Application of Artificial Intelligence in Tackling COVID19– A Review

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Abstract

The Covid-19 pandemic that originated in Wuhan, now has a gripping effect in almost all countries around the world claiming lakhs of lives. This outbreak is a matter of grave concern as the death tolls have reached the pinnacle. Furthermore, lockdown across various countries has led to a drastic downfall in the socio-economic background with countless people losing jobs. Hence, it becomes very important to control the spread of this pandemic. This is possible by rapid spread of information amongst citizens, faster and efficient testing equipment, prediction of the extent of spread of the disease and the means to overcome it. This study aims to present the scope of AI in tackling the Covid-19 pandemic and how it would benefit everyone in the long run with speedy and efficient outcomes

Keywords: Receiver Operating Characteristics (ROC), Deep Learning, Convolution Neural, Area Under Curve (AUC), SEIR Model, Natural Language Processing (NLP), Computed Tomography (CT)

1. INTRODUCTION

Severe acute respiratory syndrome coronavirus 2 (SARS-Cov-2), is the virus strain responsible for the covid-19 disease. Covid-19 a disease predominantly attacking the respiratory system of an individual causing symptoms such as shortness of breath, fatigue, fever, cough and abdominal pain. The first case of Covid-19 was identified in December 2019, and since then countries around the globe continue to be part of a battle against this global pandemic- as declared by the WHO on 11 march 2020. The outbreak of this disease has brought the world to a standstill, with death tolls peaking up to a lakh and more in several developed nations such as China, USA and many more. With deaths being on an exponential rise and the global economy crashing, there's a dire need for an efficient mechanism that could help tackle this global pandemic with regards to disease detection, prevention, cure, testing kits and the like. Artificial intelligence (AI) has the potential to help us tackle the pressing issues raised by the COVID-19 pandemic. AI has the potential to exceed humans not only through speed but also by detecting patterns in that training data that humans have overlooked. However, AI systems need a lot of data, with relevant examples in that data, in order to find these patterns.

Machine learning also implicitly assumes that conditions today are the same as the conditions represented in the training data. This study will focus on the application of AI as a tool in battling Covid-19, the detection, and prediction, estimation of this global pandemic and how AI will help in flattening the curve.

2. ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) refers to the replication of human intelligence in machines that are programmed to think like humans and mirror their actions. Any machine exhibiting human traits such as learning or problem solving can be referred to AI. Artificial intelligence has the ability to rationalize and take actions in order to fulfill a specified task/goal. AI is ceaselessly developing to profit a wide range of industries ranging from computer science, linguistics, psychology and many more. The applications for artificial intelligence are endless. AI is excessive used in automobile industries for the development of self-driven cars, in the field of finance for security and fraud detection. Ai has also found its base in health care industries for various treatments and surgical procedures. As shown in figure 1, it consists of three important components.

- Machine Learning (ML): Machine Learning is a subset of AI which allows the machine to learn from examples and experience by feeding data to the algorithm. Its categories include supervised learning, unsupervised learning and reinforced learning. Machine learning techniques are used to find underlying patterns from large data sets.
- Deep Learning (DL): deep learning is a subset of machine learning, wherein similar ML models/algorithms are used to train neural networks and improve the existing model accuracy.Deep learning models can focus on the right features by themselves, with minimal input from the programmer.
- Natural language processing (NLP): Refers to the interaction between computers and natural human language. Through natural language processing, computers figure out to apply linguistic meaning to text. The automatic translation of one language into another, spoken word recognition, or the automatic answering of questions are some of the applications of NLP.
- Data Mining: Data mining is the process of realizing patterns in data sets with the help of machine learning, statistics and database systems. It's a process of turning raw data into useful information and helps develop market strategies and increase cost.
- Data science: A concept that merges ML, statistics, data analysis and the like to analyze and extract information from the underlying data (structured or unstructured).
- Big Data: This field deals with the extraction and processing of information from considerably large and complex data sets which cannot be dealt with traditional data-processing application software.

