A Comparative Study of COVID-19 Detection Using Deep and Machine Learning Methods

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Abstract
Coronavirus disease 2019 (COVID-19) is a global pandemic that causes a very significant health risk. This pandemic has attracted the attention of artificial intelligence engineers and big data analysts. The sensitivity of the diagnostic test of COVID19 is limited because of irregularities in handling specimens in addition to other factors. Finding other methods of detecting the COVID-19 virus is very essential. Using the current advancement in computer technology is a way to achieve this goal. Using classification algorithms to detect the disease is a promising solution. Classifying computed tomography (CT) chest images into infected or normal requires gathering intensive amounts of data in addition to an innovative architecture of AI modules. In this paper, we evaluate and apply the deep learning method using the convolutional neural networks (CNN), in comparison with using a number of traditional machine learning algorithms such as SVM, KNN, and Random Forest for the same purpose. The results of the paper include the performance of each method, and compare their outcome, in order to find out the best method to be used in real cases detection. Our work represents a potential computer-aided diagnosis method for COVID19 in clinical practice. The results indicate that deep learning offers improved performance of precision, recall, and accuracy.

Keywords: *COVID-19; Coronavirus; Chest images; X-ray images; Deep learning; Machine learning.*

1. Introduction

The Coronavirus disease (COVID19) is considered to be a highly infectious disease. It is caused by severe acute respiratory syndrome coronavirus 2 (SARS− CoV− 2), which is a strain of coronavirus. It was recently discovered. The World Health Organization (WHO) declared it as a global pandemic on March 11, 2020. It poses a serious threat to human health worldwide, in addition to causing a large economic loss to the world [1]. The statistics of the WHO showed that as of 1st of October 2021, there have been 233,503,524 confirmed cases of COVID19, including 4,777,503 deaths were reported to WHO. As of 29 September 2021, a total of 6,143,369,655 vaccine doses have been administered [1]. The Wall Street banks have estimated that the losses caused by the COVID19 pandemic to the global economy may be more than $ 5.5 trillion over the next 2 years [2]. In this paper, we propose a new method of COVID-19 detection using CT chest images. We apply the deep learning method using the convolutional neural networks (CNN), in comparison with using a number of machine learning algorithms such as SVM for the same purpose. The used dataset in the training and testing process of the algorithms includes 1000 Chest X-ray images for infected cases, 1000 for normal cases, and 1000 for Lung Opacity. The results of the project will include the shows, the performance of each method, and compare their outcome, in order to recommend the best method to be used in real cases detection. The proposed method represents a potential computer− aided diagnosis method for COVID19 in clinical practice.

For laboratory confirmation of the COVID19 The WHO recommends using real-time reverse transcriptase− polymerase chain reaction (rRT-PCR) virus in respiratory specimens obtained by the preferred method of nasopharyngeal swabs. The Laboratories must strictly follow the WHO biosafety guidance in detection testing. They should also the standard operating procedures for collecting, storing, packaging, and transporting the specimens. But following these rules is not available in all cities and all cases, because some cities don't have enough medical facilities for such rules [1].

The clinical symptoms associated with COVID19 include fever, dry cough, dyspnea, and pneumonia, as described in the guideline released by the WHO. CHINA-WHO COVID19 joint investigation group reported by (February 28, 2020) that medical imaging of the lungs can be a good method to test for COVID19 infection. Chest computed tomography (CT) are available in most hospitals worldwide, and they are considered the most common medical imaging examinations for the lungs [3]. CT can be used to quickly evaluate the severity of pulmonary involvement in COVID19 patients. But the problem is the limited ability of radiologists to read CT scans timely. An alternative solution is needed. A lot of solutions based on Artificial Intelligence (AI) technologies recently were

