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Artificial intelligence technology for diagnosing COVID-19 cases: a review of substantial issues

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Abstract. – Today, the world suffers from the rapid spread of COVID-19, which has claimed thousands of lives. Unfortunately, its treatment is yet to be developed. Nevertheless, this phenomenon can be decelerated by diagnosing and quarantining patients with COVID-19 at early stages, thereby saving numerous lives. In this study, the early diagnosis of this disease through artificial intelligence (AI) technology is explored. AI is a revolutionizing technology that drives new research opportunities in various fields. Although this study does not provide a final solution, it highlights the most promising lines of research on AI technology for the diagnosis of COVID-19. The major contribution of this work is a discussion on the following substantial issues of AI technology for preventing the severe effects of COVID-19: (1) rapid diagnosis and detection, (2) outbreak and prediction of virus spread, and (3) potential treatments. This study profoundly investigates these controversial research topics to achieve a precise, concrete, and concise conclusion. Thus, this study provides significant recommendations on future research directions related to COVID-19.

Key Words:
Artificial intelligence, Coronavirus pandemic, AI, COVID-19, Machine learning, Big data.

Introduction

Novel coronavirus disease (COVID-19), which particularly affects the lungs and causes pneumonia, was identified for the first time in Wuhan, Hubei Province, China, in late December 2019[1]. Although the Chinese government has adopted timely and effective measures, such as wearing masks at public locations, frequently washing the hands, maintaining the social distancing policy, quarantining COVID-19-positive cases, and reporting the latest symptom information to regional health centers, to prevent and control the spread of COVID-19, the scope of the COVID-19 outbreak has developed widely and rapidly[2]. On January 30, 2020, the World Health Organization (WHO) announced that the outbreak of COVID-19 has become a public health emergency of international concern, and the situation has evolved quickly; on March 11, 2020, the WHO declared COVID-19 as a pandemic[3]. Today, COVID-19 is spread in all countries, and the number of infected cases and deaths rapidly and significantly increases (Figure 1); furthermore, efficient measures and treatments have yet to be developed to control this pandemic, severely affecting every aspect of our daily lives[4].

The long incubation period of the virus, which may take more than 2 weeks in some cases and may not cause symptoms in other cases, is one of the most important causes of the rapid spread of this pandemic[5]. Therefore, the early diagnosis and quarantine of COVID-19-positive cases can save numerous lives.

Artificial intelligence (AI) and machine learning (ML) technologies are being revolutionized to drive new research opportunities in various areas[6]. Many intelligent applications in different

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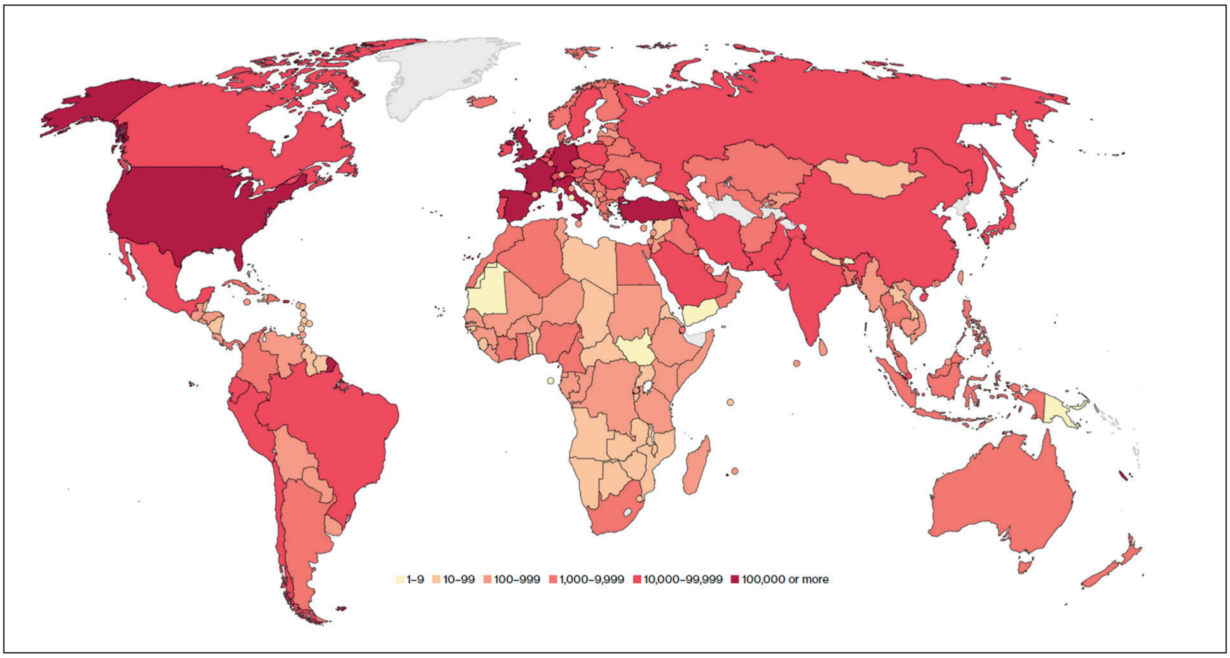

