee on Food Security (CFS) is actively working on the **Voluntary Guidelines for Food Systems for Nutrition** in order to accelerate the progress of the food system and make it more reliable.

Telecommunications Industry

The COVID-19 pandemic has demonstrated the role of telecommunications in keeping businesses, governments, and societies linked with each other. It is obvious that social distancing protocols imposed due to the pandemic on the people have caused the public to depend on technology for staying connected, providing access to medical, financial, commercial, and other essential services during mandated social isolation and, most importantly, working from home. The impact of the COVID-19 pandemic on the telecommunications industry has been sporadic. According to the authors of (fao,2019), telecommunication service providers (TSPs) and internet service providers (ISPs) have had a tremendous increase in traffic. The main reason for the heavy network is the government's lockdown measures, which has led to homeschooling as the majority of the educational institutions use online platforms for teaching and companies are making their employees work from home. According to the share price analysis of worldwide TSP's, the share prices of telecom behemoths AT&T, China Telecom, and Telefonica have decreased by around 20% between January 1 and March 25, 2020 (deloitte,2020). Also, while the telecommunication sector is less affected by the recession due to the pandemic, the launch of new smartphones has been delayed due to supply chain constraints. Also, telecommunication companies that handle sports media have seen a fall because of many sports league cancellations. Overall, telecommunication companies are turning towards faster network services to benefit customers and are focused on improving network resiliency as network usage is skyrocketing these days (GlobalData,2020).Telemedicine is also booming since the pandemic. Several hospitals and medical centers in China have come up with 5G+ telemedicine platforms for COVID-19 patients. A hospital by the name of West China has established a 5G+ teleconsultation platform in collaboration with China Telecom. Many medical centers are seen resorting to 5G networks since existing 4G networks are failing to support high data transfer speed and excellent clarity video conferencing for consultation teleconferencing due to issues like limited bandwidth (deloitte,2020). Moreover, 4G LTE connection networks disrupt the connection establishment of IoMT devices to cloud platforms, thus making it not worthy. Features of 5G networks like high latency and faster transmission speed has paved the way for virtual and augmented reality (VR/AR) applications, which has boosted telemedicine, enabling medical experts and staff to provide immediate expertise for complicated cases and better treatment strategies (D. Li et al.,2020). However, 5G networks cannot revolutionize health sector on their own. It can prove effective when grouped together with other technologies like AI and IoT. Also, the deployment of 5G networks is still in the initial stages since the infrastructure maintenance and deployment is difficult for many telecom operators.

II. Impact of COVID-19 on Lifestyle

COVID-19 (Coronavirus), which brought the world to its knees and claimed thousands of lives globally, has affected our day to day life in all aspects. The emphasis on taking extensive precautions in hygiene like washing hands, sanitizing things before use, and avoiding communication without masks has made the public more hygiene conscious. Home confinement has also lead to better family cohesion. Work from home is also a significant change that hit us, and people are slowly getting accustomed to this culture. However, this pandemic has drastically affected the physical activity and sedentary behaviour of children due to prolonged school closures and stay-at-home measures. In a survey conducted by the authors of (Wojke et al.,2020) it was found that the total screen time has

increased considerably during this pandemic affecting the physical and mental wellbeing of children. Physical activity has decreased drastically, with more children resorting to screen for leisure.

Economically, due to the slowing down of the manufacturing sector and poor cash flow in the market, a lot of people have lost their jobs or are faced with extreme financial crises leading to mental traumas for people with low socioeconomic status. Overall, this COVID-19 has affected the sources of supply and disrupted the celebration of cultural, religious, and festive events leading to undue stress among the population.

COVID-19 has also affected people with other illnesses on a large scale since patients with other diseases, and health problems are getting neglected in the healthcare sector (Xiang,et al.,2020). This category mainly includes people with chronic illnesses like diabetes, cancer, etc. These people being at a higher risk of getting infected are compelled to take extreme precautions, and their regular check-ups at hospitals are also affected due to the overburdened health care system.

