COVID-19 Detection Using X-Ray Images

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Abstract- **The novel coronavirus (COVID-19), known as SARS-CoV-2 has affected many lives across the globe. It has affected the economy of multiple countries. The critical problem the world is facing apart from the invention of a vaccine is to detect the presence of coronavirus in the human body in the early stage to prevent further spreading of the virus. To detect the presence of coronavirus the need of tools for diagnosis increased at a fast pace. The diagnosis tool should be accurate, fast, automated and the overhead cost should be less.**

Recent advancement in the field of machine learning and especially deep learning helps to identify and classify patterns in medical images. From multiple medical pieces of research, researchers found out similar irregularities in covid-19 patients in the chest. By using X-ray images for detection we can reduce overhead costs of procedure and reduce the risk of infection which comes from manual diagnosis.

In this study, we have introduced "Covid-Light" a deep convolutional neural network for the detection of Covid-19 cases using chest x-rays. It is a binary classification model(0-NORMAL, 1-COVID). The model is trained on COVID-19 Radiography Dataset[31] and achieved the test accuracy of 98.86%.

I. INTRODUCTION

Fig. 1. An illustration of binary classifier "Covid-Light" is detecting the abnormalities in the x-ray images.(a) X-Ray of a normal healthy person and (b) X-Ray of Covid person where the abnormalities are observed in the red circle.

In this pandemic of COVID-19, people will continue to suffer until we receive the vaccine. A lot of scientific research is being done continuously. So, until we receive the vaccine testing should be done in an efficient and reliable way. The testing techniques should be fast and accurate.

Test analysis is often performed in automated, high-throughput, medical laboratories by medical laboratory scientists. Test samples can be obtained by various methods, including a nasopharyngeal swab, sputum (coughed up material), throat swabs, deep airway material collected via suction catheter or saliva.

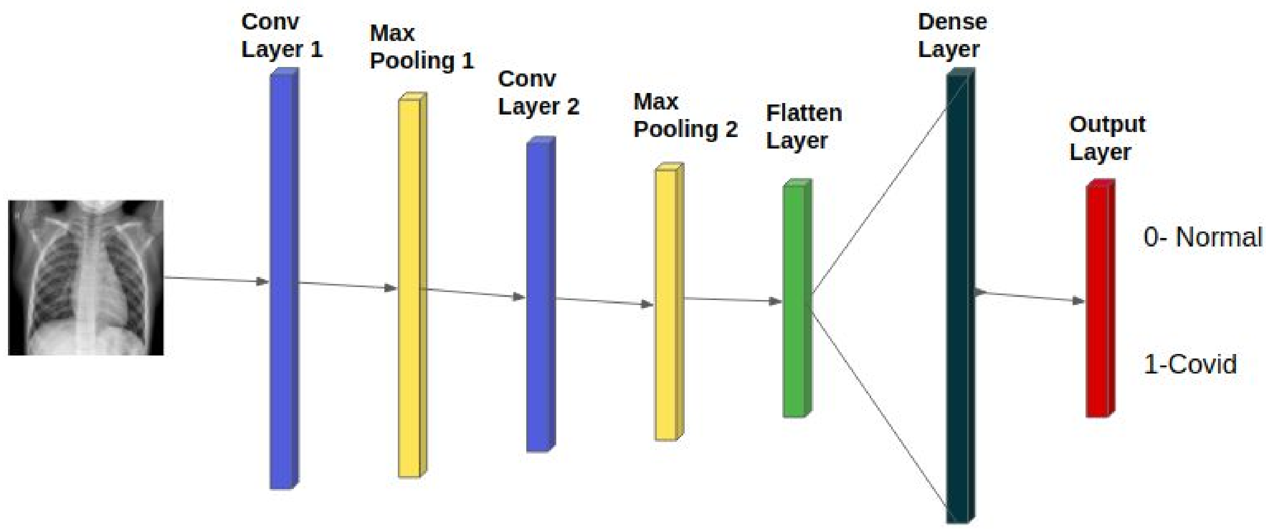

Fig 2. Complete Convolutional Neural Network Architecture(6 layers).

Reverse transcription polymerase chain reaction (RT-PCR) first uses reverse transcription to obtain DNA, followed by PCR to amplify that DNA, creating enough to be analyzed. RT-PCR can thereby detect SARS-CoV-2, which contains only RNA. The RT-PCR process generally requires a few hours.

This complete process from collection, testing and making of reports takes about a day. The situation is even worse at places that are not equipped with testing laboratories and the biggest problem is contamination of the equipment with which samples are taken.

After going through many articles the world demands a fast, reliable and secure way of testing. Here comes the role of Computer Vision, Machine Learning and especially Deep Learning as it is described as the state-of-the-art for all analysis of medical imaging and plays an important role. Recent studies and radiologists specify that the physical examination of the body shows the chest radiographs were found abnormal as it infects the respiratory system mainly. Studies also state that chest X-Rays are insensitive in the early stages of the disease. Further if quarantined the patient's X-Rays often reveals changes in the lungs. So, the above findings could be a green signal to make advancement in the field of computer vision, machine learning and deep learning as X-Ray images could help to detect the presence of Coronavirus.

Recent advancement in the field of machine learning and especially deep learning helps to identify and classify patterns in medical images. Similarly X-Rays were used to detect COVID-19 but the models are struggling to cope up with the accuracy, high false positive, high false negative rates and some of the models are not that accurate.