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developed recently in order to improve the analysis workflow of CT scans to detect COVID19 infected cases. Inspired by these updates in the Covid19 crises, we are proposing a method to detect the infection using the analysis of Chest X-ray images. We apply image classification techniques using two main approaches. The first one is using deep learning methods especially convolutional neural networks (CNNs), the second is using a number of machine learning algorithms such as Support Vector Machines, Na.ve Bayes, Decision Trees, and others. We test each method using a large dataset consisting of 1000 Chest X-ray images for infected cases, 1000 for normal cases, and 1000 for Lung Opacity. Then we compare the outcome of each method and find the best way to detect the infection using the image classification technique. The spread of the covid19 virus in the world, and the new way of living that we were forced to adopt, such as the social distancing, in addition to the loss of lives, jobs, and freedom. All these things and others motivated us and other people to work hard in order to help in this severe pandemic. It motivated us to think of a solution that can play an important role in fighting this virus using science. We do not want this situation to last forever, that means everyone should work to help to end it with his her abilities. The proposed project has great value and significance. Because it can be used to save lives by the early and accurate detection of covid19 infection. That will help in preventing new infections, and thus stopping the spread of the virus. The main contributions of the paper are:

- Provide an alternative good method for detection of covid19 infection.
- Find out what is best to be used in this case, deep learning or machine learning.
- Expand the field of applying image processing technology to new uses such as healthcare systems.
- Become familiar with artificial intelligence methods including deep learning and machine learning techniques.
- Provide a helpful project for our community and our people.

2. Literature Review

Since the spread of the covid19 virus, a lot of researchers worked in the field of detecting the virus using different approaches. Ahammed et al. [4] proposed a technique to detect coronavirus cases using chest X-ray images and machine and deep learning using chest X-ray images. They used a dataset that was obtained from Kaggle and GitHub from the COVID19 Radiography Database. The final dataset consisted of 285 normal cases, 285 viral pneumonia cases, and 285 COVID19 cases. They used the Convolutional Neural Networks (CNN) for the deep learning experiment. The CNN results were accuracy (94.03%), f-measure (94.03%), sensitivity (94.03%) and specificity (97.01%). They also used machine learning algorithms such as (SVM [5]), (RF [6]), (kNN [7]), (LR [8]), Gaussian na.ve bayes (GNB [8]), Bernoulli naïve bayes (BNB [8]), (DT [9]), XgBoost (XGB [10]), multilayer perceptron (MLP [11]), nearest centroid (NC) [12]. Seven of these algorithms showed results greater than 90%. The best was XGB, but it was less than CNN. Horry et al. [13] used deep learning model families such as VGG, Inception, Xception, and Resnet [14] to detect the coronavirus cases in x-ray images. They used x-ray images and the final dataset contained 200 normal cases, 100 pneumonia cases, and 100 COVID19 cases. The best results came from VGG19 with up to 83% precision. Kassania et al. [15] had adopted a different approach in detecting infected cases. They used deep learning frameworks to extract features form Chest X-ray image, then fed the extracted features into several machine learning classifiers. The used deep convolutional neural networks were MobileNet, DenseNet, Xception, ResNet, InceptionV3, Inception ResNet V2, VGGNet, NASNet [16]. The used dataset contained 117 chest X-ray images and 20 CT images of COVID19 positive, in addition to 117 images of healthy cases of X-ray images and 20 images of healthy cases of CT images. They applied various machine learning algorithms such as Decision Tree [9], Random Forest [6], XGBoost [10],
AdaBoost [17], Bagging [18], and LightGBM [19]. The best performance came from using the DenseNet121 as a feature extractor and the Bagging tree as a classifier with 99% classification accuracy. Yasar and Ceylan [20] applied machine, and deep learning classifiers on CT lung images to detect convid19 infections. The used dataset contained 1.396 lung CT images in total (386 Covid19 and 1,010 non-Covid19). The used algorithms were CNN for deep learning, and k-Nearest Neighbors (kNN) and Support Vector Machine (SVM) for machine learning experiments. They applied two validation approaches, 2-fold cross-validation and 10-fold cross-validation. The best results of machine learning were with SVM classifier using 10-fold cross-validation, the results were accuracy=95.8%, F−1 score=92.3%, and mean sensitivity=91.7%. The results of deep learning CNN were slightly better than SVM results using 10-fold cross-validation, the results were accuracy=95.9%, F-1 score=92.8%, and mean sensitivity=94%. Jahid et al. [21] compared the results of different deep learning CNN models including V3, Xception, and ResNeXt models. The used dataset contained 6432 chest x-ray samples, where 5467 of them were used for training (1345 normal, 490 covid, and 3632 pneumonia) and 965 for
validation (238 normal, 86 covid, and 641 pneumonia). In the training set, In the validation phase, were considered for this analysis. The Xception model gave the best results compared to other models with accuracy (i.e., 97.97%).