III. Impact of COVID-19 on Diabetics Patients

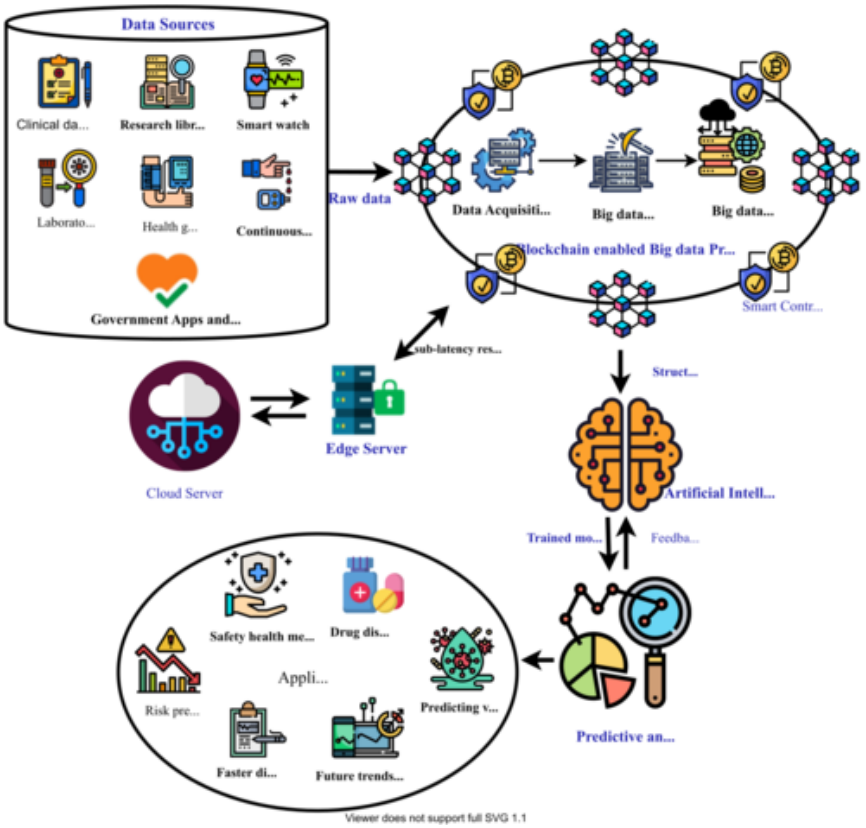
Due to the impaired immune response in diabetic patients, they are at a higher risk of contracting COVID-19. The presence of diabetes has been shown to increase morbidity and mortality due to two reasons. Firstly, they are immune-compromised. Secondly, due to an increased blood glucose level, the environment is less hostile. On analyzing the data of COVID 19 patients with diabetes, the authors of (researchgate,2020) have found COVID-19 to affect the pathophysiology of diabetes. Telemedicine has proved to be effective in managing people with diabetes in this pandemic. In Peru, the health ministry has leveraged telemedicine in diagnosing COVID-19 patients with diabetes via telecommunication (Singh et al.,2020). During this pandemic, many people with diabetes have resorted to home A1c testing using kits and uploading the results using teleconsultations, which proved to be an efficient strategy for people with diabetes; meanwhile, they do not have to go to the clinic at the risk of life (EilhartGarcía et al.,2020).

A meta-analysis was conducted in (Karin et al.,2020) to calculate the odds ratio of morbidity and mortality while comparing the diabetic patients who were in mechanical ventilation versus the diabetes patients who did not, and it was concluded that diabetes in patients with COVID-19 increased the mortality two-fold when compared to non-diabetics. Diabetic patients with COVID-19 have a higher probability of developing the hypercoagulable state due to increased fibrinogen and d dimer amounts. The standard dose of anticoagulant thromboprophylaxis is also not of much help to these patients since the dosage is insufficient to prevent the development of venous thrombosis (Kumar et al.,2020). Thus high dosage anticoagulants are preferred for patients with comorbidities like diabetes. Hence it is evident that diabetic patients should take extra precautions, reasonable glycemic control, physical exercise, and social distancing in this pandemic (Fang et al.,2020).

a. Secured Blockchain-based Edge Computing Framework for COVID Pandemic

Blockchain can be integrated with edge computing (BEC) for architecting a secured and low-latency response framework for processing the COVID related medical data. The framework is depicted in Fig. 3. The diversified big data on COVID collected from different data sources are in an unstructured format. But to make a meaningful interpretation, it must be converted into meaning data. Therefore the data accumulated are stored in Blockchain for retrieving the meaningful data safely. Since Blockchain is distributed, immutable, safer and transparent, it provides the data in a meaningful format. Blockchain-based big data processing framework will mine the diversified data and produce structured data that can be predictable. Data processing from the cloud for the ever single request may cause unprecedented delays, so to avoid this, the edge node can be used. The edge nodes with faster processing capability can reduce the processing time involved in retrieving data from the cloud server because the edge computing brings the computation closer to the network edge. Successively, AI algorithms can be used for making realtime predictive analysis on safety health measures, medical risk prediction, drug discovery, forecasting virus spread and faster diagnosis. Edge computing will

