Detection of COVID-19 Using the CT Scan Image of Lungs

Ankita Bansal, Gaurav Thakur, and Devang Verma

Department of Information and Technology, Netaji Subhas University of Technology, Dwarka, New Delhi, India

Abstract. The virus causing coronavirus disease is transmitted through droplets that are released by an infected person when he/she coughs, sneezes, or exhales. People get infected by either breathing in the droplets through atmosphere if they are released by an infected person nearby or by touching a surface which has been contaminated by the virus. Most of the people who get infected suffer mild to moderate symptoms. However, people with severe symptoms develop acute respiratory distress syndrome (ARSD) characterized by rapid onset of inflammation in the lungs. It can cause serious conditions such as blood clots, multi-organ failures etc. to happen suddenly sometimes even leading to death of the patient. In other words, COVID-19 affects our lungs with adverse infection due to which a person is unable to breathe with decorum. The broad aim of this research paper is to study the CT scan images of patients infected from coronavirus and compare them to the CT scan images of patients which may be not be infected or may have normal pneumonia (i.e. not due to coronavirus). Further, the authors have devised models using Support Vector Machine and Convolutional Neural Network to differentiate between the CT scan images of coronavirus infected patients and the patients who are not infected.

Keywords: Coronavirus · Deep Learning · Thorax CT scan · ResNet-50 · VGG16 · SVM

1. Introduction

COVID-19 has taken the lives of more than a million people and infected more than 46 million people across 215 countries [worldometers.info/coronavirus/]. The most common symptoms include fatigue, dry cough, and fever, and less common symptoms include headache, conjunctivitis, diarrhea, sore throat, body aches/mild pain, smell, or loss of taste. While most people grow mild symptoms, while some develop Acute Respiratory Distress Syndrome (ARDS), which may lead to blood clots, septic shock, or multi organ failure. The incubation period may range from 1 to 14 days [1].

Due to the highly contagious nature of coronavirus, it is rapidly spreading among people who are making close contact with infected people. It out spreads with ease and sustainably through the air, via small droplets or particles such as aerosols, produced after an infected person talks, sings, sneezes, coughs, or via contaminated surfaces, like doorknobs, phones, hands, etc. [2].

The testing time for the SARS-CoV-2 virus in laboratories using real-time RT PCR [3] ranges from six to eight hours, this is excluding the time required to collect and deliver samples to the lab. Sometimes the results that have been generated by this test suffer from high false-negative rates after utilizing a lot of time. Many laboratories across the nation are not well equipped for testing the SARS-CoV-2 virus, currently, there are only 877 labs across the nation (240 private and 637 government) which are equipped for the same, thus creating a long queue of samples to be testing which further increases the time between collecting a sample and getting the results to the patient. Due to this time lag, the infected patient does not receive appropriate treatment on time and end up spreading COVID-19 to others.

ISIC'21: International Semantic Intelligence Conference, February 25-27, 2021, Delhi, India
EMAIL: ankita.bansal06@gmail.com (A. Bansal); gauravt.it.17@nsit.net.in; (G. Thankur), devangv.it.17@nsit.net.in (D.Verma)

Fig. 1. GGO marked with yellow arrow and Pleural effusion marked with red circle on the CT scan image of lungs of COVID-19 positive patient