Saha et al. [22] created a detection schema called EMCNet. This schema can identify COVID19 patients using their chest X-ray images. CNN was used in the model to extract deep and high-level features, then these features were fed into a number of machine learning classifiers (random forest, support vector machine, decision tree, and AdaBoost). The used dataset in the study contained a total of 4600 images, 2300 were normal cases and 2300 were covid19 cases. All the classifiers showed good results with values above 95%. But the best results were from AdaBoost classifier with 98.26% accuracy, 100% precision, 96.52% recall, and 98.22% F1-score.

3. Research Methodology

A. Collecting the dataset

The used dataset in this research contains 3000 chest X-ray images, divided into 1000 normal cases, 1000 lung opacity cases, and 1000 covid19 cases. The images were retrieved from Kaggle COVID-19 Radiography dataset [23]. The dataset was created by researchers from Qatar University, and the University of Dhaka, Bangladesh along with their collaborators from Pakistan and Malaysia. The original dataset includes 3616 covid19 positive cases along with 10,192 normal, 6012 lung opacity (non-covid lung infection) and 1345 viral pneumonia images [24], [25]. For our study, we only selected three types (normal, lung opacity, and covid19) with 1000 images for each type.

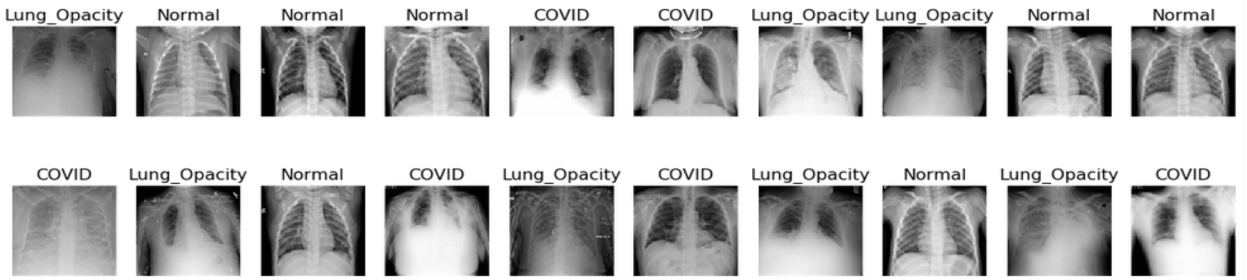

Fig. 1: Samples of Dataset [23].

B. Data preprocessing

The images in the dataset were divided into three groups according to their class (normal, lung opacity, and covid19) each group were stored in a folder with the name of their class. Then all the dimensions of the images were modified to have a standard size for all the dataset, the targeted size was 256*256. After that, the images became ready to be used in the training and testing.

C. Divide into training and testing

The dataset must be divided into two sets, one to be used in training the model, and the second to be used testing the model after training. We used 67% of the whole dataset to train the models, and the remaining 33% to test the trained models.

D. Build Deep learning model

In the deep learning experiment, we use the Convolutional Neural Networks (CNNs) (Figure 2.2), this algorithm has the benefits of neural training and the use of convolution operation in the image classification process. There are a number of variants of CNN architectures. The basic components of the CNN algorithm [26].

- The Input Layer: It has the image as pixel values.
- The Convolutional Layer: The purpose of this layer is to learn the feature representation of the images in the input layer, it consists of multiple convolution kernels that are used to compute different feature maps.
- The Pooling Layer: This layer usually is placed between two convolutional layers, its purpose is to reduce the resolution of the feature maps by down sampling along with spatial dimensionality [27], in order to reduce parameters within activation.
- The Fully-Connected Layers: It contain neurons of which are directly connected to the neurons in the two adjacent layers, without being connected to any layers within them. It is seen after several convolutional and pooling layers, which purpose is to perform high-level reasoning attempts in order to produce class scores from the activation, to be used for classification [28].