The main problem regarding the pandemic and to find a better solution is availability of large size dataset. Due to this problem if we train the large sized deep layers network they can result in overfitting or sometimes underfitting which results to degrade in accuracy of the predicting model.

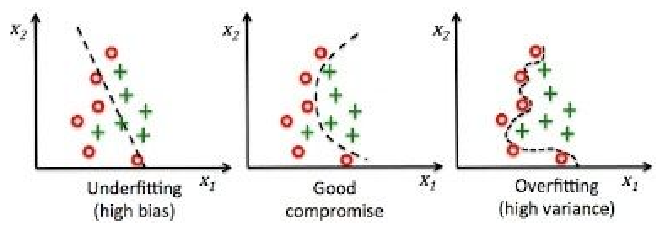

Fig. 2.(a) Underfitting, (b)Good fit and (c)Overfitting.

So, to overcome the above stated flaws we have proposed a light weighted CNN model with less number of layers, so the problem of overfitting or underfitting can be excluded after model training.

We have proposed a sequential model with 6 layers and less number of hidden layers (see Fig 2). This model overcomes the problems of small sized dataset, high false positive and high negative rates(FPR and FNR). Best of author knowledge the above implemented model has the best training and test accuracy of 99.31% and 98.86% respectively. It is 2 class based classification and is able to classify the images into 2 classes properly and accurately(0-NORMAL, 1-COVID).

Now, to make the implementation more scalable and user friendly the model is integrated with Flask based Web application.

This application can be integrated with the systems available in the laboratory. This complete process is not costly as all the laboratories are equipped with the mobile x-ray machines which can produce x-ray instantly and our application will classify the image into NORMAL or COVID. The presence of patchy and/or confluent, band-like ground glass opacity or consolidation in a peripheral and mid-to-lower lung zone distribution on a chest radiograph. Studies of chest also shows that lung shadowing goes to 69% (see Fig 1).

II. RELATED WORK IN THE AREA

A. COVID-Net: a tailored deep convolutional neural network design for detection of COVID-19 cases from chest X-ray images[21]

A deep learning Convolutional Neural Network based model named as COVID-Net which is one of the first open source network designs for COVID-19 detection from CXR images. The implementation has also generated an open access benchmark dataset consisting of 13,975 CXR images, which they call a large number of publicly available COVID-19 dataset. COVID-Net network architecture features are-

- COVID-19 sensitivity>=80%
- COVID-19 positive predictive value(PPV)>=80%

The model COVID-Net described above has the accuracy of 93.3%. Their future work is based on improving sensitivity and PPV to COVID-19 and propose a model to detect risk status and survival analysis.

B. CoroDet: A deep learning based classification for COVID-19 detection using chest X-ray images[23]

This study basically focuses on the latest data mining and machine learning techniques to overcome the shortage of testing kits. The current technique RT-PCR has a low sensitivity of 60%–70%, and it is also a time-consuming method The model CoroDet is applied on X-Ray and CT-Scan images of lungs for automated detection of COVID-19. Features of CoroDet are-

- The model consists of 22 layers of CNN.
- CoroDet is developed to find accurate results for 2 class classification (COVID and Normal), 3 class classification(COVID, Normal and pneumonia) and 4 class classification(COVID, Normal, viral pneumonia, and bacterial pneumonia).
- The classification accuracy of the above different class models are 99.1%, 94.2%, and 91.2%.

The accuracy of the proposed CoroDet method is higher than the state-of-the-art method for COVID detection.

C. Viral Pneumonia Screening on Chest X-rays Using Confidence-Aware Anomaly Detection[22]

The formulation of differentiating viral pneumonia from non-viral pneumonia and healthy controls. Moreover, when this model was directly tested on the X-Covid dataset that contains 106 COVID-19 cases and 107 normal cases and without fine-tuning this model achieves an AUC of 83.61% and sensitivity of 71.70%. The proposed CAAD model is composed of an anomaly detection network and a confidence prediction network. Both networks share a feature extractor. Given an input, the anomaly detection network aims to learn an anomaly scoring function ($\mathcal{V} = \mathcal{Q}(X;\theta,ɒ)$), where, ɒ is the trainable parameter of the anomaly detection module.
To evaluate the effectiveness of confidence prediction, we compared the anomaly detection network with the CAAD model, in which the confidence threshold Tconf ranges from 0.5 to 0.95.
The gradient-weighted class activation mapping is used to see which region plays an important role during inference.
Drawback of having false positive rate and high false negative rate.

D. Deep Learning in Medical Image Analysis[1]

The computer based analysis for better interpreting images have been in the medical imaging field. In the view of the image interpretation, recent advancement in the field of machine learning and especially deep learning has a support hand to identify and classify patterns in medical images. The hierarchical feature representations from the info , rather than handcrafted features mostly designed supported domain-specific knowledge, lies at the core of the advances. Deep Learning has proved to be the state-of-the-art in the field of image analysis in the terms of advancement of medical advancement. The decade has witnessed the importance of medical imaging e.g. computed tomography (CT), resonance (MR), positron emission tomography (PET), mammography, ultrasound, X-ray, and so on, for the first detection, diagnosis, and treatment of diseases. In real life the analysis of the medical images are done by the experts specially radiologists and physicians.
This paper has given overview of various deep learning techniques by giving explanation of DEEP
MODELS like:

1. Feed-forward neural networks, Deep Models.
2. Unsupervised feature representation learning-Stacked Auto-Encoder, Deep Belief Network, Deep Boltzmann Machine.
3. Fine-tuning deep models for target tasks.
4. Convolutional neural networks.
5. Reducing overfitting

The explanation gives a great overview how deep learning has advantage. It attracts researchers to work on this field of improving medical imaging to investigate CT, MRI, PET, and X-Ray, etc. The introduction about how deep learning can help in medical imaging for localization, cell structures detection, tissue segmentation, computer aided detection and diagnosis/prognosis.