Figure 1. Coronavirus world map[3]: distribution of COVID-19 cases as of July 8, 2020.

fields include medical diagnosis and telehealth in healthcare[7,8]. AI technologies can be used to monitor and restrict the spread of COVID-19 and to help screen and detect SARS-CoV-2; it can also be helpful for gathering suggestions and increasing awareness among populations[9]. Moreover, AI can be applied to evidence-based planning and treatments by using the reported results to prevent the spread of COVID-19. The expected scenarios of the main applications of AI in the COVID-19 pandemic are summarized briefly:

Rapid diagnosis and detection: Early detection/diagnosis via AI methods can be accomplished with X-ray, magnetic resonance imaging, and computed tomography (CT). Furthermore, diagnostic results can be helpful for making informed and rapid decisions[10].

Monitoring virus spread, tracking, and prediction: AI can be utilized to predict an outbreak from large-scale data analytics, which is necessary to plan effective disease control strategies. Moreover, AI technology can offer timely updates and define solutions for COVID-19 pandemic[11].

Potential Treatment: Currently, immediate medical solutions/vaccines must be developed to cure COVID-19 and prevent its further spread worldwide. With AI, the use of intelligent analytic tools is maximized to predict and develop effective and safe vaccines/drugs; accordingly, AI technology can help facilitate vaccine and drug manufacturing[12].

This study aims to discuss the most promising fields of research based on recent studies regarding the applications of AI in different scenarios related to COVID-19. This study also aims to achieve a precise, concrete, and concise conclusion. The key contributions of this study are summarized as follows:

- This study presents a review on the main application scenarios of AI in the COVID-19 pandemic by incorporating and discussing many controversial topics based on insights into subdomains to obtain a concise, precise, and concrete conclusion.
- This study summarizes the core domains of research topics into (1) rapid diagnosis and detection, where are discussed the most promising lines of research based on a large number of the recent literature that are based on the use of AI techniques for image processing (CT and X-ray), which is considered as a low cost, fast and simple solution to identify COVID-19 and diagnosis of the infection; (2) outbreak and prediction of virus spread, where are discussed a number of recent research works that use the ML and DL models based on authori-

tative sources (John Hopkins University, US; Italian Civil Protection sources; and National, provincial and municipal Health Commissions of China) for prediction of virus spread; (3) potential treatments, AI leverages intelligent analytic tools for predicting effective and safe vaccine/drug; accordingly, AI technology can help facilitate the development of vaccines and drugs. These areas are thoroughly investigated on the basis of the respective subdomains to obtain a concise, precise, and concrete solution.

– For researchers, this study provides recommendations on future research directions by presenting several references that can support the pursuit of enabling AI applications in the COVID-19 pandemic. The remaining parts of this paper are organized as follows. Section 2 describes the scenarios of the main applications of AI in the COVID-19 pandemic in detail in three categories: (1) rapid diagnosis and detection, (2) outbreak and prediction of virus spread, and (3) potential treatments. Section 3 concludes the work.