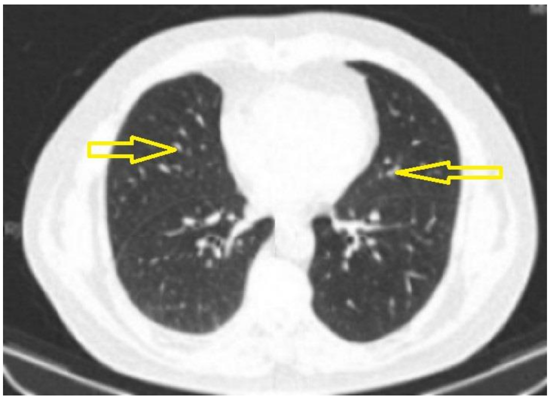

Fig. 2. GGO on the CT scan image of lungs of COVID-19 negative patient

Computer Tomography (CT) scan images used to detect SARS-CoV-2 based on infection spread in the lungs and compared to RT-PCR, CT scan only takes about 15 mins to generate images. The lung is the organ that is most commonly affected by COVID-19 and can result in adverse effects. Sometimes it leads to COVID-19 pneumonia, In the case of pneumonia, the infection causes initial damage to the small air sacs present in the lungs and makes the lungs to be filled with fluid/puss, making it hard for the patients to breathe. If the infection gets spread over a large volume of lungs, the human body starts struggling to absorb adequate oxygen to function properly and it causes severe difficulty in breathing. Patients are then admitted to the hospital to use ventilators for effortless breathing. If we take a look at the CT scan images of the lungs of the COVID-19 patient and a normal pneumonia patient we can see that initially white patches in both the images are quite similar but after few days white patches in the COVID-19 patient increases a lot which allows to distinguish between the lungs of a positive patient from the lungs of a patient suffering from normal pneumonia. These white patches are termed as Ground Glass Opacities (GGO) and the excess liquid which accumulates along the thin membranes of the lungs is called pleural effusion, as seen in the CT scan lung images of positive patients infected from coronavirus. For example, figure 1 shows GGO and Pleural effusion in the lungs of a COVID-19 positive patient, whereas, figure 2 shows the same in the lungs of a normal patient. We can see that there are lots of white patches in figure1 in contrast to figure 2. The GGO refers to an area of increased contraction in the lungs with preserved vascular and bronchioles. Thus GGO, pleural effusion, and consolidation are mainly found in patients who are suffering from COVID-19 pneumonia [4].

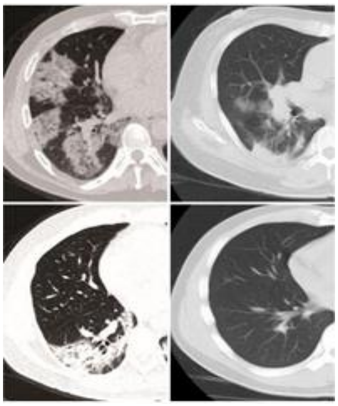

Fig. 3. Different Stages of SARS-CoV-2 infected Lung

From figure 3 we can see different stages of infection in the lungs, 1st lung (left top) has very large white patches of infection, while the 4th lung (right bottom) has almost no white patches. In 2nd lung (top right) pleural effusion can be seen and in 3rd lung (left bottom) GGO can be seen.

In this work, the authors aim to analyze the CT scan images of lungs of patients infected from COVID-19. In other words, in this work, these CT scan images act as input while training the machine learning classifiers. The GGO, pleural effusion, and lung consolidation present in the lungs of infected patients are the basis on which the authors will be differentiating between the two classes, viz. positive patients (patients who are infected with corona virus) and negative patients (patients who are not infected with corona virus). For the purpose of experimental validation, the authors have used SARS-CoV-2 CT-Scan Dataset [5] consisting of a total of 2481 CT scan images belonging to the patients of both the classes.

Deep learning has gained widespread popularity in various fields of medical science such as diagnosis of breast cancer, diagnosis of tuberculosis, identification of lung diseases and many more. The results have been promising which encourage more prediction and classification using deep learning in other fields of medical sciences as well. Thus, in this study, we have used models of Convolutional Neural Network (CNN) and Support Vector Machine (SVM) for identification of COVID-19 CT scan images. Two popular models of CNN have been used, viz. ResNet50 (a 50 layer deep CNN) [6] and VGG16 (a 16 layer deep CNN) [7].

We have observed that the models of CNN outperformed SVM by showing higher values of the performance measures.

This paper will help in improving covid-19 testing in hospitals. This will reduce the testing time as compared to RT-PCR testing which takes more than 6-8 hrs and the RT-PCR test also suffers from high false-negative rates after utilizing a lot of time. Due to this time lag, the infected patient does not receive appropriate treatment on time and end up spreading COVID-19 to others. CT scans are faster and CT scanners are readily available in almost all hospitals, thus helping to detect COVID-19 in earlier stages.

2. Related Work

Given the tremendous spread of COVID-19 in most of the countries of the world, it is an important upcoming field where research is going on to bring useful insights. In this section, we present recently applied techniques for detecting as well as segmenting the corona virus infection with the help of chest X-Ray and thorax CT scan images. We have gathered and noted down the related works where artificial intelligence has been used for the prediction and detection of infection using scans and X-rays of lungs as input.

