Artificial Intelligence Against COVID-19: A Meta-analysis of Current Research

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Abstract The epidemic of coronavirus disease 2019 (COVID-19) has posed an unprecedented challenge before humankind, with more than 3.2 million confirmed cases and death toll to more than 225 thousand till the end of April, 2020 globally. Currently, one-half of the world is under lockdown and complying with social distancing to arrest its spread. Does the COVID-19 crisis illustrate the necessity for solid artificial intelligence (AI) and machine learning (ML) strategy? AI and ML research groups across the world are extensively working to tackle various aspects of the COVID-19 crisis including epidemiological (e.g. prediction, controlling and forecasting viral dynamics), molecular studies and drug development (e.g. molecular modeling and drug targets identification), medical (e.g. AI-enable diagnostic and treatment), and socio-economical applications (e.g. economical impact forecasting and mitigation). In the last few months, several research papers have been published with AI applications against COVID-19. In this chapter, we performed a meta-analysis of the current state-of-the-art of AI against COVID-19 by using various publication repositories (PubMed, PubMed Central, Scopus, Google Scholar) and preprint servers (bioRxiv, medRxiv, arXiv). This meta-analysis helps the researcher to understand the broad spectrum of AI to combat COVID-19.

Keywords Coronavirus · SARS-CoV-2 · 2019-nCoV · Machine learning · Meta-analysis

1 Introduction

Coronavirus disease 2019 (COVID-19) outbreak has been declared as a pandemic by the WHO on 11th March, 2020. This lethal viral disease has created a public health emergency around the globe, affecting almost 210 countries with more than 3.2 million positive cases, and mortality toll to more than 225 thousand reported
till the end of April 2020, globally. Although the epic center of this viral disease is Wuhan city of China, it has mostly affected other developed countries including the USA, Spain, Italy, France, UK, Germany, Turkey, Russia, Iran, India, and so on. It has thrown an unprecedented challenge before humankind, leading to shut down half of the world complying social distancing to arrest its spread.

COVID-19 is caused by the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), one of the recent and novel strains of coronavirus which is transmitted by inhalation or contact with infected droplets or fomites and whose incubation period ranges from 2 to 14 days [1, 2]. The overall fatality rate of COVID-19 is estimated between 3 and 4% with a major threat to both the elderly population and people with compromised medical conditions. The coronavirus family includes pathogens of both animal species and humans. Scientists and researchers are restlessly working to decode this lethal virus, trying hard to understand its replication, pathogenesis to understand the preference of coronaviruses to switch between species, to identify significant reservoirs of coronaviruses which will dramatically help to prognosticate when and where such viral epidemics may occur. A systematic review that highlights COVID-19 virus genomic composition, pathogenesis, symptomatology, diagnosis and prognosis, mathematical models of viral dynamics can be found in Qazi et al. [1].

Artificial Intelligence (AI) is a powerful tool to fight against COVID-19 pandemic, allowing the application of machine learning, natural language processing, machine vision, and automation and robotics to develop computer-based models for the prediction, pattern recognition, forecasting, explanation, and optimization. AI and data science researchers are scrambling to utilize these methods to predict (epidemic), recognize (diagnose), forecast (future spread dynamics), explain (treat), and optimize (socio-economic impacts) COVID-19 infections. The meta-analysis of current research trends of AI to fight against COVID-19 is not carried out yet. In this paper, we attempt to review recent trends of AI applications to fight against COVID-19 using various indexing and abstracting databases such as PubMed, PubMed Central, Scopus, Google Scholars, and preprints servers such as bioRxiv, medRxiv, and arXiv preprints server. This meta-analysis is not an assessment of the quality of publications, rather a quantitative look at recent publication trends. This meta-analysis will help the COVID-19 researchers to find the areas where AI techniques are prominently applied, and where are the research gaps that need to be addressed.