Scenarios of the Main Applications of AI in COVID-19

Deep learning (DL) and machine learning (ML) are considered the main approaches of AI technologies, including many other methods. In ML, the ability of a machine to learn and find eloquent patterns from raw data is extended. The abilities of AI-based algorithms to perform well are based on these representative features. In DL, complex problems can be solved by learning from representations. DL can also be used to help improve COVID-19-related planning, treatments, and patient outcomes. The expected scenarios of the main AI applications in COVID-19 are summarized briefly in Figure 2. The following subsections provide a detailed discussion on these applications.

Early Detection and Diagnosis of SARS-CoV-2 Infection

The early diagnosis and quarantine of COVID-19-positive cases are among the most effective solutions to combat the COVID-19 pandemic. Reverse transcription polymerase chain reaction (RT-PCR) is used as the standard method for the classification of respiratory viruses. Although efforts have been devoted to improving this technique for detecting SARS-CoV-2[13,14], RT-PCR is costly and time consuming; it also requires specific materials, equipment, and instruments[12]. Moreover, most countries are suffering from a lack of testing kits because of limitations on budget and techniques. Thus, this standard method is not suitable to meet the requirements of fast detection and tracking during the COVID-19 pandemic. The use of AI methods in image processing, specifically for medical-related images, is a low cost, fast, and simple way of identifying and diagnosing COVID-19. Nevertheless, studies have described AI and deep learning in medical image analysis as common solutions[7,8]. This study focuses on how we can use AI and deep learning for diagnosing COVID-19. Other studies have shown that X-ray images and CT scans can be widely used as input of DL algorithms, which can enhance the detection capabilities of COVID-19-associated infections[15-20]. The use of ML and DL techniques with chest CT scans for COVID-19 detection has also been considered[15-17,21, 22]. These works have shown high performance, as they can achieve a high classification accuracy of 99.68%[15], area under the curve (AUC) scores of 0.994[16] and 0.996[17], accuracies of 82.9%[21] and 98.27%[22], specificities of 80.5%[21] and 97.60%[22], and sensitivities of 84%[21] and 98.93%[22]. Chaganti et al[23] proposed a DL and deep reinforcement learning model based on chest CT images for COVID-19 identification and diagnosis by considering the percentage of opacity (POO), lung severity score (LSS), percentage of high opacity (POHO), and lung high opacity score (LHOS). The proposed learning model revealed that Pearson's correlation coefficients between the ground truth and the predicted output are 0.97 for POO, 0.98 for POHO, 0.96 for LSS, and 0.96 for LHOS based on trained and tested data on a dataset of 568 CT images and 100 samples, respectively. Another study has investigated a random forest (RF) model[24] to assess the severity of COVID-19 by extracting 63 features, e.g., the infection ratio of the lungs and ground class opacity lesions, from chest CT images. This model can achieve a sensitivity of 0.933, a selectivity of 0.745, an accuracy of 0.875, and an AUC score of 0.91[24], and its key finding is that the severity level is more dependent on the features extracted from the right lung. Furthermore, a deep convolutional neural network (CNN) model is designed for the detection of COVID-19 cases by using an open-source dataset with 13,645 patients related 16,756 images for training purposes; a descriptive accuracy of 92.4% is obtained[25]. X-ray scans are usually cheaper than CT images, so some studies