Figure 3. Secured BEC framework for diversified COVID-19 big data processing using AI



ensure low latency response by faster data processing. Furthermore, edge computing with AI adds more intelligence to the edge nodes, making it a cognitive edge. This framework will be more secure and faster for COVID-19 data processing.

IV. COVID-19 in Accelerating the AI Health Care Revolution

This pandemic disclosed how vulnerable our health care systems are with overburdened staff, untimely services, adequate medical supplies like personal protective equipment (PPE) and not enough hospital beds and cures. COVID-19 revealed that our hospitals are equipped only to handle linear demand, whereas the virus is growing at an exponential rate. We failed to estimate the importance of AI in these areas before the pandemic hit the world.

The pandemic has paved the way for the inclusion of AI-based platforms in these areas to facilitate the fight against this virus. In China, an algorithm was announced by Alibaba, which has the potential to diagnose suspected cases within a short span of 20 seconds with 96 per cent accuracy, which is multi times better than human capability. The scans of diagnosed patients can also be quickly analyzed to assess health declines or progress, based on signs such as a white mass in the lungs.

In another effort by the scientists, robots were designed to deliver foods, medicines, and goods to quarantined families in Wuhan province of China (ATT Business Editorial Team,2020). All the medical services in a hospital at Wuhan were carried out by robots made by CloudMinds who's AI System was used to check for vital symptoms in feverish people. The robots also provided food and drinks to the patients at the hospital, apart from passing important information to them. Hence, proper

utilization of medical robotics can facilitate a lot of procedures in health care systems by minimizing person-to-person contact and risk of life threat to doctors and medical staff actively participating in COVID-19. In California, AI systems were designed to monitor older adults remotely to check for COVID related symptoms.

ML algorithms are also being leveraged in analyzing CT Scans at a faster pace. These scans can easily differentiate the CT Scans of patients with COVID from non-COVID patients. China's Zhongnan Hospital has already used an AI-driven CT Scan interpreter, which identifies COVID-19 when there is a dearth of radiologists. A General Hospital in Florida has deployed an AI system at its entrances to limit the entry of individuals who show potential COVID-19 symptoms with the help of cameras located at the entrances with a facial thermal scanner to look for signs including sweat and discolouration (wired.com,2020).

A COVID-19 Screener by the name Partners Covid-19 Screener makes use of a chat interface where the patients are provided with a series of questions based on content from the U.S. Centers for Disease Control and Prevention (CDC). The scanner helps to scan a large number of people and distinguish patients with higher severity of disease from those who might be sick with Covid-19 from those with low-risk ailments. This AI bot can improve the system's care to facilitate treatment of patients with mild to severe symptoms, set up virtual urgent care, respiratory illness clinics, and vital support to medical staff.

Hence it is evident that the pandemic has made the adoption and scaling of AI platforms in health care more comfortable and paved the way for a digital revolution in healthcare. However, it is important to note that instead of relying completely on AI models, human intervention and expertise are crucial to making sure the results are proper and deliver safe and secure care to the patients.

CHALLENGES AND FUTURE DIRECTIONS

1. Challenges

AI Systems can be of great use in these trying times to save human resources and combat the virus. However, most of the AI platforms are still in the developing stages due to many reasons, thus hindering their impact. There are several challenges that limit the effective application of AI technologies.

a. Data Collection in COVID-19

The first step before applying the AI methods in the preparation of the data, which is crucial for big data (Wittbold,et al.,2020). The data collected mostly consist of customer log details at public buildings and markets, medical information, such as clinical reports, records, images and several other information which can be transformed into data that can be interpreted by a machine which then applies various AI methodologies depending on the nature of data. Objectives of data collection include identifying main features such as data volume and data summarization. Collecting, analyzing, and using data like consumer, patient, physical, and clinical data ends in big data. The various steps involved in big data processing is given below.

