

Original Research Paper

A Comprehensive Review on Artificial Intelligence Techniques for Covid-19 Pandemic

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Article History

Received:
23.03.2021

Revised:
09.06.2021

Accepted:
12.06.2021

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Abstract: The pandemic situation due to the emergence of Covid-19 presents various problems physically, economically and mentally for the individuals world-wide, therefore faster solutions with wider access is essential to solve the problems which aids as a support to the healthcare. This is made possible through the incorporation of Artificial Intelligence (AI) technology to handle the situation of pandemic. This paper aims to present a comprehensive review of the applications employed using AI for the problems faced during Covid-19 pandemic. The AI applications involved in screening, predicting, forecasting, neighborhood contact tracing and drug discovery of Covid-19 are addressed in this review. This review also presents detailed working of AI algorithms in each application. This paper helps the researchers with vivid information of AI applications of Covid-19 pandemic.

Keywords: Artificial Intelligence, Covid-19, Machine Learning.



1. Introduction

The emergence of series of pneumonia cases with undefined causes has been seen at the end of 2019 in Wuhan. A novel virus Severe Acute Respiratory Syndrome Corona Virus 2 (SARS-Cov-2) has been identified as the causative agent for the series of pneumonia cases [1]. On February 11th 2020, the World Health Organization (WHO) named the disease Covid-19 which is caused by SARS-Cov-2 and on March 11th 2020, the WHO announced the world pandemic [2] [3]. The Coronavirus Disease (Covid-19) has been originated from Wuhan, a city in China. The most vivid symptoms of Covid-19 include fever, cough and sore throat [4] [5] [6].

The paper is organized as follows various AI applications employed for Covid-19 has been discussed under each category namely screening, detecting (diagnosis), forecasting, contact tracing and drug discovery. The detailed working principle of each methodology in each application has been provided. The comparison table has been presented as the result of the survey which covers the data used, methodology, advantages and limitations of all the Artificial Intelligence (AI) applications related to Covid-19.

AI is the 21st century state of the art technology. It is used in many applications from news recommendations systems to autonomous systems [7]. It acts as a decision support system which aids the healthcare industries in monitoring, detecting, contact tracing, controlling and drug (vaccine) discovery. AI is the efficient decision support system technology since it has better scale-up, speed up processing power and reliability [8] [9]. Machine Learning and Deep Learning are branches of AI.

2. Review on Artificial Intelligence Applications for Covid-19

The Review on AI applications for Covid-19 pandemic has been performed based on application category. The categories considered in this review includes screening, predicting/forecasting, contact tracing and drug discovery.

2.1. AI applications for screening Covid-19

2.1.1. Screening based on X- Ray Images

Muhammad and Chowdhury [10], presents a robust technique for screening Covid-19 from the digital chest X-ray images using pre-trained deep learning techniques. Several pertained Convolutional Neural Network (CNN) deep learning technique has been used. The analysis has been carried out in two different types

1. Data with image augmentation
2. Data without image augmentation.

The various pretrained CNN models considered in the analysis are ChexNet, DenseNet201, InceptionV3, MobileNetv2, ResNet18, ResNet101, SqueezeNet, and VGG19. From the amodels, DenseNet201 outperforms all other models with image augmented data whereas chexNet outperforms all other models without image augmented data.

2.1.2. Screening based on cough samples

Imran [11], deploys AI powered mobile app named “AI-4COVID-19” for screening Covid-19 based on cough samples. The app records cough sample for 3 seconds, sends the sample to the AI engine in the cloud and retrieves the result. The user is asked to record the cough sample using the app, the app send the sample to the cough detection engine to check the quality, if the sough sample is of good quality it is send to the diagnosis engine, otherwise it is reverted to the user for re-recording.