- Completely explains the impact that computational modeling has on clinical applications and scientific research.
- After explaining the deep learning techniques to work on gives a great idea behind the state-of-the-art in the field of image analysis.
- It does not explain the working of all the techniques or models to interpret the model intuitively.

E. Finding COVID-19 from Chest X-rays using Deep Learning on a Small Dataset[2]

This paper describes the current testing technique by explaining that the tests require a significant amount of time to produce results with a 30% of false positive rates. COVID-19 has been an issue for everyone and affected each and every sector. The biggest problem is that testing demands testing tools and kits which are unable to match with the demand. X-Ray machines are widely available and provide images for diagnosis quickly. X-Ray tests can be performed without increased risk, unlike laboratory tests that involve probing the patient's respiratory system. This paper explains the usefulness of X-Ray images for the diagnosis.

Details of the dataset used:-

1. 135 chest X-Ray of COVID-19.
2. 320 chest X-Ray of viral and bacterial pneumonia.

A pre-trained deep convolutional neural network, Resnet50 was trained on 102 COVID-19 and 102 pneumonia samples in 10-fold cross validation. The model has an overall accuracy of 89.2% with a COVID-19 true positive rate of .8039 and an AUC of 0.95.

An ensemble of the three types of CNN classifiers(Resnet50, VGG and other CNN models) was applied to a test set of 33 unseen COVID-19 and 218 pneumonia cases. The overall accuracy was 91.24% with the true positive rate for COVID-19 of 0.7879 with 6.88% false positives for a true negative rate of 0.9312 and AUC of 0.94. In this model the last layer has been removed and replaced by a trainable part which consists of global average pooling followed by a fully connected layer of 64 units with dropout and finally a classification layer with sigmoid function.

- This paper provides the information of the models used and other hybrid models.
- It also has a comparative study about the CT scan and X-Ray images findings.
- Proper explanation of how the false positive rate can be decreased is also mentioned.
- 6% of false positive rate which is not feasible to make the model for real time use.
- Dataset size is small which is the biggest disadvantage the model faced while training.

F. Convolutional neural networks for multi-class brain disease detection using MRI images[3]

This paper is based on the classification of brain diseases using MRI images. It is difficult for the manual diagnosis of the brain abnormalities as it is difficult to observe the minute changes in the MRI images in the early stages. The challenging task is to select the features and classifiers to obtain the high performance. Hence, deep learning models have been widely used for medical image analysis over the past few years.

The work proposed is related to employing many pre-trained models like AlexNet, Vgg-16, ResNet-18, ResNet-34 and ResNet-50 to classify MRI images into normal, cerebrovascular, neoplastic, degenerative, and inflammatory diseases classes.

Here again the state-of-the-art is described as deep learning transfer learning models. Among all the above five models ResNet50 wins with the accuracy of 95.23% ± 0.6. They confirm that their model is ready to be tested with real time MRI images to detect abnormalities.

The main problem has been highlighted here about the availability of the labelled data. Previous studies in the literature had to deal with feature extraction, and this arises performance and accuracy drawback for the developed hybrid solutions. Both the above problems can be solved by using pre-trained models as they already know how to classify the data fed.

Their contribution is that being the first study which involves five brain classes: degenerative disease, inflammatory disease, cerebrovascular disease, neoplastic disease, and normal class and they almost doubled the number of images used(1074 images).

They used 2 major steps to train the model with MRI images:

1. They have only trained the attached few layers of the models for 15 epochs and set the learning rate hyper-parameter to the value of 1e-3.They fine-tune both convolutional base and fully connected layers by unfreezing all layers.
2. Fine-tuning term is used to unfreeze all the layers of pre-trained models. In other words, initially, only the attached layers of pre-trained models are trained for 15 epochs, then the whole network is unfreezed to re-train all layers.

The model presented in the paper has an accuracy of 95.23% ± 0.6 with MRI images.

The model is classifying into normal, cerebrovascular, neoplastic, degenerative, and inflammatory diseases classes with such great accuracy.
The main problem is the lack of availability of labelled data.

G. COVID-19 detection from chest X-Ray images using Deep Learning and Convolutional Neural Networks[4]

This paper tells about the state-of-the-art that pre-trained convolutional neural networks were evaluated as of their ability to detect infected patients from chest X-Ray images. due to the tiny number of samples, they used transfer learning, which transfers knowledge extracted by pre-trained models to the models to the model to be trained. A dataset consisting of 336 X-Ray images was created by mixing available X-ray images from patients with confirmed COVID-19 disease, common bacterial pneumonia and healthy individuals. The experimental results demonstrate that the classification performance can reach an accuracy of 95% for the simplest two models.
The proposed model during this paper incorporates an outsized number of CNN architectures in an effort to not only distinguish X-Rays between COVID-19 patients and other people without the disease, but also find the pneumonia patients. The model is totally a classifier for respiratory diseases.
A brief description about Deep learning approaches for COVID-19 detection supported image classification is introduced. The proposed CNN model is predicated on pre-trained transfer models (ResNet50, InceptionV3 and Inception-ResNetV2). In terms of getting high accuracy from the tiny dataset sample of X-ray images a transfer learning technique is applied by employing the ImageNet dataset. The result after training and testing was that ResNet50 was found to be superior.
The ResNet18 pre-trained ImageNet network is used and the results showed an accuracy of 95.12% on CXR images. A deep convolutional neural network called COVID-Net showed a high sensitivity (87.1%) and a precision of 96.4% for COVID-19 cases.
The results demonstrated a robust correlation between estimated uncertainty in prediction and classification accuracy, thus enabling false predictions identification. Finally, after the evaluation of the performance of 5 pre-trained CNN networks regarding the detection of COVID-19 from CXR. The results showed that VGG19 and MobileNetv2 achieved the higher accuracy, 93.48% and 92.85% respectively.