The study by Rajinikanth's et al. (2020)[8] research, have implemented a machine learning based model using a support vector machine algorithm. They have used 500 images as their dataset and achieved more than 92% accuracy on SVM and their work will also help in determining the procedure of infection rate in the lungs. Another paper by Sharma (2020) [9] has proposed models based on Res-Net and Grad-Cam. In this paper, the author has used preprocessing techniques which are mainly based on Convolutional Neural Network (CNN) for enhancing or resizing the CT scan images of lungs. The author has also gathered the dataset from distinct hospitals and collected around 2200 CT scan images(800 of COVID-19 patients,600 are of other viral pneumonia and rest are of a healthy person) and achieved more than 91% accuracy on their model. The study by Narin et al. (2020)[10], has been implemented using CNN and has used image filters for sharpening the images like Sobel, Prewitt, Roberts. Their model has achieved an accuracy around 98.97% and 95.38% for X-Ray and CT scan images respectively. Similarly the authors Bai et al. (2020)[11] have implemented a model which is also based on Deep learning and their work is based on RT-PCR and CTSI. Their experimental findings showed sensitivity(93%) and specificity(100%) on 205 Non-COVID-19 and 219 COVID-19 pneumonia images. The study by researchers Khan et al. (2020)[10] has implemented a model based on Deep Neural Network to detect COVID-19 using X-ray images of the chest. Their work provided a classification accuracy of 89.5% on their model. The Study by Horry et al. (2020)[12] has used CNN based models (VGG19) on different types of images. They have used 3 different images (X-ray, CT scan, Ultrasound) and preprocessing techniques to remove noise from images. Their work provides an accuracy of 86% for X-Ray, 84% for CT scan, and 100% for Ultrasound. Ultra sound images provide better accuracy. The Study by Ardakani et al.(2020) has used different well-known CNN models on CT scan images of lungs. They have used 10 CNN models and achieved the highest accuracy on Resnet 101(99.51%).

Table 1. Summarization of the recent research on COVID-19

Study in literature	Model used	Preprocessing techniques used	Dataset	Findings
Rajinikanth et al.(2020)[8]	SVM With linear kernel	Firefly and Shannon's entropy based image threshold	500 lungs CT scan(250 of COVID & 250 normal)	Achieved accuracy >92%
Sharma. (2020)[9]	Their model is based on Grad-Cam and ResNet architecture	Image Pre processing Techniques, CNN based techniques to enhance images	2200 CT scan images which include 800 COVID-19 pneumonia images, 600 are of other viral pneumonia images and rest 800 are of a normal healthy person	Achieved 91% accuracy

Narin et al. (2020)[10]	They have used a simple configura tion of CNN Model	They have used sharpening filters like Roberts, Sobel, Scharr, Prewitt	The database consists of CT scan and X-Ray images which are available on the GitHub	Achieved accuracy of 98.97% & 95.38% for X-Ray and CT scan images
Bai et al. (2020)[11]	Used Deep Learning to develop model	Their work is based on RT PCR and CTSI for the examination	They have used 205 Non COVID-19 and 219 COVID-19 pneumonia case	Achieved sensitivity (93%), specificity(100%)
Khan et al. (2020)[12]	Used Deep Learning to develop model	Image pre processing techniques, reshape, resize	The dataset consisting of X-Ray images of chest available on github	Achieved accuracy of 89.50%

These studies have been summarized in table 1 in terms of various parameters like the models used, the preprocessing techniques used, the dataset used and the findings of the study. We can see from the survey that deep learning has been by researchers to identify COVID-19 in patients using CT scan images and have shown promising results. However, since, the results vary according to the dataset and the techniques used for classification under deep learning, more empirical evaluations and research is appreciated to draw significant and useful insights. Hence, the authors in this study have compared and evaluated two models of CNN and SVM to classify the CT scans images of lungs as the image of a COVID patient or healthy patient.

3. Research Methodology

In this part of section, we discuss the proposed method of implementation to detect SARS-CoV-2 infection using CT scan images of patients and compare different machine learning models and their results.

The methodology followed in this study to bring out the validation results is summarized as follows:

– Collecting all images and segregate them into different folders – Labeling and preprocessing the images
– Training the model and k-fold validation
– Testing model on unused test dataset
– Exporting model and its weights for further usage.