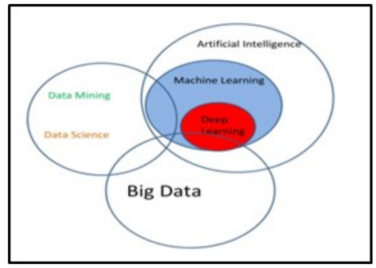

Figure 1. Representation of components of AI

3. EXISTING MODELS

Zifeng Yang et al. [1] focus on deriving the epidemic curve and predict the trend of Covid-19 in China using AI approach. The 2003 SARS epidemic data between April and June 2003 across the whole of China retrieved from an archived news-site (SOHU) was used for AI-training. The population migration data and the current COVID-19 epidemiological data along with the Susceptible-Exposed-Infectious-Removed (SEIR) model were used to predict the epidemic progression. The original SEIR-equation to represent a powerful Susceptible [S] and Exposed [E] populace state was altered by presenting the move-in, and move-out parameters, as shown below in figure 2.

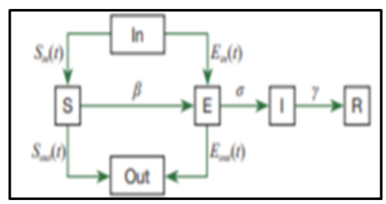

Figure 2. SEIR model[1]

The paper discusses the use of Long-Short-Term-Memory (LSTM) model, a type of recurrent neural network (RNN), used to process and predict various time series problems to predict numbers of new infections over time. Due to the lack of excessive data set, a simpler network structure was developed to prevent overfitting with ‘adam’ optimizer run for about 500 iterations. This dynamic SEIR model was effective in predicting the epidemic peaks and sizes as in Table 1.Furthermore, an AI-based model trained on past SARS dataset also shows promise for future prediction of the epidemics.

Table 1. Summary of predictions[1]

Model	Area	Control time	Epidemic peak: New daily infections – Time	Epidemic peak: New daily infections – Number	Epidemic peak: Cumulative active infections – Time	Epidemic peak: Cumulative active infections – Number	Epidemic size
SEIR	China	23-Jan	7-Feb	4,169 (95% CI: 3,615, 4,919)	28-Feb	59,764 (95% CI: 51,979, 70,172)	122,122 (95% CI: 89,741, 156,794)
		5 days earlier	2-Feb	1,391	23-Feb	19,962	40,991
		5 days later	12-Feb	12,118	Mar	173,372	351,874
	Hubei[a]	23-Jan	5-Feb	3,623 (95% CI: 2,327, 4,119)	20-Feb	42,792 (95% CI: 30,149, 52,941)	59,578 (95% CI: 39,189, 66,591)
		5 days earlier	3-Feb	2,061	15-Feb	15,635	22,116
		5 days later	10-Feb	9,908	25-Feb	115,061	167,598
	Hubei[b]	23-Jan	8-Feb	4,526 (95% CI: 3,439, 5,614)	18-Feb	51,581 (95% CI: 39,874, 63,994)	73,180 (95% CI: 51,308, 85,839)
					11-Mar	47,144 (95% CI: 36,305, 58,484)	
		5 days earlier	30-Jan	891	11-Feb	8,031	15,965
					6-Mar	7,067	
		5 days later	9-Feb	11,814	21-Feb	106,293	166,930
					17-Mar	90,992	
	Guangdong	23-Jan	2-Feb	208 (95% CI: 181, 233)	20-Feb	1,202 (95% CI: 1,042, 1,340)	1,511 (95% CI: 1,097, 1,948)
		5 days earlier	26-Jan	43	15-Feb	157	453
		5 days later	2-Feb	584	26-Feb	3,553	10,061
	Zhejiang	23-Jan	28-Jan	161 (95% CI: 138, 181)	20-Feb	1,172 (95% CI: 1,004, 1,314)	1,491 (95% CI: 1,066, 1,851)
		5 days earlier	23-Jan	21	14-Feb	157	453
		5 days later	2-Feb	484	25-Feb	3,522	10,061
LSTM	China	23-Jan	4-Feb	3,886			95,811

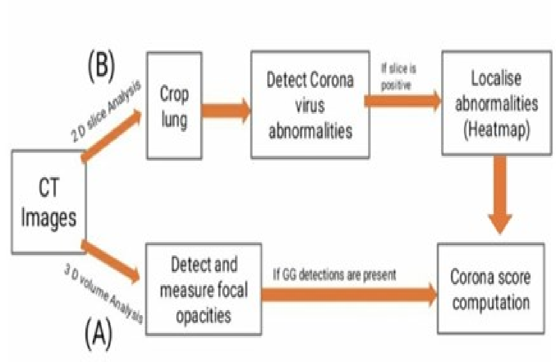

Figure 3. System block diagram[2]