E. Preparing machine learning algorithms

In the machine learning experiment, we used multiple algorithms. They included Support Vector Machines [5], KNearest neighbors [7], Na.ve Bayes [8], Decision Trees [9], and Random Forest [6]. The algorithms were trained and tested on the same dataset used with the CNN algorithm. We used the sklearn library to prepare these algorithms with the correct parameters. The machine learning classifiers we used as follows:

- Naïve-Bayes (NB): The base of this classifier is the probabilistic Bayes' rule and is particularly suited when it's required to be applied on huge data. The main idea of the Na.ve Bayes classifier is that it assumes that on any given class the effect of features is independent of other predictors, this assumption reduces the complexity of the high dimensionality. Despite being simple and easy to construct, it is proved that it performs very well in many fields such as text classification and internet traffic identification [8].
- Support Vector Machine (SVM) is considered one of the most popular classification methods. It was introduced in 1995, and it's being used in various fields such as text classification, gene analysis and facial expression recognition. It can be seen as a method for constructing a linear classifier, that theoretically guarantees good predictive performance, which means high quality of unseen data classification. For this method, the theoretical foundation is given by statistical learning theory [5].
- K-Nearest Neighbor (KNN): In the trivial classifiers, they classify an object if its attributes match one of the training examples. In this method, many test records will not be. In k-nearest neighbor (kNN) classification, it searches the training set for a set of k objects that are the closest to the test object and assigns the predominance class label in this neighborhood [7].
- Decision Tree (DT) learning is a commonly used algorithm in automatic learning. The trees are composed of nodes, branches, and leaves. The nodes represent tests on attributes, branches represent the paths based on the values of the attributes, and the leaves represent the classification label. To predict a class for any attribute, a path needs to be traced from the root to a leaf node that has the class label. It's fast to construct and can be better accurate than other classification methods [9].
- Random Forests (RF) This classifier consists of a combination of tree predictors, each tree depends on random vector's values, which are sampled independently and have the same distribution for all trees in the forest. The generalization error for the forest depends on the strength of the individual trees and their correlation, and it converges as the forest becomes large. It is fast and easy to implement, has very accurate predictions, and can be used with large input variables without overfitting. It's considered one of the most accurate general-purpose learning techniques available [6].

F. Training

The training process includes using the images in the training set with each algorithm. The algorithm analyzes the images and finds the important features that can be used to identify each class of these images. Then these features will be used in the classification process.

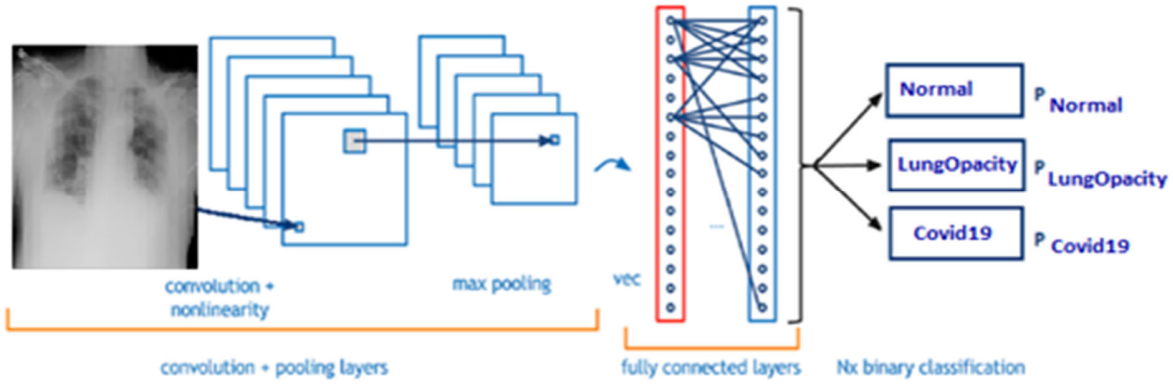

Fig. 2. The CNN algorithm.