First, the CT scan of the top view of the chest (Thorax CT scan) of positive patients and negative patients are stored on the computer. We have used SARS-CoV-2 CT-Scan Dataset from Kaggle website [5], it consists of 1252 CT scan images of positive patients (infected from coronavirus) and 1229 CT scan images of negative patients (not infected from coronavirus). These CT scan images are the images of actual patients from multiple hospitals of Sao Paulo, Brazil.
GGO, pleural effusion, and lung consolidation are present in the lungs of coronavirus positive patients and are the basis on which we will be differentiating COVID-19 positive patients from COVID-19 negative patients or a healthy person. We labeled these images and saved them into a separate folder. These images are a mixture of greyscale, RGB, and RGBA images so they are converted into grayscale images and resized into 224x224 pixels along with Anti-Aliasing to reduce data loss in image and remove any visual distortions which might have occurred during resizing an image. These pre-processed images are stacked into a dataset and shuffled. Shuffling of training data aims to reduce variance and improve robustness to the model. Then the dataset is split into training and testing datasets, we split our dataset into an 80%-20% ratio, so the training dataset contains 1985

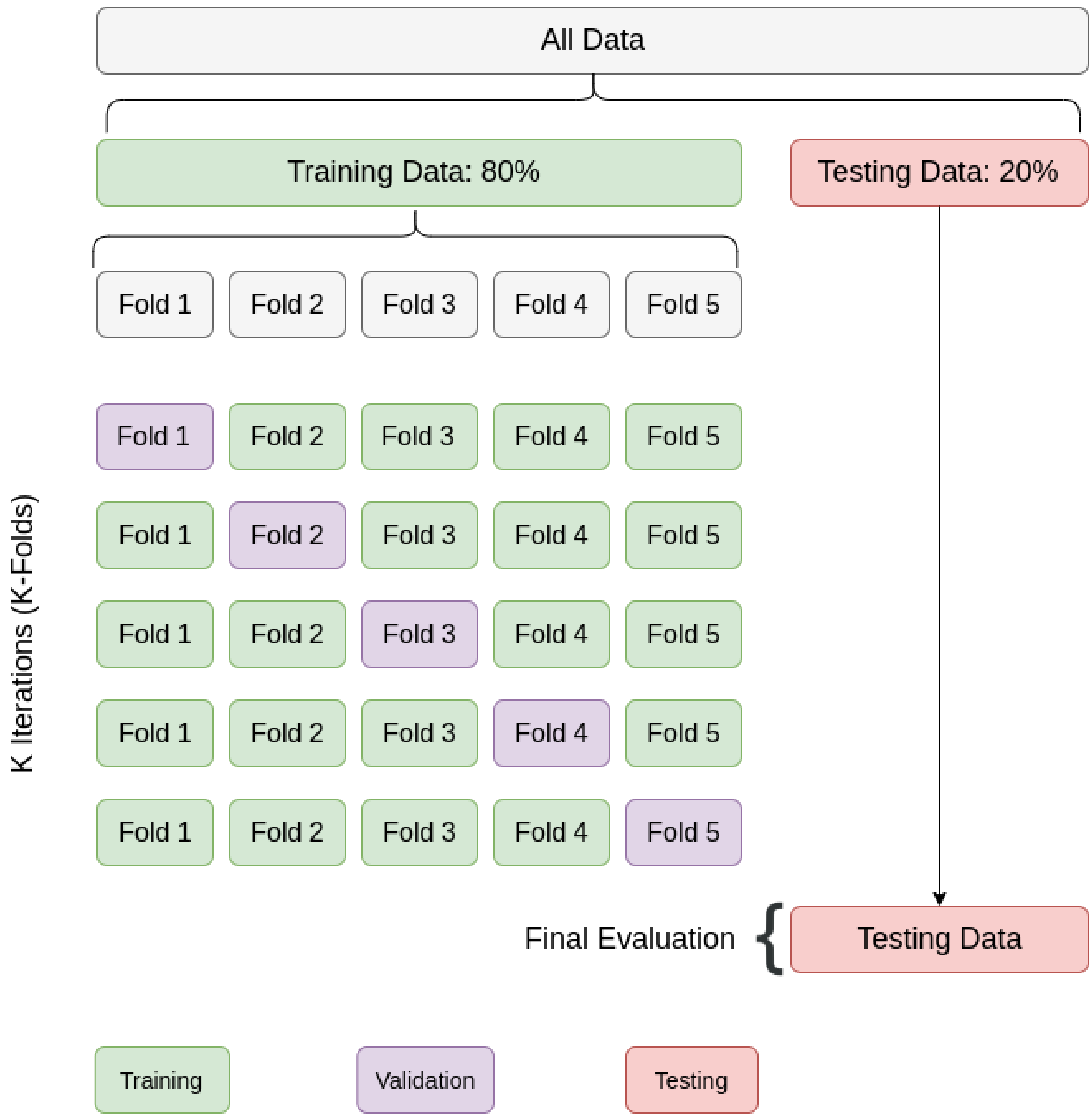

Fig. 4. K-Fold Validation

images and the testing dataset contains 496 images (figure 4). The testing dataset is kept aside for the final evaluation of the model and to obtain results, it is not used during the training of the models. During training our network, we split our training dataset into 5 equal parts for K-Fold validation, (where K=5) and have 5 iterations of training the model, where during each iteration of training a different part of the training dataset is used for validation. For training CNN's we have used a smaller learning rate of 1e-6 to allow the model to learn a more optimal or even globally optimal set of weights, on the downside, it takes a significantly longer time to train. Using a larger learning rate would maybe lead to faster learning but at the same time it may lead to sub optimal weights. To avoid over-fitting of training data we have used 50 epochs.

We are using Residual Neural Network architecture (ResNet-50, a 50 layer deep CNN), Visual Geometry Group architecture (VGG16, a 16 layer deep CNN), and Support Vector Machine, and we will be comparing them based on different parameters.