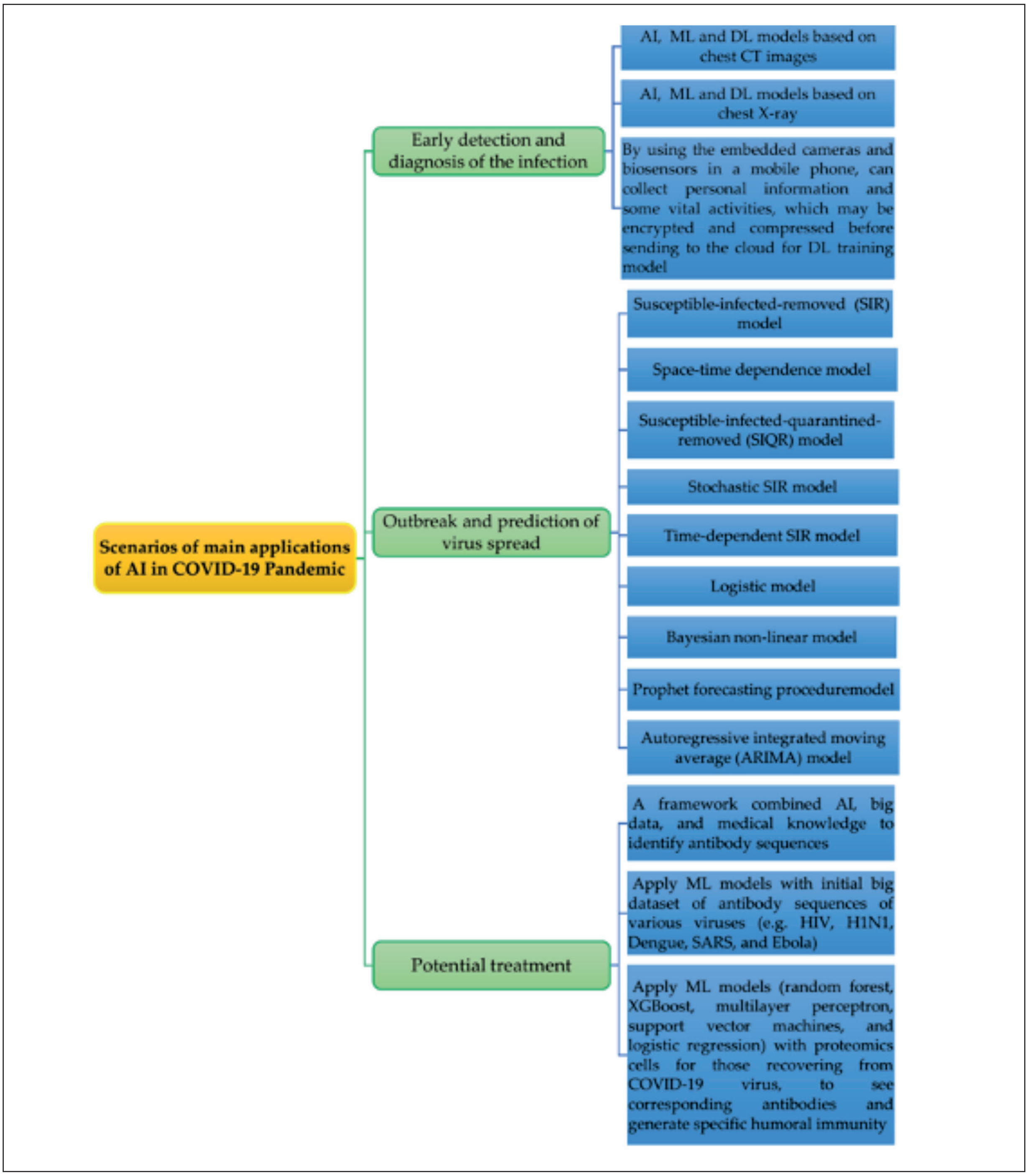

Figure 2. Expected scenarios of the main applications of AI in the COVID-19 pandemic. *Abbreviations:* Artificial intelligence (AI), machine learning (ML), deep learning (DL), computed tomography (CT).

have explored the use of DL models with X-ray for COVID-19 detection[26]. Asnaoui et al[26] enhanced a deep CNN model to process chest X-ray images for the classification of COVID-19 and to hasten training time, reduce computation costs, and make the DL model trainable with small datasets. To develop a scalable and cost-effective solution for COVID-19 diagnosis, Imran et al[27] proposed an AI-based framework by using smartphones to record cough and sound signals as input data. Despite interesting results, its average accuracy is 97.74%, and its response time is within 60 s. The implementation of this framework is also limited by several issues, such as the quantity and quality of datasets and the lack of clinical validation.