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H. Detection of coronavirus Disease (COVID-19) based on Deep Features[5]

This research paper states the implementation of SVM classifier. The suggested classification model, i.e. resnet50 plus SVM achieved accuracy, FPR, F1 score, MCC and Kappa are 95.38%,95.52%, 91.41% and 90.76% respectively for detecting COVID-19 (ignoring SARS, MERS and ARDS). It also states that the model is superior compared to other classification models. The dataset is collected from various resources like Github, Kaggle and Open-i in the form of X-Ray images. The model is based on deep CNNs for the identification of COVID-19 as a classification task.
They prepared two dataset first 25 X-Ray COVID-19 images from Github and Kaggle and the second contains 133 X-Ray images from Open-i. These two dataset are examined separately and the features were extracted based on deep learning architectures such as AlexNet, VGG16, VGG19, GoogleNet, ResNet18, ResNet50, ResNet101, InceptionV3, InceptionResNetV2, DenseNet201 and XceptionNet. The deep features obtained are classified by SVM.
The deep features are extracted from fully connected layers and fed to the classifier for training purposes. The deep features obtained from each CNN network are used by SVM classifiers.
Discussing the results ResNet50 with SVM gives the highest accuracy of 95.38% and in terms of F1 Score, MCC and Kappa, again stands apart from others. Hence, resnet50 and SVM result in better classification for detection of COVID-19 with accuracy, FPR, F1 score, MCC and Kappa are 95.38%,95.52%, 91.41% and 90.76% respectively.
ResNet50 with SVM gives the highest accuracy of 95.38%.
Other characteristics that show great results such as FPR, F1 score, MCC and Kappa are 95.38%,95.52%, 91.41% and 90.76% respectively.
The models are suffering from a small size dataset.

I. CovidAID: COVID-19 Detection Using Chest X-Ray[12]

As the number of cases is rapidly increasing day by day and with the limited testing kit for diagnosis, it is impossible for every patient with respiratory illness to be tested using conventional techniques, as conventional techniques take more time for diagnosis it is difficult to give faster results. In this work, we proposed the use of chest X-Ray to detect COVID-19 infection as this will help quarantine high-risk patients which have

COVID-19 infection detected in their chest X-Ray as X-Ray machines are easily accessible in many hospitals. We can prioritize the selection of patients by the use of chest X-Ray to decide whether to keep the patient in the ward along with other patients or isolate them in COVID-19 areas.CheXNet is a 121-layer DenseNet based model trained on the Chest X-ray14 dataset comprising of 112,120 frontal-view chest X-Ray images which can classify into the following classes: Normal, Bacterial Pneumonia, Viral Pneumonia and COVID-19. Our model is trained in two divisions, the one which classifies into the above four classes, and the other configuration with three classes (clubbing viral and bacterial pneumonia into one).Our model gives 90.5% accuracy with covid-chestxray-dataset.

X-ray imaging is much more widespread and cost effective than conventional diagnostic tests.

J. Classification of COVID-19 in chest X-ray images using DeTraC deep convolutional neural network[15]

Chest X-ray is the first imaging technique that plays an important role within the diagnosis of COVID-19 disease. CNN architecture is one of the only deep learning approaches as its ability to seek out out features automatically from domain-specific images. to train CNN architecture the favored strategy is transfer learned knowledge from a pre-trained network. Three major scenarios to accomplish Transfer Learning-

- shallow tuning
- deep tuning
- fine-tuning

This paper uses Decompose, Transfer, and Compose (DeTraC), for the classification of COVID-19 chest X-ray images. The DeTraC model consists of three phases. To extract deep local features from each image we train the pre-trained CNN model of DeTraC.For simplification of local structure we apply the class-decomposition layer of DeTraC.We use a category composition layer to refine the last word classification of the photographs. The dataset used consists of 80 samples of normal CXR images.CXR images which contain 105 and 11 samples of COVID-19 and SARS.

High accuracy of 93.1% (with a sensitivity of 100%) was achieved by DeTraC within the detection of COVID-19 X-ray imagesDeTraC can affect any irregularities within the image dataset by investigating its class boundaries using a class decomposition mechanism.Validating the method with larger datasets isn't possible.

K. Unveiling COVID-19 from Chest X-ray with deep learning: a hurdles race with small data[11]

In this work, possible obstacles have been highlighted in successfully training a deep model, ranging from the proper choice of the architecture to-be-trained to handling removable biases in medical datasets. The model consists of certain phases. First pre-processing of chest images and lung segmentation will help in removing any bias present in the data. Deep models will be Pre-trained on the feature extractor.