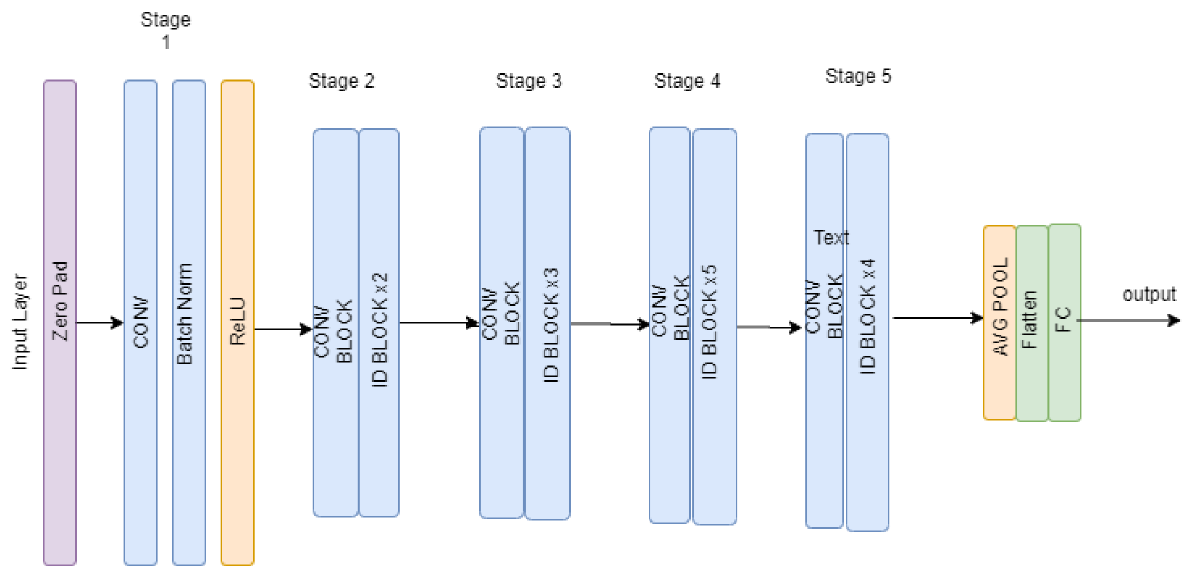

Fig. 5. ResNet-50 model summary

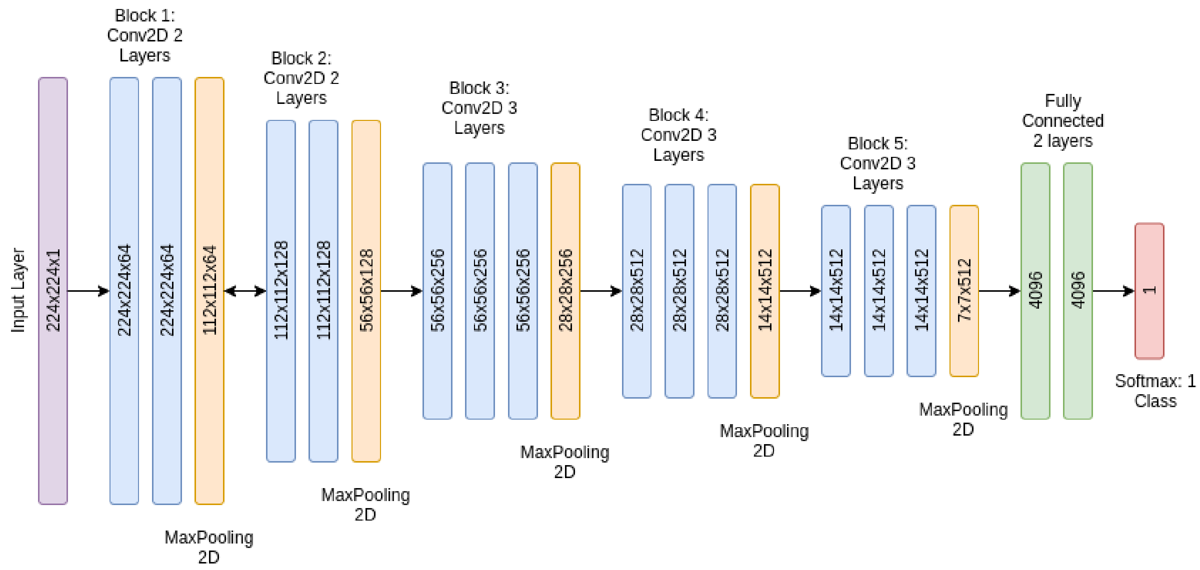

Fig. 6. VGG16 model summary

ResNet-50 (Figure 5) is a deep neural network that consists of 50 layers and is widely used for many computer vision tasks. ResNet was the winner of ImageNet Large Scale Visual Recognition Challenge (ILSVRC) in 2015. ResNets allow us to train deep neural networks with upto 150+ layers deep.

VGG16 (Figure 6), also known as OxfordNet is a deep neural network that consists of 16 layers and has over 138 million trainable parameters, named after the Visual Geometry Group from Oxford, who developed it. VGG's was used to win the ILSVRC (ImageNet) competition in 2014. It follows the structure of the convolution network and max pool layers repeated throughout the model. For the output, it has two fully connected layers having a sigmoid activation function.

Support Vector Machine comes under the category of machine learning algorithm which is based on finding a line/plane/hyperplane which divides the data points into their respective