To develop a scalable and cost-effective solution for COVID-19 diagnosis, Li et al[28] introduced a robust, sensitive, specific, and highly quantitative solution based on multiplex polymerase chain reactions (MPCRs) that can be utilized to detect SARS-CoV-2. This model consists of 172 pairs of specific primers associated with the genome of SARS-CoV-2 from the Chinese National Center for Biological Information. The proposed MP-CR scheme is an efficient and low-cost method to diagnose *Plasmodium falciparum* infections, with high coverage (median 99%) and specificity (99.8%). Eden et al[29] implemented a molecular diagnostic method for the genomic analysis of SARS-CoV-2 strains to study Australian travellers with COVID-19 by using available genome data, which provide important insights into viral diversity and evidence supporting COVID-19 diagnosis in areas lacking genomic data.

These AI algorithms are based on different datasets from various individual efforts. The most efficient algorithm is still unknown because of the different numbers of samples used. Consequently, standard datasets should be obtained for reliable and accurate solutions. Government agencies, large firms, and heath organizations, such as the WHO, can play a key role in providing high-quality, realistic, and big datasets, such as X-ray images and CT scans collected from patients in various hospitals.

Outbreak and Prediction of SARS-CoV-2 Spread

Studies have been performed using ML and DL models for the modelling and prediction of COVID-19 outbreak by employing data from authoritative sources, which are essential for planning effective COVID-19 control strategies[30-32]. Some of these authoritative sources (1) national, provincial, and municipal health commissions in China; (2) Italian civil protection sources; and (3) John Hopkins University in the USA, which are obtained from confirmed cases, death cases, and recovered cases in all countries. These data are mainly used to calculate prediction errors, optimize data modeling, and improve the quality of future estimation. However, accuracy may depend on the number of contributing factors, including infected cases, population, living conditions, and environments. For example, a susceptible-infected-removed (SIR) compartmental model is used to predict infectious diseases. Dandekar et al[33] argued that a traditional SIR model is not suitable for perceiving the effects of more granular interactions, including quarantine policies and social distancing. Therefore, Dandekar et al[33] suggested that a quarantine policy should be encoded as a strength function, which is then included in a neural network for predicting the size of the COVID-19 outbreak in Wuhan, China. SIR models have been considered in several studies with different variants, space-time dependence of the COVID-19 pandemic[34], susceptible-infected-quarantined-removed SIQR model[35], where an additional compartment, namely, quarantined, is considered in the traditional SIR model, and a stochastic SIR model[36]. Interestingly, Chen et al[37] proposed a time-dependent SIR model that can adapt to changes in infectious disease control and prevention laws, such as city lockdowns and traffic halt. They showed that the proposed time-dependent model can be used to accurately predict the number of confirmed cases in China and the outbreak time of some countries, such as the Republic of Korea, Italy, and Iran. In addition, Brauer et al[38] developed more complex models that can accurately formulate the dynamics of the pandemic based on large data sets from Italian Civil Protection sources. Another study[39] has utilized a large dataset from various regions and countries, such as South Korea and China, to estimate the pandemic based on a logistic model that can determine the reliability of predictions. Interestingly, government reports on COVID-19 in China, South Korea, Italy, and Iran have been collected and analyzed using a data optimization model to generate an accurate prediction of the daily infected cases and potentially provide long-term predictions on future outbreaks[40]. Some researchers suggested to work on empirical data directly and extract the estimated outbreak size by utilizing various tools, such as logistic model[41], Bayesian non-linear model[42], prophet forecasting procedure[43], and autoregressive integrated moving average (ARIMA) model[44,45]. Magdon-Ismail[46] presented a data-driven approach to learn the phenomenology of COVID-19. The proposed model can be utilized to read asymptomatic information, e.g., a lag (also known as incubation period) of about 10 days and a virulence of 0.14%. Another interesting work[47] has proposed a modified auto-encoder (MAE) for modeling the transmission dynamics of COVID-19 worldwide. The proposed MAE model can accurately predict an outbreak site with an average error of less than 2.5% by using the data collected from the WHO situation reports. In summary, these models can predict the outbreak of COVID-19 and warn governments and policy makers so that preemptive actions can be implemented to prevent the outbreak; fast and effective interventions can reduce the maximum number of confirmed and death cases by around 166.89 times per week[12].