Extensive experiments show that extracting a “COVID” feature from CXR isn't a simple task. Such a problem should be addressed very carefully: it's very easy to misinterpret excellent results on test-data, still showing poor generalization on new data within the same domain. Such a test can be performed thanks to the possibility of using CORDA, a larger dataset comprising COVID cases. Of course, the quantity of available data is still limited but allowed us to find some promising seminal classification results. The ongoing collection and sharing of an outsized amount of CXR data is the only way to further investigate if promising CNN results can aid within the fight to COVID pandemic.

- The only way introduced in the paper is through CXR with CNN.

L. A Critic Evaluation of Methods for COVID-19 Automatic Detection from X-Ray Images[13]

In this research paper two experiments were conducted in both cases our training and test sets consist in combinations of the four datasets - NIH dataset, CHE dataset, KAG dataset, COV dataset. In this paper,different testing protocols used for automatic COVID-19 diagnosis are compared and evaluated from X-Ray images in the recent literature. Which shows that similar results can be obtained using X-Ray images that do not contain most of the lungs. The lungs are removed from the pictures by turning to black the middle of the X-Ray scan and training our classifiers only on the outer part of the pictures.

Dataset used:

1. NIH dataset
2. CHE dataset
3. COV dataset

Hence, it is deduced that several testing protocols for the recognition are not fair and that the neural networks are learning patterns in the dataset that are not correlated to the presence of COVID-19. The validity of the usual testing protocols is discussed in this paper as most papers dealing with the automatic diagnosis of COVID-19. This paper showed that these protocols might be biased and learn to predict features that depend more on the source dataset than they do on the relevant medical information.

M. COVID-19 detection from chest X-ray images using CNNs models: Further evidence from Deep Transfer Learning[14]

The paper describes reducing COVID-19 spread around the world by bringing early diagnosis of the novel coronavirus can be really helpful with the help of detection of COVID-19 infection from chest X-ray images using Deep Learning. Details of the dataset used:

Split	COVID-19	Healthy	Pneumonia
Training set	247	799	1598
Testing set	62	201	402

Due to the small dataset it is tough to train CNN models from scratch, so they've proposed a deep transfer method in this study as it can extract features learned on one problem and can use them on a new one. To make the model ideal for feature extraction, they have not included the classification layers at the top and create a new classifier and add it at top of the model. At last before training they froze the convolutional base.

N. Comparative study on the clinical features of the coronavirus 2019 pneumonia with other pneumonia[6]

This paper provided a study between covid-19 pneumonia and non-covid-19 pneumonia patients, All patients had a history of exposure to COVID-19 patients or travelled back from Hubei before their illness. Similar symptoms were presented by both groups of patients including fever and cough, these symptoms are also common in other acute respiratory infections, such as influenza, respiratory syncytial virus, and other respiratory viruses as well.
Most COVID-19 patients but non-COVID-19 patients had bilateral pneumonia with the feature of multiple mottling and ground-glass opacity on CT images. This result suggests that COVID-19 infection has similar features with many other respiratory virus infections, triggered a strong innate inflammatory immune response, and caused depletion of lymphocytes after infection. The ratio of the mean of neutrophils was more in COVID-19 than in non-COVID-19 patients, although there was no statistical difference between them. Previous studies show that high neutrophils contribute to acute lung damage, and are associated with severe disease in patients with influenza infection. Previous reports showed that a proportion of COVID-19 patients had differing degrees of liver function abnormality. The results suggested that patients with COVID-19 may have multiple tissue or organ damage besides a liver injury.

- Patients with Covid-19 patients showed similar abnormalities in other acute respiratory infections.
- Although they slighter higher neutrophils which contributed to other severe diseases in patients with other influenza diseases.
- The limitations of this research was lack of data.
- Some laboratory tests were not conducted in some patients because the COVID-19 patients were from 2 hospitals.
- There was a lack of severe infection to compare findings with severe infection with mild infection
- There was a lack of a pediatric population.

O. Efficient Pneumonia Detection in Chest X Ray Images Using Deep Transfer Learning[7]

This paper described how CT scans can be utilised to diagnose Covid-19 in early stages, the paper also describes the best comparative study between multiple implementations. As the dataset was very less so using data augmentation techniques, a larger dataset was created. The chest x-ray images were passed through the process of scan line optimization such that it eliminates all the other body parts.
Multiple existing models are taken into consideration including Dense CNN, GoogleNet121, ResNet etc.
Following architecture was discussed:

- **Transfer learning:** In transfer learning, a model that is trained for a particular task is employed as the starting point for solving another problem.
- **Data Augmentation:** Duplicating dataset to make sure the model doesn't overfit.
- **Fine tuning the architecture:** SGD(Stochastic Gradient Optimizer) was used to provide better generalisation and models were trained for 25 epochs.
- On multiple implementations, it was turned that all models had 99% or more accuracy and 0.03% except the Xception model.
- DenseNet121 turned out to be best among, but using a single model wasn't able to solve the problem completely.
- A weighted matrix was used with multiple models, resulting in each model contributing to 97% accuracy with 0.087% loss.
- Weighted matrix results outweighed others in confusion matrix.
- Following analysis shows that using a deep learning model can provide faster diagnosis.