Ophir Gozes et al.[2] in their research deal with the development of AI-based automated CT image analysis tools for detection, quantification, and tracking of Coronavirus and also focus on differentiating patients affected by corona virus from the ones who are not. Multiple international datasets, including from Chinese disease-infected areas were included. The paper presents a framework that uses powerful 2D and 3D profound learning models, adjusting and adjusting existing AI models and consolidating them with clinical comprehension. Different thoracic CT images with COVID-19 highlights are acquired. A system is developed comprising of several components and analyzes the CT case at two distinct levels:

3D investigation of the case volume for nodules and focal opacities utilizing existing, recently created algorithm. This uses a product that distinguishes nodules and little opacities inside a 3D lung volume (RADLogics Inc., Bostonand)

Recently created 2D examination of each cut of the case to identify and limit bigger measured diffuse opacities including ground glass infiltrations which have been clinically depicted as illustrative of the coronavirus. In this, the lung area of interest (ROI) is extricated utilizing a lung segmentation module. The U-net engineering for image segmentation was prepared utilizing 6,150 CT slices of cases with lung irregularities. Resnet-50 - 2D deep convolutional neural network architecture, a network of 50 layers deep is used to classify images.

The paper additionally proposes a Corona score which is a volumetric estimation of the opacities burden which is figured by a volumetric summation of the network actuation maps. Using the deep learning and image analysis framework created, the paper gives arrangement results to Coronavirus versus Non-coronavirus cases per thoracic CT investigations of 0.996AUC and the suggested corona score provide improvement in the patients with progression of time .

Linda Wang et al.[3] present COVID-Net, a profound convolutional neural network design custom fitted for the recognition of COVID-19 cases from chest X-ray(CXR) images that is open source and accessible to the public. Initial network design prototype is constructed based on human-driven design principles which make the following predictions: a) no infection (normal), b) non-COVID19 infection and c) COVID-19 viral infection. It also describes COVIDx, a CXR dataset utilized to prepare COVID-Net that includes 13,800 CXR pictures across 13,725 patient cases from two open access data archives.

It is observed that COVIDNet achieves good accuracy by achieving 92.6% test accuracy, thus featuring the adequacy of utilizing a human machine collaborative design strategy for making profoundly customized deep neural system models in a speedy way, custom-made around task, data, and operational prerequisites.

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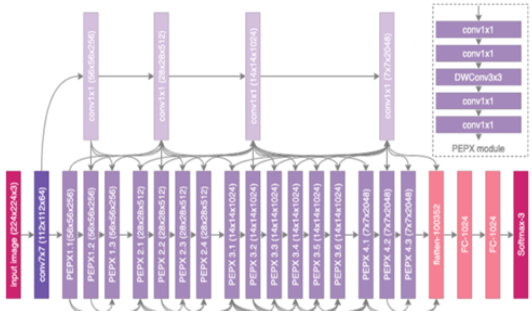

Figure 4. COVID –Net Algorithm[3]

Zixin Hu et al.[4] propose artificial intelligence (AI)-roused strategies for real-time forecasting of Covid-19 to gauge the size, lengths and ending time of Covid-19 across China. A modified stacked auto-encoder (MAE) was developed for modelling the transmission dynamics of the epidemics which was applied to real-time forecasting the confirmed cases of Covid-19. The number of nodes in the MAE was 8,32, 4 and 1(in the input, the first latent layer, the second latent layer and output layers respectively) unlike in the case of classical auto encoders, where they decrease from input to latent layers. The provinces/cities for investigating the transmission structure were grouped based on the latent variables in the auto-encoder and clustering algorithms.