2 Meta-Analysis

2.1 Journal Database Search

We considered PubMed, PubMed Central (PMC), Scopus, and Google Scholar indexing databases, and bioRxiv, medRxiv, and arXiv preprints server for our meta-analysis of AI against COVID-19 research. The reason for including the preprints
server in the analysis is that there are several research articles posted on these servers for faster dissemination but are under review with some of the journals. We applied a search strategy with the query string “artificial intelligence” occurring either in the title, abstract or full text, AND keyword either “COVID-19” OR “coronavirus” OR “SARS-COV-2” OR “2019-nCoV” occurring in the title, and publication duration was set from 01/01/2020 to 15/04/2020. This search strategy was applied for all the considered journal indexing databases. As Google Scholar does not provide advance searching facility, therefore we utilized Publish or Perish 7 tool [3] for advance search and filter. The number of publications found in these databases is shown in Fig. 1. Google Scholar has the highest publication (count = 288) among these because it indexes almost all the Journals, Conferences, Pre-Prints including PubMed, PMC, Scopus, bioRxiv, medRxiv arXiv, and others. After manual curation of these publications, we filtered 288 publications showing AI applications in the various aspects of COVID-19 research. Hence, we considered publications found in Google Scholar for our further analysis.

2.2 Publication Profiling

The selected 288 publications showing the application of AI in various aspects of COVID-19 research were profiled based on their application areas. These publications were clustered into 13 groups (or groups) as shown in Table 1 (shown in descending order of the number of publications). The distribution of these publications in percent is shown in Fig. 2 (Pie-chart).
| S.No. | Application area                               | Number of publications |
|-------|-----------------------------------------------|------------------------|
| 1.    | Diagnosis and prediction                      | 70                     |
| 2.    | Epidemiology (viral forecasting, control and spread dynamics) | 60                     |
| 3.    | Reviews (including advisory, comment, correspondence, editorial, news, guidelines, public awareness) | 48                     |
| 4.    | Radiological image analysis                   | 47                     |
| 5.    | Drug design and treatment                     | 22                     |
| 6.    | Governance, economy and affairs               | 9                      |
| 7.    | Social network analysis                       | 8                      |
| 8.    | Others (health monitoring, surveillance, etc.) | 6                      |
| 9.    | Commerce and business                         | 4                      |
| 10.   | Survival and health risk prediction           | 4                      |
| 11.   | Education and training                        | 4                      |
| 12.   | Text analytics/NLP                            | 3                      |
| 13.   | Molecular and protein disorder                | 3                      |

Fig. 2  Distribution of publications on AI application on various aspects of COVID-19 research. The number of reviews and diagnosis and prediction publications is further classified in the subsequent pie chart.
3 AI in Various Aspects of COVID-19 Research

AI technologies cannot replace human intelligence, but they are very helpful in COVID-19 patient diagnosis, forecasting, mitigating and controlling the outbreak, disinfecting areas, assisting in the development of therapeutics and treatment, healthcare management, business and commerce, better governance and policymaking, and so on. In this section, some of the prominent areas of applications of AI in COVID-19 research are highlighted.

3.1 AI in Diagnosis and Prediction of COVID-19

The laboratory methods to diagnose COVID-19 infection are real-time reverse transcription-polymerase chain reaction (rRT-PCR), isothermal nucleic acid amplification, serology, and radiological images. The rRT-PCR and isothermal nucleic acid amplification are based on nasopharyngeal swab or sputum sample which detects antibodies in response to infection. The serology test is still under the development stage, and recently it has been approved by various authorities (FDA-USA, ICMR-India) as a rapid diagnostic test that gives results in 10–20 min. Further, enzyme-linked immunosorbent assay (ELISA) tests give results in 1–5 h [4]. Radiological images such as x-ray and CT scans are also useful to diagnosis COVID-19 [5]. One of the major challenges of COVID-19 diagnosis is the availability of its testing kits and required reagents. Although rRT-PCR-based diagnosis method is the most commonly available, it is also very sensitive, on the other hand, serological tests measure the amount of proteins/antibodies responding to infection. These diagnosis methods are costly, time-consuming, and available in limited laboratories. Hence, there is a need for an alternative diagnostic method to detect COVID-19 infections faster and at a cheaper cost.