P. A Deep Learning System to Screen Novel Coronavirus Disease 2019 Pneumonia[8]

This paper described Covid-19 detection from pneumonia using CT scans. CT scans were routinely performed on every patient with fever and respiratory symptoms in the early stage and was repeated for dynamic observation since it was cheap and easy to operate. Using CT images to screen patients can improve the early detection of COVID-19, and ease the pressure on laboratory nucleic acid testing.
The CT imaging of COVID-19 presents several distinct features, according to past studies. These features include focal ground-glass shadows mainly distributed along the pleura, multiple consolidation shadows accompanied by the “halo sign” of the surrounding ground-glass shadow, multiple consolidations of different sizes, and grid-shaped high-density shadows.In this study, deep learning technology was used to design a classification network for distinguishing COVID-19 from IAVP. In terms of the network structure, the classical ResNet was used for feature extraction. A comparison was made between models with and without an added location-attention mechanism. The experiment showed that the aforementioned mechanism could better distinguish COVID-19 cases from others. Furthermore, multiple enhancement methods were involved in our studies, such as image patch vote and Noisy-OR Bayesian function, in order to determine the dominating infection types. Models with a location-attention mechanism can classify COVID-19, IAVP, and healthy cases with an overall accuracy rate of 86.7%, and would be a promising supplementary diagnostic method for frontline clinical doctors.

- Covid-19 infected patients showed various abnormalities in lungs including ground glass opacities or mixed ground glass opacities.
- ResNet120 + SVM showed better accuracy than other models.
- The following implementations had some weakness, which includes that it doesn’t work properly in blurry images or images where patients had other infectious diseases as well.
- The overall accuracy turned out to be 86.7% for CT scans.

Q. COVIDX-Net: A Framework of Deep Learning Classifiers to Diagnose COVID-19 in X-Ray Images[9]

This paper discusses the disadvantages of using CT scans to detect Covid-19 in patients and how X-ray images can be utilised to detect Covid-19 in real time.
The main disadvantage of using CT scans is the higher risk of ionization and cost. But X-ray images cannot easily distinguish soft tissue with a poor contrast to limit the exposure dose to the patients.
To overcome these limitations, Computer-Aided Diagnosis systems have been developed to assist physicians to automatically detect and quantify suspected diseases of vital organs in X-ray images and in recent years.
The paper aims to develop a new framework COVIDX-Net which utilises multiple existing implementations to provide a generalised solution for detecting the virus.

The proposed framework includes three main steps to accomplish the requirements:

- **Preprocessing** : All X-ray images have been collected in one dataset and loaded for scaling at a fixed size of 224 X 224 pixels to be suitable for further processing within the deep learning pipeline.
- **Training model and validation** : In order to start the training phase of selected and/or tuned one of seven deep learning models, the preprocessed dataset is 80-20 split according to the Pareto principle.
- **Classification** : In the final step of the proposed framework, the testing data is fed to the tuned deep learning classifier to categorize all the image patches into one of two cases: confirmed positive COVID-19 or normal case (negative COVID-19).

Using X-ray images is more feasible than CT scans. Most existing models fail when it comes to detecting normal cases properly.The highest precision of deep learning classifier to detect only positive COVID-19 was achieved by ResNetV2, InceptionResNetV2, Xception, and MobileNetV2, but their corresponding performances were worst to classify the normal cases correctly.

VGG19 and DenseNet201 models to be applied for in the CAD systems to identify the health status of patients against the COVID-19 in X-ray images.

R. Imaging Profile of the COVID-19 Infection: Radiologic Findings and Literature Review[10]

This paper describes various findings in covid-19 patients from Shenzhen and Hong Kong.
All patients had at least one chest CT performed, while four patients also had follow-up CT. Five patients had chest radiographs (CXR), three of which had CXR on a daily basis. Two patients had six CXR and one patient had ten follow-up CXR.
These tests had limitations, as the number of patients were very less and analysing was time taking.

All tests were taken into consideration and following results were analysed:

- They found out that the most common findings on chest CT were bilateral ground-glass opacities with or without consolidation in the lung periphery.
- Pleural effusions and lymphadenopathy were absent in all patients.
- They found out many similarities with SARS, Both pathogens demonstrate predominantly ground-glass opacities.

In Chest Radiograph scans, they found out of fiive patients had CXR along with CT thorax examinations that:

- Two patients showed normal CXR findings, despite also having CT examinations performed on the same day showing ground glass opacities.
- The other three CXR examinations showed consolidation.
- One CXR showed lower zone predominance, whilst the other two CXR examinations did not show any zonal predominance.

S. Deep-COVID: Predicting COVID-19 from chest X-ray images using deep transfer learning[18]

Since December 2019, a novel corona-virus (SARS-CoV-2) has spread from Wuhan to the whole China, and many other countries.Asymmetric patchy or diffuse airspace opacities are reported for COVID-19 (Rodrigues, 2020).Such subtle abnormalities can only be interpreted by expert radiologists.Considering huge rate of suspected people and limited number of trained radiologists, automatic methods for identification of such subtle abnormalities can assist the diagnosis procedure and increase the rate of early diagnosis with high accuracy.

Artificial intelligence (AI)/machine learning solutions are potentially powerful tools for solving such problems. We fine-tuned each model for 100 epochs. The batch size is set to 20, and ADAM optimizer is used to optimize the loss function, with a learning rate of 0.0001. All images are downsampled to 224 × 224 before being fed to the neural network. We reported a deep learning framework for COVID-19 detection from Chest X-ray images, by fine-tuning four pre-trained convolutional models (ResNet18, ResNet50, SqueezeNet, and DenseNet121) on our training set. Due to the limited number of COVID-19 images publicly available so far, further experiments are needed on a larger set of cleanly labeled COVID-19 images for a more reliable estimation of the accuracy of these models.