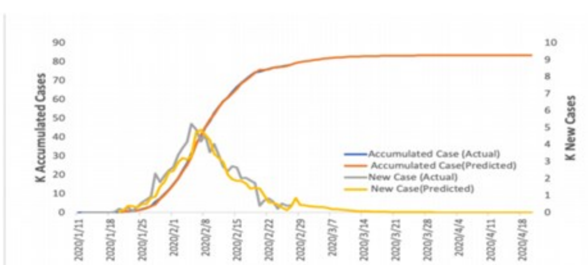

Figure 5. The national reported and forecasted curves of the cumulative and confirmed cases of Covid -19[4]

Successful forecast of cumulative confirmed cases of Covid-19 across China from Jan to April 2020 was made. Predictions were made that the time the regions/cities entering the level of the determined transmission dynamic curves would differ.

Muhammad E H Chowdhury et al.[5] aim to use digital x-ray images to automatically detect COVID-19 pneumonia patients and maximize the accuracy of detection with the help of image pre-processing and deep learning techniques.

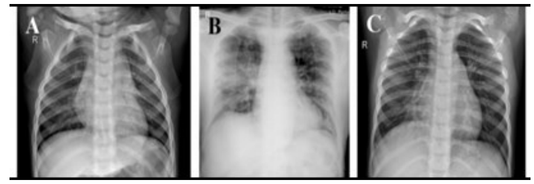

Figure 6. Sample X-ray image from the dataset[5]

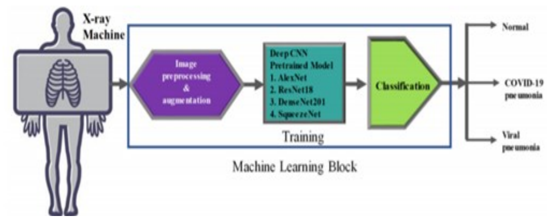

Figure 7. Block diagram of the overall system[5]

An image augmented training set was created with around 2600 images of each category for training and validating four different pre-trained deep Convolution Neural Networks (CNNs). Four different popular CNN based deep learning algorithms were trained and tested for classifying normal and pneumonia patients using chest x-ray. It was observed that SqueezeNet outperformed the other three CNNs. The classification Accuracy, sensitivity, specificity and precision of normal and COVID‐19 images, and normal, COVID19 and viral pneumonia were (98.3%, 96.7%, 100%, 100%), and (98.3%, 96.7%, 99%, 100%) respectively[5].

Fan Hu et al.[6] proposes a multi task deep learning model for prediction of potential commercially inhibitors against SARS-CoV-2. Manually ten drugs are selected as potential inhibitors and the multi task deep learning model reveal the important binding sites. The model is trained two perform two major tasks namely, binary classification and regression. Model was trained for filtered virus specific dataset acquired from GHDDI and it predicted the score to estimate the binding affinity between the drug and the target, higher is the predicted affinity score more potential is the inhibitor. To predict the most critical binding sites a non – parametric method known as occlusion is used, which predicted RdRp, 3CL protease and papain-like protease as major binding viral proteins.

The model was able to correctly predict the drug darunavir and darunavir (ethanolate) as a potential inhibitor. These two drugs were already used in clinical trial for Covid-19 and were put in the test dataset. Based on these results, partial accuracy of the model can be proven. The affinity score of other drugs are given below in Table 2.

Table 2. The potential inhibitors for SARS-CoV-2[6]

Drug	CAS	Target	Affinity(nM)
Abacavir (sulfate)	188062-50-2	3C-like proteinase	28.42
		Papain-like protease	22.90
		RdRp	3.03
		helicase	3.06
Darunavir	206361-99-1	3C-like proteinase	57.30
		Papain-like protease	46.16
		RdRp	6.09
Darunavir (Ethanolate)	635728-49-3	3C-like proteinase	44.51
		Papain-like protease	35.86
		RdRp	4.73
Itraconazole	84625-61-6	Papain-like protease	127.98
		RdRp	16.90
Almitrine mesylate	29608-49-9	3C-like proteinase	29.31
		RdRp	3.12
Daclatasvir	1009119-64-5	RdRp	15.03
Daclatasvir (dihydrochloride)	1009119-65-6	RdRp	19.87
Metoprolol tartrate	56392-17-7	Papain-like protease	153.23
Fiboflapon sodium	1196070-26-4	Papain-like protease	197.63
Roflumilast	162401-32-3	3C-like proteinase	248.89