Various methods of data collection to effectively apply machine learning methods and human intervention in the analysis are given in Table 2.

I. A. Fake News Detection

Following the outbreak of the COVID-19, social media platforms have been struggling to contain misinformation and myths. Several ML, NLP models, Deep learning, and matrix-tensor factorization techniques have come up to identify language patterns and classify based on decision trees effectively. Although AI technologies have succeeded to an extent in detecting fake news and uses sentiment analysis, it fails at identifying the tone of the sentence or cultural context. Deep learning decision making is based on very complex representations of training data, and it's often difficult to understand

Table 2. Datasets for COVID-19 Research

Ref	Data Source	Data Type	Data Range	Description
(Kamta Nath Mishra and Chinmay Chakraborty,2020)	The open paths technology platform	Image	44 states in US	Open source Security, Inc used their building access logs by state and industry as part of their physical access control system and services to generate graphs on social distancing index beginning from the week of February to know how people responded to social distancing protocols.
(openpath.com,2020)	Clinical data	Text	Region	Clinical data is classified and merged using artificial intelligence and deep learning algorithm to distinguish between active and discharged COVID cases.
(Wolkewitz et al.,2020)	Phone surveys	Text	Country	Phone surveys are used across several countries in Africa to assess the impact of COVID 19 in various households.
(worldbank.org,2020)	Laboratory tests	Image	State	In India using national notifiable disease surveillance system laboratory test report of covid patients are send to public health agencies.
(cdc.gov,2020)	Screening in community surveys	Text	Regional	RT-PCR screening as part of community survey in low covid regions to understand the prevalence of covid in that area.
(A. S. Joaquin,2020)	Saliva test	Text	Some states in US	Collecting saliva samples of people in a region to find the spread of virus in the area.
(thehindu,2020)	Governmental apps	Images	Country	People voluntarily register in the app and data regarding number of infected people can be retrieved using the app.
(theindianexpress,2020)	CT Scans	Images	States	Examination of CT Scans available in the clinic can help in distinguishing the no of COVID cases from the normal cases.
(X. Gu,et al.,2018)	News article content	Images and text	Region	News articles which contain keywords like SARS-CoV-2, COVID-19 and Corona Virus are examined and classified if its reliable or not.
(Xinyi Zhou et al.,2018)	CoAID Dataset Covid-19 heAlthcare mIsinformation Dataset)	Images and text	Regional	Various COVID-19 healthcare misinformation which includes fake news on websites and social platforms coupled with users' social engagement.
(Limeng Cui, Dongwon Lee,2020)	CORONAVIRUS (COVID-19) TWEETS DATASET	CSV	Worldwide	Dataset has sentiment scores of COVID-19 related tweets
(ieee-dataport,2019)	Malicious URL dataset from 'Phishtank'	Text	Country	Use static features of URL to identify malicious websites with misinformation

the reason behind their output. Also, even if it's possible to identify the genuinity of news, it's challenging to detect the origin of the message. Irregularities in language expressions can also lead to skewed results. Moreover, human intervention is also essential to make accurate conclusions.

b. Breach of Privacy

Data privacy concerns have put the public in fear that the government may use the data even after the pandemic ends. Moreover, the use of AI for monitoring the crowd and using their information is considered a breach of privacy by many people(Aldwairi and Rami, 2020.). Blockchain, a decentralized distributed and valid ledger, ensures integrity, security, and privacy in data sharing. The Blockchain with big data for medical use-cases will guarantee sub-latency response with faster query processing mechanisms (Song,et al.,2020). In addition to storing the test reports, the network of block chain enabled platforms can be utilized to store COVID-19 patient details which includes age, medical history, sex, presence of any chronic illness, the severity of the disease, the prominent symptoms shown by the patient, and the prescribed medication. Although blockchain-based solutions can be used to tackle privacy concerns may people are unwilling to use Blockchain as it is relatively new and people associate it only with crypto currencies and deceptive activities. Another issue with the block chain based solutions is the lack of scalability. Scalability is an inevitable concern in the current pandemic as it affects most of the people around the world. However a vast majority of the blockchain systems suffer from scalability.

c. Inadequate Amount of Training Data

It can't be denied that AI models need a considerable amount of training data to give accurate outputs. Inadequate amount of historical data due to the unprecedented nature of such a pandemic has hindered the performance of AI algorithms since predictive models rely on historical data for future events. Noisy and outlier data have also impeded the performance of these models (Nguyen, et al.,2020).