Data are relevant to guarantee the success of any AI applications, and authorities should be more vigilant in asking their people to share personal information, such as diagnosis reports, CT scans, daily activities, and GPS location, which are needed to lessen the damage, make updated policies, and decide on immediate actions. However, to secure and ensure the privacy of personal data, we must consider some potential solutions.

Potential Treatment

Vaccines and medicines for SARS-CoV-2 are not available, so fast and efficient solutions must be developed to combat COVID-19 and prevent further outbreak. In AI, the use of intelligent analytic tools for predicting effective and safe vaccines/drugs is maximized; accordingly, AI technology can help facilitate vaccine and drug manufacturing. By using datasets provided by healthcare organizations, governments, and clinical labs. Magar et al[48] introduced a data-driven framework that combines AI, big data, and medical knowledge to identify antibody sequences. The initial dataset is composed of 1,831 antigen and antibody sequences of various viruses (e.g., HIV, H1N1, dengue, SARS, and Ebola). Ortea et al[49] used proteomic cells infected with SARS-CoV-2 for diagnosis. More specifically, data include 6,381 proteins in human cells with SARS-CoV-2. A cooperative analysis of an impact pathway analysis and a network analysis has been derived to examine the data gathered from the Kyoto Genes storage. Lon et al[50] also experimentally generated data; in particular, all the six epitopes (A, B, C, E, F/G, and H) can induce the body to produce corresponding antibodies and specific humoral immunity. The sequences of S, E, and M proteins and their proximal sequences have been employed, and 420, 334, and 329 sequences have been obtained from the National Center for Biotechnology Information (NCBI) database[51] to build the final dataset after genome annotation. In addition, Lon et al[50] focused on a diagnostic procedure that involves the prediction of the 3D structure of a target protein and the conformational B cell epitopes of the target protein of SARS-CoV-2 coupled with an analysis of epitope conservation. In the same context, Lai et al[52] proposed mining 102 data samples from the RCSB protein data bank[53] and thus added to the initial data set to create the final dataset of 1,933 samples. An average pool layer over-extracted features has been applied to reduce the computational complexity and variance of the training data. Moreover, five ML models, namely, random forest, XGBoost, multilayer perceptron, support vector machines, and logistic regression, have been utilized to evaluate their performance. Interestingly, experimental results have shown that the XGBoost model is superior to the other methods; as such, it has been selected to find potential antibody candidates for SARS-CoV-2. Thus, the XGBoost model is highly promising, as it can achieve an outstanding out-of-class prediction over various virus families, e.g., 100% for SARS and dengue, 84.61% for influenza, and 75% Ebola and hepatitis; where that the COVID-19 virus has similar characteristics 88%-89% similarity with SARS-CoV-2[52]. These results will be useful for further academic studies and development of effective medicines and vaccines for the treatment of COVID-19.

Conclusions

This study highlighted the most promising fields of research on AI technology for the diagnosis of COVID-19. AI technology can play a key role in combating the COVID-19 pandemic through a variety of appealing applications and viable solutions, including outbreak tracking, virus detection, treatment, and diagnosis support. With AI, the use of intelligent analytic tools for predicting effective and safe vaccines/drugs is maximized. Accordingly, it can help facilitate vaccine and drug manufacturing. By using datasets provided by healthcare organizations, governments, and clinical labs. Standard datasets (X-ray and CT scans from trusted sources, such as WHO) are further optimized by utilizing AI applications, and the accuracy and reliability of data analytics are enhanced to improve the diagnosis and treatment of COVID-19.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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