The AI engine performs four class classification. The four classes are:

1. Covid-19
2. Pertussis
3. Bronchitis
4. Normal (healthy)

The AI engine consists of three classifiers, they are:

- a. Deep Transfer Learning based Multi-Class classifier (DTL-MC)
This classifier uses CNN as a model with Mel-spectrograms as input, it uses SoftMax and ReLu as activation function and Adam as optimizer.
- b. Classical Machine Learning based Multi-Class classifier (CML-MC)

This classifier uses Support Vector Machine (SVM) as a model, it uses Mel Frequency Cepstral Coefficients (MFCC) and Principal Component Analysis (PCA) based features as input.

- c. Deep Transfer Learning based Binary-Class classifier (DTL-BC)
This classifier uses CNN as model and performs only binary classification.

The mediator in the AI engine combines the results of the above specified three classifiers. If the three classifiers provide different results then the mediator provides “test inconclusive” as a result to avoid misdiagnosis.

2.1.3. Screening Based on Chest Computed Tomography

Mei [12], provides a study which focuses on usage of AI algorithms that integrates chest Computed Tomography (CT) findings with clinical symptoms, exposure history and laboratory test findings which are used to diagnose patients who are Covid-19 positive.

Three AI models are built to generate probability of a patient being Covid-19 (+) based on:

- a. Chest CT scan (image information)
Two CNN models are used. The first CNN model is for slice selection and the second CNN model is for diagnosis. CT scans are sliced. Each slice has been ranked based on the probability of parenchymal abnormality. The abnormal lung slices from the CT scans are selected. The top ten abnormal CT images are fed to the second CNN model which provides the likelihood of Covid-19 positivity (probability 1).
- b. Clinical information (non-image information)
Demographic and clinical data are given as input to the machine learning model (SVM/random forest) which classifies Covid-19 positivity (probability 2).
- c. Integration of the chest CT scan and clinical information (image and non-image information)
Multi-layer Perceptron provides the final output of the join model with the features generated by CNN and machine learning model.

2.1.4. Screening Based on Routine and Prior Clinical Data

Andrew et al. [13], develops early detection models using demographic, routine and prior clinical data. Multivariate Logistic regression, random forest and extreme gradient boosted trees were used to perform screening test for Covid-19 in emergency departments and hospital admission units. Multi-step forecasting has been followed.

2.2. AI Applications for Predicting/Forecasting Covid-19

2.2.1. Forecasting Based on Data from January 11, 2020 to February 27, 2020

Hu [14] proposed the Artificial Intelligence model for real time forecasting of size, length and ending time of Covid-19 across china. The modified stack auto-encoder has been developed for modelling the transmission dynamics of the epidemics. The transmission structure has been analyzed using the latent variables in auto-encoder and clustering algorithms to group provinces and cities.

2.2.2. Forecasting Based on Data till July 30, 2020

Sengupta [15] presents “Time Series Forecasting Model”. The probability of hike in cases has been forecasted using machine learning techniques namely linear regression, Support Vector Machine (SVM), polynomial regression and deep learning techniques namely LSTM (Long Short-Term Memory). Statistical models have also been used.

2.2.3. Predicting Based on Geographical, Travel, Health and Demographic Data

Wendi [16] proposes boosted random forest algorithm for predicting the severity of the case along with the possible outcome – recovery or death. The analysis reveals that there is positive correlation between patients’ gender and deaths. The parameters of the random forest have been optimized using grid search hyper parameter tuning method. From the results it has been evident that the male death rates were higher than female death rates.

2.2.4. Predicting Based on Data That Consists of Death, Recovered Cases Along with the Date
Sujath [17] presents a model which is used to predict the spread of Covid-19. The data consists of the number of recovered and death cases with its corresponding date. The machine learning models used for the prediction includes Vector Auto-Regression (VR), Multi-Layer Perceptron (MLP and linear regression). The results indicate that MLP performs better than linear regression and VR.

2.3. AI applications for Contact Tracing

Contact tracing is necessary step in monitoring for fighting against Covid-19. Population-wide datasets are now emerging that reflect society's reaction to Covid-19. The data includes widely used phrases in internet search engines, human activity satellite mapping data and emerging interactive digital contact tracing data [18] [19] [20].