Future Directions

1. Performance of AI algorithms

A. Scalability

Scalability is typically measured by the effect an increase in training set data size has on the computational performance of an algorithm. The issue of scalability turns judicial in realtime applications dealing with massive data sets, unapproachable computational problems requiring learning, which is evident in the COVID-19 scenario. Most of the ML algorithms struggle in providing an accurate balance between minimizing error, training time, and maintaining accuracy(Strigl, D,et al.,2010). Iteratively fed data into the training algorithm, and the memory representation of data plays a crucial role in scalability. The focus on research of newer algorithms that proves better in efficiency compared to existing algorithms can help in reducing the number of iterations needed to acquire similar performance, which in turn improves scalability. It is crucial that the deployed models should scale effortlessly with changing demands for inference of model. Hence picking the right machine learning framework, leveraging the right processors, the chosen format of storing data, and the input-output hardware also plays a vital role in the scalability of the system (codementor,2020).

B. Security

Blockchain technology can be highly beneficial in facilitating the secure sharing of data. The use of consensus algorithms and smart contracts substantially reduces the possibility of the dissemination of bogus data and deceitful information. Blockchain's built-in feature of being immutable enables the data stored in the network to be inviolable and, therefore, be trusted by all healthcare professionals. It

is also resistant to unauthorized changes because of its tamper-proof nature(Manoj et al.,2020). The shared network can be used as a single source of updating and retrieval of data. Digital monitoring and management of COVID-19 patients can be achieved using Blockchain-based applications hence saving human resources hospital staff and other healthcare personnel. Blockchain technology can also help in facilitating testing and reporting, storing the information of COVID-19 patients, enforcing lockdown measures, and limiting supply chain disruptions (Miglani et al.,2020). Blockchain big data applications can be implemented in IoT based EHRs systems connected through WSN. This will ensure identity verification and fraud detection. However, the resource constraints of IoT acts as a major challenge (Deepa et al.,2020).

C. Storage

As more and more data pile up on a daily basis, it is difficult to analyze each medical record and identify ways to stop the virus. Hence, significant data role in the COVID-19 crisis is crucial in storing data and analyzing patterns as worldwide organizations such as WHO, CDC, and Microsoft are creating big data models to predict potential hotspots and alert the healthcare authorities beforehand.

Another necessary significant data process used against this pandemic is outbreak analytics, which handles the collection and analysis of outbreak response data, including mortality rate, data visualization, confirmed cases, contact tracing, and population densities. These models can also predict peak infection rates and help the government in preventing future outbreaks. Moreover, big data is also used in analyzing screening data of patients and determining the risk factors (Mauro, et al.,2016).

2. Industry 5.0 in COVID 19

With the fifth industrial revolution, namely Industry 5.0, which comprises smart digital technologies and manufacturing information, significant improvements can be made in healthcare and industries. Industry 5.0 is the evolution which brings back the human to the factory where the collaborative robots will be a companion for the human thereby producing a more personalized products. During the COVID-19 pandemic, a remote monitoring system in healthcare can be implemented using Industry 5.0 technologies, including personalized therapies to patients infected with COVID. These technologies can be mainly leveraged by doctors in the healthcare system to monitor critical patients and provide better treatment suggestions. Hence Industry 5.0 technologies play a major role in making the lives of doctors better(Javsaid et al.,2020).

CONCLUSIONS

While COVID-19 has claimed thousands of lives globally, and the world continues to grapple under its impact, efforts of AI technologies have hit our daily lives and facilitated our battle against this virus. A survey of various AI applications relevant to the existing crisis, control strategies, and challenges were presented as the paper unfolded. The exploration of various uses of AI includes crowd surveillance, medical diagnosis, screening, drug repurposing, etc. While AI speeds up the methods to combat COVID-19, it should be noted that human intervention is also crucial, and AI techniques aren't entirely reliable since there is a dearth of vast amounts of training data to provide accurate computational models. However, the number of AI studies related to COVID-19 can be expected to increase significantly in the upcoming months when more COVID-19 data such as medical images and patient records are available. Till the time a cure for this disease in the form of vaccine or so surfaces, the responsibility to combat the virus and limit its impact lies in the hands of these technologies coupled with effective human intervention.

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