category (classes). For example, in the problem of binary classification, if the data is linearly separable, it finds a line which separates the data points on each side of the line based on their category. In other words, in a set of the training data, each data point is marked as belonging to one category or the other.

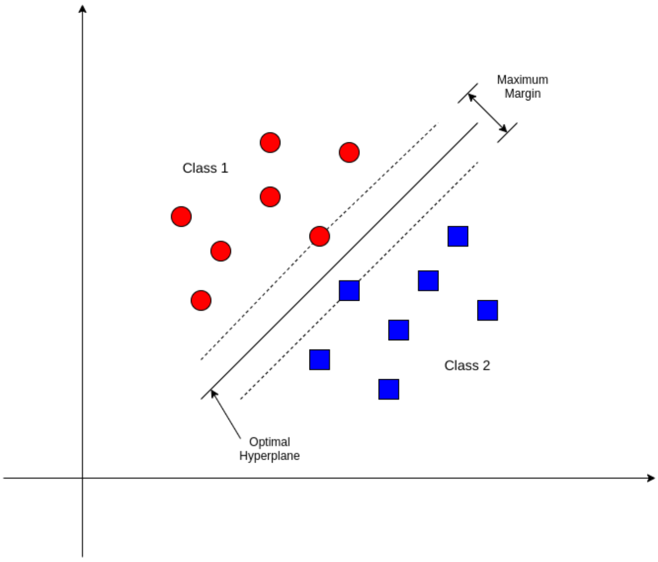

Fig. 7. Support Vector Machine summary

4. Results and Evaluation

In this part of section, we discuss the results of validation obtained using the three models. The dataset consists of 1252 CT scan images of SARS-CoV-2 positive patients and 1229 CT scan images of SARS-CoV-2 negative patients. For training and testing, we split our dataset into an 80-20 ratio, so the training set contains 1985 images and the testing set contains 496 images. For the purpose of training, we have used k-cross validation, where the value of k is taken as 5. We have used 4 performance measures, viz, accuracy, F1 score, recall and precision for validating the performance of the models. These are calculated using a confusion matrix.