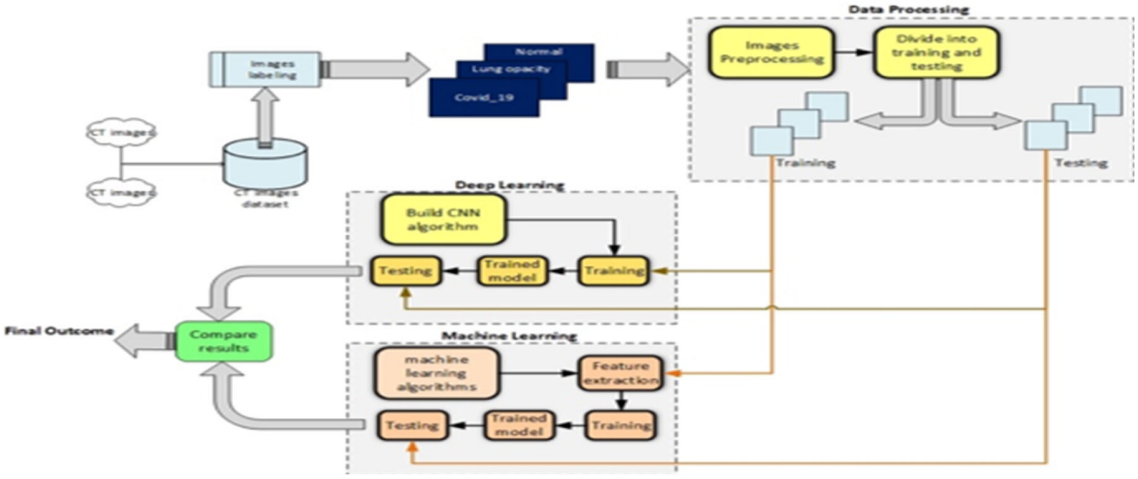

Fig. 3: Workflow of the experiments

G. Testing

The trained algorithms are evaluated in this stage by testing them on the images in the testing set. The classification results are compared with the real values to find the performance of each classifier.

H. Metrics used

The final results of each classifier are recorded to be used in comparing the algorithms. To measure the capability of classifiers, we used these evaluation metrics [29]: Accuracy: Accuracy will be used to refer to the ratio of images identified correctly compared to all images as a whole Precision is defined as true classifier covid19 images to total classified covid19 images. It can be obtained by equation 1.

$$Precision = \frac{TP}{TP+FP} \qquad (1)$$

where TP is true positive, and FP is false positive. Recall is defined as the ratio of correctly classified covid19 images in total actual covid19 images and it can be calculated as follow:

$$Recall = \frac{TP}{TP+FN} \qquad (2)$$

F-measure is the harmonic mean of precision and recall, and it can be calculated as follow:

$$F - measure = \frac{2*Precision*Recall}{Precision+Recall} \qquad (3)$$

I. Comparing results

In this phase, we compare the performance of each algorithm to find which method is better, deep or machine learning, and which algorithms are the best to be used in

4. Experiments and results

In this paper we present the results of each experiment. We conducted a number of experiments in both the machine and deep learning approaches. After this we compare the outcomes of each approach and show the final result of the research. The next figure shows the workflow of the done experiments.

A. Comparing results

In this experiment, we used five algorithms to classify the three types of images. The following figures show the results of each classifier. The results show the values of the accuracy, precision, recall and f-measure. The results of the experiment showed that the machine learning algorithms can be used in covid19 detection, but the results are not as required. Random Forest algorithm was the best algorithm, and it is the only one that reached 90% accuracy. The Na.ve Bayes has the worst results with 75.3% accuracy, which is not good to be used in critical thing like infection detection. The results of the other algorithms (KNN, SVC and DT) were not good enough to be used in the detection process.

The Random Forest algorithm has the best results, and most of the wrong predictions were between the covid19 and lung opacity. The results show that when it comes to classifying the normal CT, the accuracy reaches 94.5% (189 correct detections out of 200). The similarities between the covid19 and lung opacity CTs reduces the accuracy of the algorithms.