AI and deep learning deemed to be a powerful tool in assisting COVID-19 diagnosis, treatment and decision making. There are several machine learning and deep learning-based models proposed to diagnose COVID-19 cases using clinical symptoms and radiological images. To identify COVID-19 cases faster and automated, an AI-based framework was proposed using a mobile phone-based survey [6]. As far as the diagnosis and prediction is concerned, literature reports a large number of AI-based methods for radiological images such as x-ray [6, 7], CT-scan [8–12], deploying a wide range of machine learning and deep learning. A recent systematic review on the diagnosis and prognosis of COVID-19 can be found in [13–16]. The development of automated AI-based models to detect, diagnose and predict COVID-19 infections for a bigger population is still an open research problem.
3.2 AI in Epidemiology (Viral Forecasting, Control and Spread Dynamics)

Forecasting and prediction of the COVID-19 spread are valuable inputs for government, public health authorities, companies, and people to plan, prepare and manage the pandemic. In order to forecast and predict the spread of COVID-19 disease over time and space, AI techniques can be utilized. A machine learning-based model may be trained with the available outbreak and demographic data to predict its spread. However, due to the lack of data and too much outlier and noisy data, AI-based forecasts of viral spread are not yet very accurate and reliable [17]. Hence, most of the models used to track and forecast COVID-19 outbreak uses epidemiological models, such as SIR (Susceptible, Infected, and Removed) [18, 19], SEIR (Susceptible, Exposed, Infected, and Recovered [20, 21], SIRD (Susceptible, Infected, Recovered, Dead) [22]; extended SIR model incorporating time-varying quarantine protocols such as government-level macro isolation policies and community-level micro inspection measures [23]; ARIMA (Auto-Regressive Integrated Moving Average Model) model [24]. The scope of this section is to focus on AI-based approaches.

Some of the AI-based models reported in the literature are interior search algorithm and multi-layer feedforward ANN to forecast COVID-19 infections [25]; modified stacked auto-encoder for transmission dynamics [26]; non-linear hybrid cellular automata classifier to predict affected, recovered and deaths [27]; agent-based artificial intelligence simulation platform (EnerPol) to predict growth and containment strategy [28]; multi-input deep CNN to predict cumulative number of confirm cases [29]; topological autoencoder to generate similarity map of transmission dynamics [30]; SEIR-SD (with social distancing) model with Differential Evolution as parameter estimator to forecast viral spread dynamics [31]; Polynomial Regression (PR), Support Vector Regression (SVR), Long Short Term Memory (LSTM) network, and deep feedforward neural network to forecast transmission [32]; Bayesian estimation for the logistic growth model to estimate the viral spread [33]; modified SEIR-LSTM model to predict epidemic peaks and sizes [34], and hybridized deep learning and fuzzy rule induction method for epidemic forecasting using incomplete or limited data in early epidemic Composite Monte-Carlo simulation [35]. As more epidemic data are available, the performance of these models will improve. Although, these models play a greater role in clinical diagnosis, optimizing various strategies and critical decision making, however, the next step may be to estimate whether the second wave of COVID-19 will hit China [36] or other suffered country.