Dave DeCapprioet al.[7] aims to predict individuals who are more vulnerable against Covid-19 using various ML techniques. To predict the vulnerability against Covid-19,the dataset of complications caused due to similar respiratory infections such as Pneumonia, influenza and other specified respiratory diseases were taken. Based on patient's medical history related the dataset of the respiratory diseases the dataset for the Covid-19 model is created. In this study 3 models are used for predicting the vulnerability of an individual towards covid-19, i) Logistic Regression ii) Gradient Boost Algorithm using limited feature set (diagnosis history and age) iii) Gradient Boost Algorithm using complete feature set. For logistic regression features for training the model was formed based on the risk factors given by Centers for Disease Control (CDC). The model trained by Logistic Regression resulted in ROC AUC of 0.731, sensitivity at 3% alert rate was 0.214 and at 5% alert rate it was 0.314. For Gradient Boost trees were done first by using limited features i.e. diagnosis history and age, then it was performed by taking complete feature set. The major advantage of using Gradient Boost trees is to ensemble simpler models to create a high accuracy model. ROC AUC of model for limited features came out to be 0.810 and same ROC AUC scored was acquired for Gradient Boost with complete feature set but the sensitivity of the models was different, for Gradient Boost with limited features sensitivity at 3% alert rate was 0.234 and at 5% alert rate was 0.324.

Whereas, for Gradient Boost with complete feature set sensitivity at 3% alert rate was 0.231 and at 5% alert rate was 0.327. The main of the research is to contribute to the intervention technique of the current pandemic and encourage others to work on same.

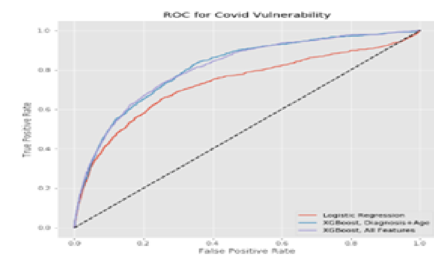

Figure 8. A recessive operating characteristic graph depicting the performance of the 3 models[7]

Shuai Wang et al.[8] focuses on using CT images to determine if an individual is Covid-19 positive by using a deep learning technique for classification. The prediction design flow was as follows, i) Pre-processing of input CT images ii) Feature extraction from region of interest (ROI) of the image and training the model iii) Classification using a transfer learning neural network based on inception work.

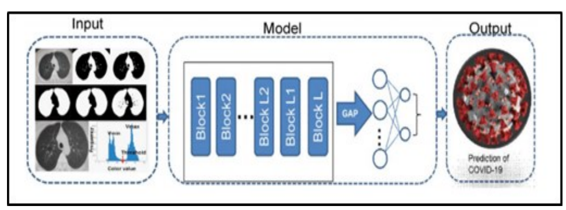

Figure 9. Computer vision model[8]

A Computer Vision (CV) model was used in extracting the ROI images. The CV model at first converts the image to grayscale then the grayscale image is then binarized. Flood filling algorithm is then used to fill the background area. All the contour areas are formed by reverse coloring and two largest contour areas are kept as lung areas, the ROI images are obtained by cropping the smallest rectangle from the lung area as the ROI frame. The images obtained are then converted to one- dimensional feature vectors. For making predictions a deep neural network is used based on inception work.

The performance metrics used for evaluation of the model were accuracy score, sensitivity, specificity, Area under Curve (AUC), F1-Score, PPV, NPV and Youden Index. The model training was recapitulated for 15000 times with a step size of 0.01. The graphs below show the training loss curve of the model for internal (A) and external validation (B).

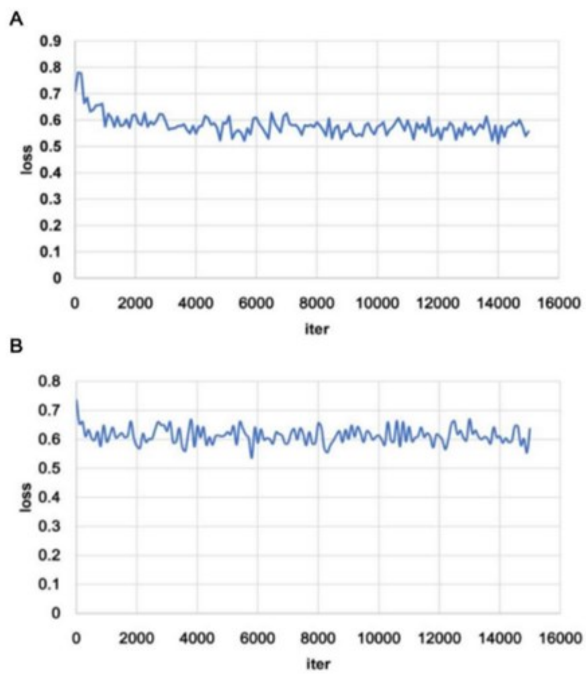

Figure 10. Model Training[8]