T. Coronavirus disease (COVID-19) detection in Chest X-Ray images using majority voting based classifier ensemble[17]

As per the expert's opinion, the virus mainly infects the human tract resulting in severe bronchopneumonia with symptoms of fever, dyspnea, dry cough, fatigue, and respiratory failure, etc. The limited availability of test-kits and domain experts within the hospitals and rapid increase within the number of infected patients necessitates an automatic screening system. They have aggregated a dataset from three public repositories – COVID-Chestxray set, Montgomery set, and NIH ChestX-ray14 set. All input images are preprocessed, which incorporates image resizing (512 × 512 pixels), format conversion (Portable Network Graphics), and colour space conversion (Gray Scale). The augmented images alongside the first CXR images were wont to re-train the models and classification performance was evaluated.

From the obtained results shown in, it had been observed that the supervised models trained using augmented images performed significantly better compared to the models trained using original CXR images for both the phases

The obtained promising performance using augmented images are often justified by the very fact that the augmented images provide sufficient instances to coach the model for possible variations in input CXR images, which could occur thanks to diverse imaging parameters and platforms in several hospitals.

U. Automatic Detection of Coronavirus Disease (COVID-19) Using X-ray Images and Deep Convolutional Neural Networks[16]

The virus that causes COVID-19 infectious disease is named severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). Deaths from pneumonia developing thanks to the SARS-CoV-2 virus are increasing day by day. .We performed 3-different binary classifications with 4 different classes (COVID-19, normal, viral infection and bacterial pneumonia). 5-fold cross-validation method has been utilized in order to urge a strong end in this study performed with 5-different pre-trained models that are InceptionV3, ResNet50, ResNet101, ResNet152 and Inception-ResNetV2.While 80% of the info is reserved for training, the remaining 20% is reserved for testing.

The use of artificial intelligence-based systems is extremely common in detecting those caught within the COVID-19 epidemic.They have achieved 95.7% accuracy with the approach without pre-training and 98.3% accuracy with pre-trained COVID-CAPS.Furthermore they proposed a deep transfer learning-based approach using Chest X-ray images obtained from normal, COVID-19, bacterial and viral infection patients to predict COVID-19 patients automatically. The classification performance of various CNN models are often tested by increasing the amount of COVID-19 Chest X-ray images within the dataset

In a future study, studies are going to be conducted to work out the demographic characteristics of patients and COVID-19 possibilities with artificial intelligence-based systems.

V. CVDNet: A novel deep learning architecture for detection of coronavirus (Covid-19) from chest x-ray images[19]

The following paper describes the dataset used in the study and detailed distribution of the images to train, test and validate.
Moving on, they propose their model CVDNet to classify patients and healthy persons using chest X-ray images.
They've used a dataset from Kaggle's COVID-19 Radiography Database which is an aggregated dataset of patients infected with COVID-19, chest x-ray images of cases with viral pneumonia and Chest x-ray images of healthy parsons (Normal).

They performed experiments to assess the performance of the proposed CVDNet, which is trained to classify chest x-ray images. Four out of five sets were used to train and validate our model whereas the remaining set was employed for the test (i.e. 70% of chest X-ray images are used for training, 10% for validation and 20% for testing).All experiments were implemented in Tensorflow and the proposed CVDNet was trained for 20 epochs with a batch size of 8.

They also proposed a novel deep convolutional neural network (CVDNet) model for the detection of COVID-19 cases, in order to distinguish more precisely the patients affected by COVID19 from healthy persons and viral pneumonia patients using chest X-ray images.It was observed that CVDNet achieved an average accuracy of 97.20% for detecting COVID-19 and an average accuracy of 96.69% for three-class classification (COVID-19 vs normal vs viral pneumonia), which exhibit superior and promising performance in classifying COVID-19 cases.

W. A new approach for classifying coronavirus COVID-19 based on its manifestation on chest X-rays using texture features and neural networks[20]

The paper describes how X-ray imaging plays a vital role when it comes to diagnosis of any disease.
Medical Imaging is a tool for disease diagnosis and detection, and AI based medical diagnosis tools have recently been put forward for the task of automatic diagnosis and abnormality localization.
The paper also discusses the utilisation of public data repositories which consists of 7 types of lung images related to Covid-19.

The paper furthermore discusses various data repositories from known sources and puts up analytics from it. They also discuss each phase of analysis in detail.

The first method corresponds to flattening all the images in a unidimensional vector and using the vector as input values to a feed-forward 4-layer shallow neural network.

The obtained results look promising for achieving in the near future the automated chest X-rays and computerized tomography analysis for COVID-19 diagnosis.This experimentation can be further improved by adding more balanced classes, which are translated to more states or diseases that can appear in the lungs in X-rays and CT scans.

X. Convolutional capsnet: A novel artificial neural network approach to detect COVID-19 disease from X-ray images using capsule networks[25]

Pneumonia is an infection that causes inflammation in the lungs, and besides the covid-19 virus, bacteria, fungi, and other viruses often play a role in causing this disease

The high resolution images require a powerful system to analyze the images with the original size by using capsule networks.

They described the need of larger datasets in order to analyse the performance of the proposed model. The results showed that capsule networks can effectively classify even in a less amount dataset. Since the datasets consist of images from different sources, all images were first resized into the same size.