3.3 AI in the Molecular Study, Drug Design, and Treatment of COVID-19

Molecular biology and AI have emerged as an interdisciplinary subject of research. Modern molecular biology needs the support of advanced software in tackling
complex biological problems, analyzing and interpreting data that remain unresolved in typical laboratory practices. The motivation behind AI research is the hope that their algorithms would provide a fresh outlook on many complex biological problems. Machine learning methods and deep learning, in particular, have been applied for molecular design, simulation, modeling, and drug development. These can contribute to combat the current COVID-19 pandemic, assist in identifying leads for therapies and vaccines, suggesting potential inhibitors, finding structural effects on genetic variation in virus, and so on [37]. Our meta-analysis reported in this article states almost 25 publications showing the application of AI in the molecular study, drug design, and treatment of COVID-19. The random forest machine learning technique has been used to predict infection risk and monitor the evolutionary dynamics of COVID-19 [38]. The data of spike protein sequences of 2666 coronaviruses was used. There were 7 clusters human coronaviruses found namely, 229E, NL63, OC43, HKU1, MERS-CoV, SARS-CoV, and SARS-CoV-2. It was observed that the cluster for SARS-CoV-2 is very close SARS-CoV, hence suggesting that both viruses have the same human receptor [38]. Prediction of protein structures of COVID-19 usually take months by the traditional approach, therefore, Google DeepMind has developed a deep learning system, called AlphaFold [39], which has released predicted protein structures that may serve as valuable information vaccine design [40].

To date, there is no effective and efficient drug exist in order to treat COVID-19 patients, hence an effective and efficient therapeutic is immediately required for the treatment of growing COVID-19 patients globally. Due to the lengthy process of new drug development, drug repurposing is one of the faster solutions adapted to treat COVID-19 infected patients. However, long term drug development objectives are to identify inhibitors aimed to target replication processes associated with this disease, and inhibiting key coronavirus proteins, and what could serve as starting points for drug development [41]. AI has been applied in several studies to develop a therapeutic strategy and drug design for COVID-19. Savioli [42] reports that Heptad Repeat 1 (HR1) domain on the glycosylated spike (S) protein is the region having less mutability, therefore it is an encouraging target for new inhibitors. Savioli [42] trained a Siamese Neural Network (SNN) with a whole 2019-nCoV protein sequence and found knowledge of peptide linkage among virus protein structure. A large number of peptides were tested towards the specific region HR1 of 2019-nCoV exhibiting a good affinity between peptidyl-prolyl cis-transisomerase (PPlase) peptide and HR1 that may open new horizons of research. Chenthamarakshan et al. [43] proposed a deep learning generative model framework, called CogMol, to design drug candidates specific to a given target protein sequence. This model was applied to three 2019-nCoV proteins, namely non-structural protein 9 (NSP9) replicase, main protease, and receptor-binding domain (RBD) of the S protein. Batra et al. [44] applied a machine learning and high-fidelity ensemble docking for rapid screening of possible therapeutic molecules from millions of compounds, based on binding affinity to either S protein at its host receptor region or S protein-human ACE2 interface complex. Beck et al. [45] applied a pre-training deep learning-based drug-target interaction model, known as Molecular Transformer-Drug Target Interaction (MT-DTI), to repurpose drugs and found that atazanavir (an antiviral used to treat HIV) is showing a good
inhibitory potency against 2019-nCoV 3C-like proteinase, followed by remdesivir, efavirenz, ritonavir, and dolutegravir. Further, their prediction also shows that several antiviral agents, including Kaletra (lopinavir/ritonavir), may also bind to the replication complex components of 2019-nCoV with acceptable inhibitory potency. Some of the other AI and machine learning assisted drug repurposing was carried out by [46, 47].

The repurposing of known approved drugs, including ritonavir, lopinavir, etc., are not very effective in treating COVID-19. Hence, it is an essential and immediate need to find novel chemical compound against this deadly virus. Tang et al. [48] developed an advanced deep Q-learning network with fragment-based drug design (ADQN-FBDD) to generate potential lead compounds that target 3CL of 2019-nCoV. They reported 47 lead compounds fully generated from the ADQN-FBDD model accessible from the author’s molecular library (https://github.com/tbwxmu/2019-nCov). A deep learning-based drug development framework has been developed to produce novel drug-like compounds [49]. Some of the reviews and discussions addressing AI-assisted drug development for COVID-19 can be found in [50, 51].