The results in table 2 shows a comparison between 3 different models (Resnet 50, SVM, and VGG16). Using 4 performance measures, viz. accuracy, F1 score, recall and precision. ResNet-50 (a 50 layer deep CNN) achieved an accuracy of 95.16%, F1 score of 94.8%, recall of 95.63%, and precision almost 94.00%. SVM has achieved an accuracy of 87.29% which is a bit low as compared to the other 2 models, F1 score of 87.37%, recall around 89.00%, and precision of 85.82%. VGG16(a 16 layer deep CNN) we have achieved an accuracy of 95.76% which is the highest among models, F1 score of 95.38, recall 94.75%, and precision more than 96.00%. The Highest accuracy has been achieved by the VGG16 model 95.76% and ResNet-50 achieved 2nd highest accuracy of 95.16%.

To summarize the results, we discuss two important take-aways of this study:

1. We concluded that the CNN models outperformed SVM by depicting higher values of all the performance measures.
2. Amongst CNN modes, the VGG16 model outperformed the ResNet-50 model. VGG16 achieved an accuracy of 95.76% and F1 score of 95.38%, which is much higher when compared to other research work (as mentioned in the related work section).

Table 2. Evaluations of results

Model/Algorithm	Accuracy	F1 Score	Recall	Precision
ResNet-50	0.9516	0.9480	0.9563	0.9399
VGG16	0.9576	0.9538	0.9475	0.9601
SVM	0.8729	0.8737	0.8897	0.8582

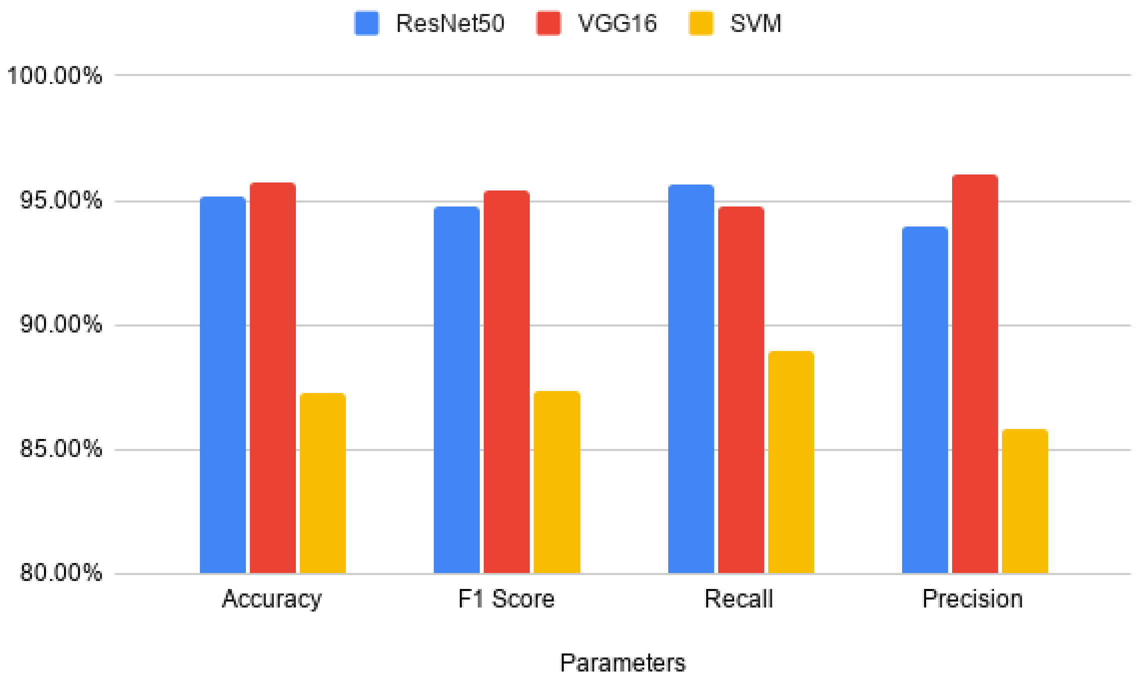

Fig. 8. Result Bar Graph (Scale: 80% - 100%)

Based on the substantial experimentations and the results, we suggest the following research directions:

1. Compared to real-time RT-PCR, machine learning methods on a lungs CT scan should be used as the first line of testing as it is much faster and cheaper.