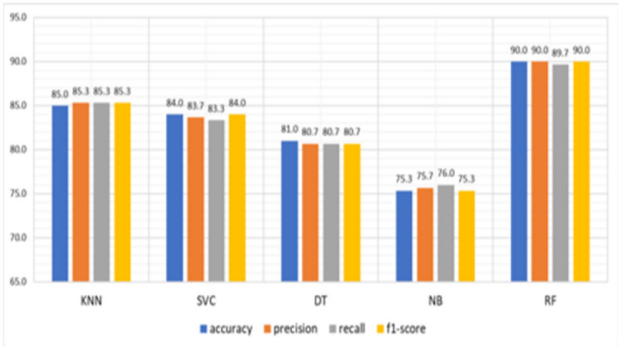

Fig. 4: The results of machine learning

B. The Deep learning experiments

In this part, we used the CNN algorithm to classify the images into different classes. we performed a number of experiments by changing the values of some parameters such as the number of convolutional layers, the dropout percent in each layer, the images dimensions, the test set percent and the used number of epochs. In the following Table I, we show the performed experiments with the parameters value of each one.

The results of the experiments are shown in Figures 5,6,7, 8, and 9. The results show that changing the parameters affects the results. We can see that increasing the number of layers to 8 layers in experiment 6 made the worst results where accuracy reached 54.8%. Also reducing the size of the images resulted in bad results as in experiment 9. Increasing the size of the images has good effect on the results, which means that larger images are better in classification process because it contains more features and more data to be processed. The best results were with the largest image size (256,256). Also, the increased number of epochs has a good effect on results, but increasing the epoch number causes much longer processing time that may reach many hours. The best results were in the first experiment which reached 94.5%. In Figure 8, we can see the change in accuracy with the increased number of epochs for the first experiment.

Table1: The details of each experiment

Experiment No.	Layers	Dropout	Image Size	Test Size	Epochs
Exp1	7	0.25	(256,256)	20 %	200
Exp2	6	0.25	(256,256)	30 %	200
Exp3	5	0.30	(256,256)	30 %	200
Exp4	7	0.30	(256,256)	30 %	200
Exp5	7	0.35	(256,256)	30 %	200
Exp6	8	0.30	(256,256)	30 %	200
Exp7	5	0.30	(128,128)	30 %	200
Exp8	3	0.20	(256,256)	20 %	200
Exp9	7	0.35	(64,64)	25 %	200
Exp10	3	0.10	(64,64)	20 %	200
Exp11	7	0.25	(128,128)	20 %	200
Exp12	1	0.20	(256,256)	20 %	200

C. Results Discussion

The two models have good results, but as we can see in Figure 9that the deep learning model has better results that all the machine learning algorithm. In the machine learning model, the Random Forest algorithm is the best classifier. But the results of the CNN algorithm in the deep learning model is better than the Random Forest algorithm. Which means that using the CNN algorithm is the best choice for detecting the covid19 infection using Chest X-ray images. CNN can uncover details that other algorithms would never notice, to determine the class of Chest X-ray image. That is the strength of a CNN. Other learning algorithms or models can also be used for image classification. CNN has emerged as the model of choice for multiple reasons. These include the multiple uses of the convolution operator in image processing, The CNN architecture implicitly combines the benefits obtained by a standard neural network training with the convolution operation to efficiently classify images. Further, being a neural network, the CNN is also scalable for large datasets, which is often the case when images are to be classified. CNN is really effective for image classification as the concept of dimensionality reduction suits the huge number of parameters.

5. Future Work

For a future improvement, the proposed models will be refined to further enhance accuracy. We are planning to use other deep learning models other that CNN model. Also, using images with higher accuracy and larger dimensions something that is expected to have better results with longer execution time, which is an experiment that we are willing to perform and find out the results.