The stability of the training curve after descending indicates that the training process is converging. The deep learning model resulted in an accuracy score of 89.5% for internal validation and 79.3% for external validation. The ROC AUC came out to be 0.93 for internal validation and 0.81 for external validation.

Sensitivity is another important performance matrix and the given model resulted in sensitivity of 0.88 for internal validation and of 0.83 for external validation. Result of other performance metrics are given in Table 3.

Table 3. Performance comparison[8]

Performance Metric	Internal	External
Specificity	0.87	0.67
PPV	0.71	0.55
NPV	0.95	0.90
Kappa*	0.69	0.48
Yoden index	0.75	0.50
F1 score‡	0.77	0.63

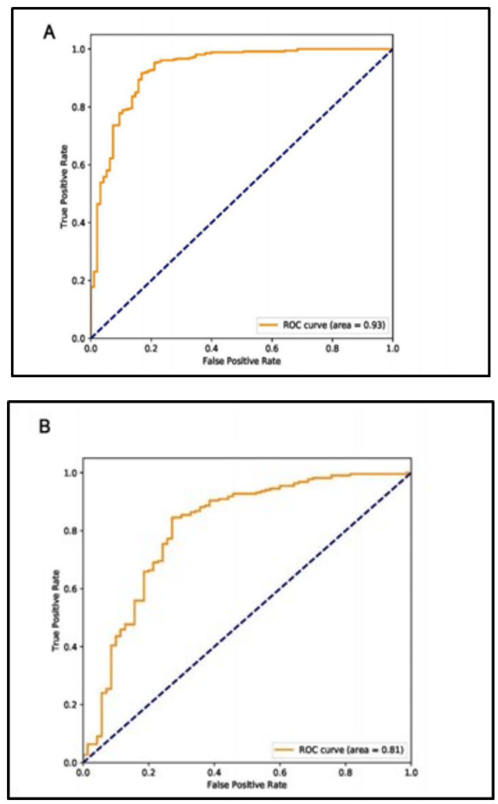

Figure 11 A & B. Training curves[8]

When compared to a radiologist the given deep learning model has far better accuracy as the radiologist could make the prediction of Covid-19 by eye recognition with an accuracy approximately 55% which very less compared to the deep neural network model developed. The model was also able to successfully distinguish between Covid-19 and other typical viral pneumonia.

The time for prediction of each case is 10 seconds, thus this can help in fast and early detection of Covid-19. Thus, this study shows how AI can be a powerful weapon to combat with the current pandemic.

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4. DISCUSSION

The existing AI technologies have been effective to an extent in combating the Covid-19 pandemic by offering speedy and efficient detection and meticulous predictions. As mentioned by Zifeng Yang et al. SEIR model was effective in predicting the epidemic peaks and sizes and compartmentalizing the population into four possible states: Susceptible [S],Exposed or latent [E], Infectious [I] or Removed [R] with the incorporation of the migration index. On the flip side, the utilization of LSTM model requires more time and memory to train and is easy to over fit. The SEIR model too has a limitation of being oversimplified, as it assumes that individual characteristics of immunity, susceptibility, and ability to recover, are essentially the same for all members of the population. Moreover, this model does not take into account those who have been diagnosed and are in quarantine.

Present day AI technology combined with CT detection platform is used in detection of corona virus positive patients and differentiating them from the healthy patients. U-net model is used for image segmentation which gives qualitatively better results, but learning may slow down in the middle layers of deeper models, so there is some risk of the network learning to ignore the layers where abstract features are represented.