2. We suggest that the researchers can use CNN models for accurate and effective identification of CT scan images as the image of COVID-19 or healthy patients. 3. Training and testing on high quality image datasets will further improve the accuracy of the model.

From the bar graph, as shown figure 8, it can be seen

that this shows a comparison between three models, and among these models, VGG16 has achieved the highest accuracy, F1 Score, and precision. ResNet-50 has achieved the second highest accuracy of 95.16% and highest recall. The least accurate model was SVM with 87.29%.

5. Conclusion

Coronavirus disease is a worldwide issue and has affected not only the lives of everyone but also the global economy. This paper aims to develop a reliable method to detect COVID-19 in patients using a lungs CT scan. These results from Machine Learning models and algorithms could help doctors in diagnosing patients and could save time compared to current testing mechanisms. We have observed that the models of CNN outperformed SVM by showing higher values of the performance measures. The results have been promising which encourages more prediction and classification using deep learning in other fields of medical sciences as well.

In future work, we can include differentiating between pneumonia caused due to COVID-19 and pneumonia of a healthy patients. We can build our deep learning network having a lesser number of CNN layers for faster training and also determine the severity of COVID-19 in patients based on infection spread in their lungs and associate a heuristic to its severity. Implementation of lung segmentation techniques and developing new models to detect COVID-19 in the early stages of infection by inducing self-bias to small GGO clusters. Developing new models using cluster algorithms, decision trees, or linear regression for classification.

References

[1] Guo, Y., Cao, Q., Hong, Z. et al. The origin, transmission and clinical therapies on coronavirus disease 2019 (COVID-19) outbreak – an update on the status. Military Med Res 7, 11 (2020).

[2] Q, Li., X, Guan., P, Wu., X, Wang., L, Zhou., Y, Tong., et al. Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. N Engl J Med. 2020.

[3] Real-time RT-PCR https://www.medmastery.com/guide/covid-19-clinical-guide/how-real-timereverse-transcription-polymerase-chain-reaction-rt-pcr.

[4] What Do 'Ground Glass Opacities' Mean in Lung Scans of COVID-19 Patients?, Meredith Health Group https://www.health.com/condition/infectiousdiseases/coronavirus/ground-glass-opacities-covid-19.

[5] SARS-CoV-2 Ct-Scan Dataset : https://www.kaggle.com/plameneduardo/sarscov2-ctscan-dataset.

[6] Mahajan, A. and Chaudhary, S., "Categorical Image Classification Based On Representational Deep Network (RESNET)," 2019 3rd International conference on Electronics, Communication and Aerospace Technology (ICECA), Coimbatore, India, 2019, pp. 327-330.

[7] Szegedy, C., Liu, W., Jia, Y., Sermanet, P., Reed, S., Anguelov, D., Erhan, D., Van houcke, V., and Rabinovich, V. Going deeper with convolutions. In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, pages 1–9,2015.

[8] Rajinikanth, V., Dey, N., Raj, A., Hassanien, A., Santosh, K., Raja, N. Harmony Search and Otsu based System for Coronavirus Disease (COVID-19) Detection using Lung CT Scan Images, 2020.

[9] Sharma, S., "Drawing insights from COVID-19-infected patients using CT scan images and machine learning techniques", Springer-Verlag GmbH Germany, part of Springer Nature 2020.

[10] Narin, A., Kaya, C., and Pamuk, Z., "Automatic detection of coronavirus dis ease (covid-19) using x-ray images and deep convolutional neural networks",arXiv preprint arXiv:2003.10849, 2020.

[11] Bai, H.X. et al. Performance of radiologists in differentiating COVID-19 from viral pneumonia on chest CT. Radiology 2020.

[12] Khan, A., Shah, J., Bhat, M., CoroNet: A Deep Neural Network for Detection and Diagnosis of Covid-19 from Chest X-ray Images, 2020.