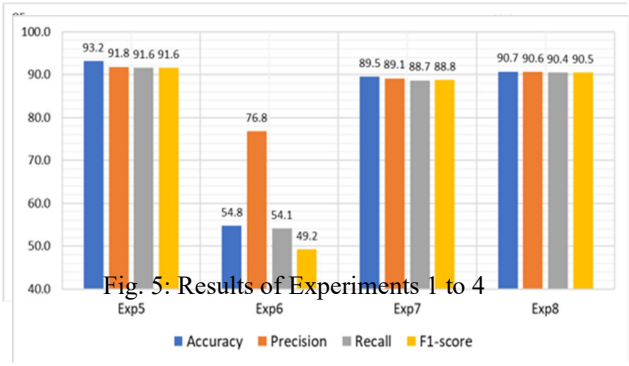

Fig. 5: Results of Experiments 1 to 4

Fig. 6: Results of Experiments 5 to 8

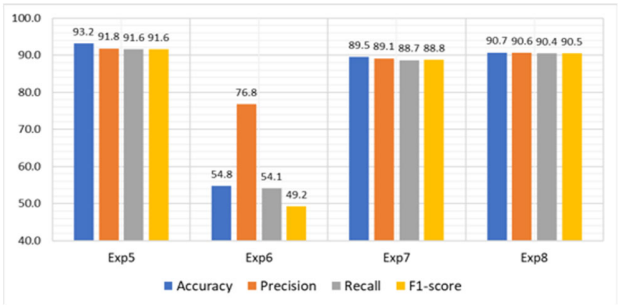

Fig. 7: Results of Experiments 9 to 12

6. Conclusion

The Coronavirus disease (COVID19) is considered to be a highly infectious disease. It poses a serious threat to human health worldwide, in addition to causing a large economic loss to the world. In this study, the prediction of COVID-19 outbreak was carried out with deep learning and machine learning models. Three different datasets were analyzed with 5 different machine learning algorithms and the CNN deep learning algorit8hm. In the first stage of the study, the data were preproces5sed and prepared for the learning models. and then it w3as divided into training and testing, after that it was used 7as inputs for the deep learning and machine learning mode3ls.

Later, classificati7on was carried out and the performances of the mod1els were measured with precision, recall, accuracy, and F1-scores. The best meaningful results observed from the deep learning model using CNN algorithm with accuracy of 94.5%, recall of 93.5%, precision 93.7% and F1-scores of 93.5%. the best results in the machine learning model were with the Random Forest algorithm with accuracy of 90%, recall of 89.7%, precision 90% and F1-scores of 90%.

Finally, the Chest X-ray images and other health informatics must be integrated to develop a more robust

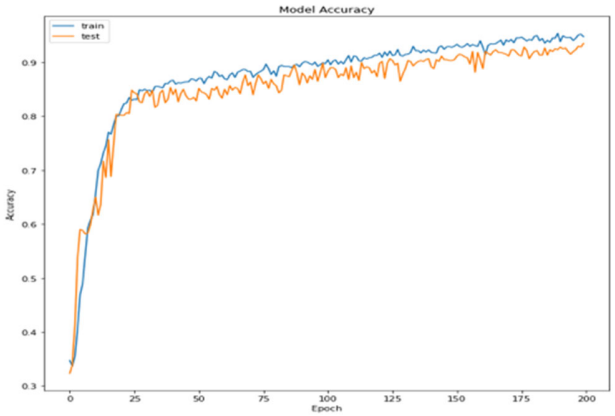

Fig. 8: Accuracy with increasing epoch number (Exp1)

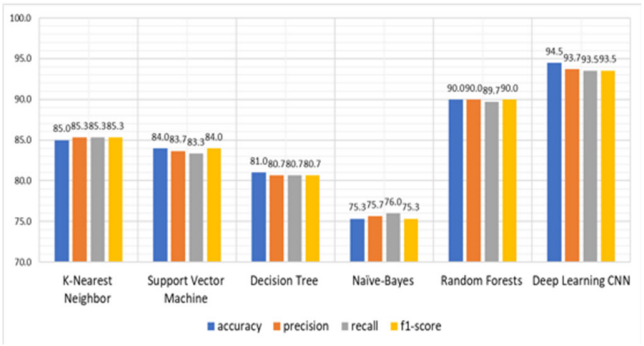

Fig. 9: The final results

detection models for efficient COVID-19 management covering containment, mitigation, identification, tracking as well as disease detection, diagnosis, and treatment. With our humanity and ability to exploit our technological advances, we will collectively defeat this scourge and use today's experiences to prepare for future similar battles when they come.

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