3.4 AI in Commerce, Business, Governance, Education and Training

The epidemic of COVID-19 has greatly impacted commerce, business, governance, education and training globally. This deadly virus has badly affected the people in particular and society at large. The people have been stacked out of the states and are unable to return to their homes due to lockdown. A country like India where around 73 million people come under the extreme poverty line is the daily wager workers who depend on their daily income. They don’t have space to live and not enough food to survive this pandemic. This epidemic has slowed down economic activities around the world. Most of the airports have been sealed, local public transport has been fully suspended, and hence export and import, business and commerce have been impacted. Also, educational institutions, tourism industries, hospitality services, entertainment industries, shopping malls, the textile industry, have been stopped which had badly affected the employment and economy. Global financial markets are already facing serious downfall in trading—pushing the economy into a financial shock.

AI can play a vital role in fighting the economical crisis, commerce, and business, education and training, governance and policymaking in this pandemic situation. E-commerce companies are applying AI for supply chain management [52], planning and procurement, production, and marketing [53]. The integration of AI in e-commerce not only helps in gaining competitive benefits in the online market but also boosts sales and customer satisfaction. AI has potential applications in marketing, including sales forecasting, Chatbots as personal assistants, identifying the trends, AI-powered business market, and improved digital advertising [54, 55].
As far as education and training are concerned, AI-assisted education and training is a growing field, called Educational Intelligence. It is defined as “leveraging data at multiple points across the student lifecycle to make intelligent decisions to positively impact students’ outcomes” [56]. AI technologies are useful to develop and imitate human reasoning and decision-making in the teaching-learning model. AI is employed for adaptive education systems within e-learning, including massive open online courses (MOOCs), educational data mining, and learner analytics [57]. Some of the education intelligence platforms are Questa (https://www.novatia.com/home-questa), Cognii (https://www.cognii.com/), and Kidaptive (https://www.kidaptive.com/) that uses AI help education institutions collect data and increase learning engagement. Other AI-assisted educational and training tools are Knewton (https://www.knewton.com/), Querium (http://querium.com/), Century Tech (https://www.century.tech/) and Volley (https://volley.com/). Knewton is an adaptive learning technology that helps in identifying gaps in a student’s knowledge and assigns suitable coursework. Querium provides customization tutorials and exercises by using AI. Century Tech platform provides personalized learning plans, reducing workloads for instructors by using cognitive neuroscience and data analytics. Similarly, Volley synthesizes course and quiz results by using AI-based knowledge-engine and helps in finding knowledge gaps among the employees.

4 Conclusion

Coronavirus disease 2019 (COVID-19) epidemic touched almost every corner of the globe. This lethal viral disease has greatly impacted the social life of the people, leading to acute economical, financial, food and health-related crises. It has put an unprecedented challenge before humankind, leading to shut down half of the world’s countries complying with the social distancing to arrest its spread. It is caused by the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), which is transmitted by inhalation or contact with infected droplets or fomites. The overall fatality rate of COVID-19 is estimated between 3 and 4% with a major threat to both the elderly population and people with compromised medical conditions. Artificial Intelligence (AI) is a powerful tool to fight against COVID-19 pandemic, allowing the application of machine learning, natural language processing, machine vision, and automation and robotics to develop computer-based models for the prediction, pattern recognition, forecasting, explanation and optimization, drug development and understanding the molecular mechanism of SARS-CoV-2 virus. AI and data science researchers are scrambling to utilize these methods to predict (epidemic), recognize (diagnose), forecast (future spread dynamics), explain (treat), and optimize (socio-economic impacts) COVID-19 infections. This article presents a meta-analysis of state-of-the-art AI applications against COVID-19, highlights four major areas of applications: (i) diagnosis and prediction, (ii) epidemiology (viral forecasting, control, and spread dynamics), (iii) molecular study, drug design and treatment and (iv) commerce, business, governance, education and training.
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