2.3.1. Principle of Contact Tracing

The main aim of contact tracing process is to find the cluster of infected people. The medium which is used for tracing is smartphone [21]. The main technologies used for contact tracing are Bluetooth and Global Positioning System (GPS) [22].

2.3.2. AI Based Contact Tracing – SQREEM Technologies

The SQREEM technologies has developed AI based Contact tracing. The platform acts as proximity locator without affecting privacy of the individual. There is no need for any application to be downloaded by the user for contact tracing. The government handles the data strictly and SQREEM is only the platform provider and does not have access to the data [23].

Monitoring Mechanism:

1. The Country is divided into areas of 5 square meter blocks.
2. The device which entered and left an individual's 5 square meter block is monitored.
3. The time and speed of devices entering the 5 square meter is recorded for 24/7 for a week duration.

Working Mechanism:

1. When a person is infected and tested COVID positive, the government officials runs the AI engine powered SQREEM channel by providing the inputs of the infected person.
2. The SQREEM channel which has deployed AI in it, receives the input, process it and produces the people who was in contact with the infected individual for the past 14 days.

Alert Mechanism:

1. The government officials can send the messages to the individuals who was in contact with the COVID positive patient.
2. The messages can be sent without even identifying the number, person name manually.

2.4. AI Applications for Drug Discovery of Covid-19

Drug discovery process involves finding of new candidate medications [24].

Terminologies

- (1) Targets: The Targets are the naturally existing molecular structure created and the targets are created within the pharmaceutical company [25].
- (2) Screening and design: The drug discovery process consists of rigorous High Throughput Screening (HTS) wherein it involves testing of large libraries of chemicals to check their ability to modify the target.

Need of AI in drug discovery

AI can be used to speed up the process of drug discovery which involves screening of therapeutic agents and drug repositioning or repurposing.

ML based screening of therapeutic agents

Batra et al [26] presents a machine learning model for screening therapeutic agents which is an essential step in drug discovery. Random Forest (RF) regression trees has been used as the machine learning model. Two RF models has been trained to estimate the vina score of S-protein and S-protein: ACE 2 interface.

ML assisted Prediction of commercially available drugs – Drug repositioning

Mohapatra [27] presents a ML assisted prediction of commercially available drugs for the treatment of Covid-19. Naive bayes model has been used due to its advantage of computational speed and reliability.

3. Comparative study of AI applications of Covid-19

Table 1 presents the summary of AI applications of Covid-19 with comparative study by presenting the advantages and limitations of each applications based on the following categories namely screening, predicting/forecasting, contact tracing and drug discovery.

Table 1. Comparison Table of AI Applications of Covid-19

No	Ref	DATA USED	METHODOLOGY	ADVANTAGES AND LIMITATIONS
AI APPLICATIONS FOR SCREENING Covid-19				
1	[10]	X- RAY Images	Deep Convolutional Neural Network (CNN) models ChexNet DenseNet201 InceptionV3 MobileNetv2 SqueezeNet ResNet18 ResNet101 VGG19	Advantage: Exhibits an excellent performance in classifying Covid-19 and the computer aided diagnostic tool improves the speed and accuracy of screening of Covid-19 positive cases.
2	[11]	Cough Samples	AI Models – Tri-pronged mediator (1) Deep Transfer-Learning Multi-Class classifier (DTL-MC) (2) Classical Machine Learning based Multi-Class classifier (ML MC) (3) Deep Transfer Learning Binary-Class classifier (DTL-BC)	Advantage: The tri-pronged mediator AI engine improves the diagnosis of Covid-19 with negligible misdiagnosis. Limitation: Lack of large-scale trials with more labelled data.
3	[12]	Image information-CT scan Non-image information (1) Clinical symptoms (2) Exposure history (3) Laboratory tests findings	Joint Model (1) CNN model (2) SVM (3) Random Forest (4) Multi-Layer Perceptron (MLP)	Advantage: The joint model which combines CT images and clinical information shows equivalent accuracy and can used as screening tool to quickly diagnose Covid-19. Limitation: <ul style="list-style-type: none"> • The sample size used in this study is small. • Model shows bias towards the samples of patients with Covid-19.
4	[13]	Routine and Prior	Three Models	Advantage:

		Clinical data	(1) Multivariate Logistic regression (2) Random forest (3) Extreme Gradient Boosted trees. (XgBoost)	This AI model performs as an effective screening tool for Covid-19 in emergency departments and hospital admission, which provides high impact settings wherein the rapid testing is not available.
AI APPLICATIONS FOR FORECASTING/PREDICTING COVID 19				
5	[14]	Data of confirmed cases in china: The data consists of Matrix rows representing provinces and columns representing the number of cases.	AI Models (1) Modified stack Auto encoder (2) Clustering Algorithms (K means Algorithms)	Advantage: Forecasting accuracy is high. Limitation: Training time was longer.
6	[15]	Confirmed cases data obtained from authenticated government websites till July 2020	Time Series Forecasting Models Machine Learning Models (1) Linear Regression (2) Support Vector Machine (3) Polynomial Regression Deep Learning Models (1) Long Short-Term Memory (LSTM)	Advantage: Absence of data extremities and outliers due to the incorporation of feature engineering techniques which converts the data to logarithmic scale.
7	[16]	Geographical, travel, health and demographic data – Kaggle repository	Machine Learning Model (1) Boosted Random Forest Optimization Techniques (2) Grid Search	Advantage: The Boosted Random Forest algorithm provides high accurate predictions even on imbalanced dataset.
8	[17]	Data consists of recovered and death cases along with date- Kaggle repository	Machine Learning Models (1) Linear Regression (2) Multi-Layer Perceptron (MLP) (3) Vector Autoregression (VAR)	Advantage: MLP provides accurate predictions. Limitations: Lack of integration of data from several hospitals.
AI APPLICATIONS FOR CONTACT TRACING				
9	[23]	SQREEM uses data from the person's mobile phone apps.	AI techniques, back tracking and forward tracking method.	Advantages: (1) Privacy of the individual is ensured. (2) Accuracy of the system is 90%.
AI APPLICATIONS FOR DRUG DISCOVERY OF COVID 19				
10	[26]	<ul style="list-style-type: none"> • all FDA-approved CureFFI data set • a data set of common active ingredients from Drug Central and • a BindingDB data set 	Machine Learning Model Random Forest regression	Advantage: The model has presented highly efficient screening of therapeutic agents for treatment of COVID19.
11	[27]	Bioassay Dataset in the Pub chem	Machine Learning Model (1) Naïve Bayes	Advantage: Computational speed Reliability

4. Inferences From the Review

There are some inferences from the review, are:

- (1) AI has been used in COVID pandemic for the following categories
 - i. Screening of Covid-19
 - ii. Prediction /Forecasting
 - iii. Contact tracing
 - iv. Drug discovery
- (2) Machine Learning algorithms has been used for numerical and categorical data.
- (3) Deep Learning algorithms has been used for image-based data.
- (4) Multi-models in most applications performed well. Multi models involves combining the features of image and non-image data, providing it as input to multi models and finally combining predictions of various models.

5. Conclusion

The outbreak of Covid-19 has made government officials, health providers and scientists to seek for a fastest and reliable technology to fight against Covid-19 pandemic. AI is the most appropriate technology which can aid the healthcare in quick screening, prediction/forecasting, contact tracing and drug discovery for Covid-19. This paper presents all AI applications employed to fight against Covid-19. The comparative study provided in the form of table presents the data used in each AI application, AI techniques along with advantages and limitations. The inferences from the review is also presented. From the review, it is evident that AI based approach produces accuracy and quickness. This review will be useful for the researchers to have an idea of all existing AI applications for tackling Covid-19 pandemic.

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