In order to overcome the existing problems and further improve the technology in combating Covid-19 we can propose a model where we can do comparative study of various ML and DL algorithms on an already available dataset. We can use several ML algorithms such as Naïve Bayes Classifier, Random Forest, Support Vector Machine and other classification algorithms, we can also use various pre-existing CNN models. We can train them on already available dataset to classify an individual as Covid-19 positive or negative. The dataset can have following features of already existing or cured Covid-19 patients such as Age, medical history, travelling history etc based on which we can use the most appropriate features for training our models. Based on the performance metrics such as accuracy score, sensitivity, specificity, AUC ROC etc. we can decide the model which is best for predicting whether an individual is likely to be Covid-19 positive, this would help us in early detection of Covid-19 in an individual and would also help the doctors in quick testing and treating of the patients.Anymodelgivingaccuracyofmorethan80 %forthetestdatasetcouldbeusedforprediction.A model giving quick results will help in testing more number of individual in less time and will help the country to find the major hotspots and thus take quick action to stop the virus from spreading further.

Table 4. Competitive study of algorithms used in study

Algorithm	Dataset	Pros	Cons
1) SEIR and LSTM model [1]	2003 SARS epidemic data use for training the model.	• A confidence interval of 95% in predicting the number of cases on a particular day also taking in account whether interventions were delayed or were provided earlier. • Due to smaller incubation period used by LSTM model, a comprehensive fit can be observed between real and LSTM predicted values.	• Due to large incubation period used the SEIR model lagged in predicting the epidemic peak. • Diagnostic capacity was not taken as one of the parameters for prediction this would have resulted in predicting lesser than the real value.
2) U-net(for Image Segmentation) and RESNET-50(for Classification) [2]	50 abnormal thoracic CT scans (slice thickness, (5,7,8,9,10)mm) from China of patients that were diagnosed by a radiologist as suspicious for COVID-19 (from Jan-Feb 2020). Cases were annotated for each slice as normal (n=1036) VS abnormal (n=829)	• Corona Score helps in seeing the progress of the patient under treatment. • High accuracy score and high sensitivity and specificity shows that the model is very useful for classification of CT images as Covid-19 positive or negative.	• U-net model may slow down the learning in the middle layers of deeper models, so there is some risk of the network learning to ignore the layers where abstract features are represented. • Not taking CT images of other respiratory diseases in the training dataset may result in misclassification.

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3) Occlusion(predicting critical binding sites) and multi task deep learning model(to predict potential inhibitor) [6]	The amino acid sequences of the proteins were extracted from NCBI (NC_045512.2). The virus-specific dataset is achieved from GHDD-ailab.	• Successfully predict the affinity scores of 10 drugs which are under test. • Using occlusion the most critical binding site of the virus is successfully predicted	• First the 10 drugs have to be manually selected and then the model predicts for only 10 drugs, therefore the model can be improved to work with more number of drugs and even the manual selection should be replaced by an AI model. • The specificity for external validation is less.
4) Logistic Regression [7]	Four categories of diagnoses were chosen from the Clinical Classification Software Refined (CCSR) classification system. Patient's historical medical claims data was used to predict the likelihood that they will have an inpatient hospital stay.	• Logistic regression can be easily trained by making a simple dataset of features, based on the risk factors as described by Center for Disease Control (CDC).	• ROC –AUC for logistic regression is less and it doesn't give the best classification accuracy. • Feature selection not done properly which may be one of the reasons for less accuracy.
5) Gradient Boost Algorithm [7]	Four categories of diagnoses were chosen from the Clinical Classification Software Refined (CCSR) classification system. Patient's historical medical claims data was used to predict the likelihood that they will have an inpatient hospital stay.	• The ensemble approach of gradient boost tree is more robust and thereby increases the classification accuracy and area under the curve.	• The drawback of the ensemble models is that they are significantly more complex, however, "by hand" implementations of such models is impractical.

5. CONCLUSION

This study describes how AI has served to be an important tool in tackling this global pandemic and has helped improve the current situation. With the help of AI and the abundant data set made available, it is possible to predict the trend of this disease hence, enabling the respective governments to take precautions and other measures accordingly. With the development of various AI models and with the help of CT scan images, it is possible to differentiate between coronavirus and non-corona virus patients. Classification of covid 19 patients from the normal reports were made with greater accuracy using AI combined with image processing and deep learning techniques.

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