The final accuracy of 91.2%, and 97.2% for binary class problems without data augmented and with data augmented, respectively. Capsule networks are planned to be trained with larger datasets to achieve the level of success that can assist medical staff in the diagnosis of the virus.

Y. COVID-19 Prediction and Detection Using Deep Learning[29]

This paper describes the process of covid-19 detection X-ray images and how it can further be modified to forecast new Covid-19 confirmations, recoveries and deaths, The standard diagnostic technique is the reverse transcription polymerase chain reaction method but it's not accurate enough.CTscans and Xrays show better results but due to the limited number of radiologists they cannot be substituted completely, hence AI can be used to pace up their procedure speed.Almost all covid-19 patients exhibited similar features including ground-glass opacities in the early stages and pulmonary consolidation in the later stage.

The paper also describes the other related works for example

- Narin et al, proposed CNN based models to detect covid-19 patients using 100 chest X-ray images with 50% of infected and 50% of healthy ones, they evaluated three CNN models- ResNet-50, Inception-v3 and Inception-ResNet-v2—using five-fold cross-validation a reported that ResNet-50 had the best detection accuracy (98%).

Even other implementations were able to reach 96% accuracy. The main disadvantage with CT scan is that it is expensive, compared to X-rayFor covid-19 forecasting, they researched multiple algorithms(PA, ARIMA and LSTM) to predict confirmation, recoveries and death due to Covid-19 over the next 7 days, and PA delivered the best performance.For diagnosis, the model using VGG16 was proposed due to rapid and reliable detection enabling it to achieve 99% accuracy.

Z. A deep learning approach to detect Covid-19 coronavirus with X-Ray images[28]

In the following paper, challenges and deep learning approaches to detect Covid-19 were discussed.The proposed method is implemented in four phases viz, data augmentation, preprocessing, stage-1 and stage-2 deep network model designing.They discussed challenges faced, the similarity between pneumonia and covid makes it harder to classify between pneumonia and covid patients. The other issue was lack of dataset, which prevented implementation to bring better and accurate results.

They proposed a two-stage model where the first model uses ResNet-50 shows 93.01% for differentiating healthy and bacteria-induced pneumonia people. Later on, they moved on to building a second stage model with an accuracy of 97.22%. The last implementation utilises deep learning techniques which can distinguish between Covid-19 patients and healthy patients.

AA. Extracting Possibly Representative COVID-19 Biomarkers from X-ray Images with Deep Learning Approach and Image Data Related to Pulmonary Diseases[26]

The paper describes finding low-cost, rapid and automatic detection of Covid-19. It was demonstrated that the various infections may be distinguished by a computer-aided diagnostic system, utilising deep features extracted by Deep Learning methods.

This strategy may be beneficial for medical-decision assisting tools to provide a second opinion in challenging cases. It could be also applied to achieve a first assessment of the likelihood of disease in patients with less or no symptoms. Besides, the advantage of automatic detection of COVID-19 from X-ray or CT-Scan images reduces the exposure of medical staff to the virus.The paper moreover talks about using CNNs from scratch as it outperforms other transfer learning techniques, both in distinguishing X-rays between the seven classes and between Covid-19 and non Covid-19. A classification accuracy 87.66% was achieved.

The results suggest that training CNN models from scratch may reveal vital biomarkers related but not limited to the COVID-19 disease only, while the top classification accuracy suggests further examination of the X-ray imaging potential.

AB. Artificial Intelligence-Based Classification of Chest X-Ray Images into COVID-19 and Other Infectious Diseases[30]

The page talks about multiple characteristics in X-ray images of the chest in Covid-19 infected patients. All the methods mentioned above have some limitations such as time required, costs, equipment dependence, shortage of testing kits, availability of trained healthcare workers, interoperator variabilities, especially in a pandemic like this, making them cumbersome diagnostic procedures.

Faster diagnosis of the COVID-19 patients can enable help in the optimization of available resources, including trained human resources, for all the supportive measures required for confirmed patients. Automated AI-based chest X-ray classification has such great potential for this need, as found out from various researches. The most commonly used radiological diagnostic imaging is chest X-rays, as compared to computed tomography (CT) and magnetic resonance imaging (MRI), due to its low cost and less processing time and lower radiation exposure. Their paper focuses on the generalisation of the approaches, to use the best from machine learning and deep learning concepts while providing augmented datasets. Due to the limited availability of chest X-ray images for COVID-19, the AI-based models trained on fewer images have the chance of overfitting in the classification models. However, the performance of our models on independent datasets rules out any indication of overfitting of the models.

In the future, the model training will be enhanced further by incorporating a larger dataset to develop more robust and more scalable classification models. The currently developed AI models in the study are CPU powered, hence slow in the classification of chest X-rays, in future they also discuss moving toward GPU powered solutions.

AC. Improving the performance of CNN to predict the likelihood of COVID-19 using chest X-ray images with preprocessing algorithms[24]

This paper discusses and aims to develop and test a computer-aided diagnosis (CAD) scheme of chest x-ray images to detect covid-19. The model presented uses data preprocessing to generate input of a CNN model.

Steps involved:-

- Original Image
- Diaphragm Removed
- Image Applied Histogram Equalization
- Bilateral Filtering Applied.

These above images are fed into 3 channels of the CNN model to stimulate RGB image. The model used transfer learning techniques. VGG-16 which was pre-trained on the Imagenet Large Scale Visual Recognition Challenge using a large dataset with 14 million images.

- The overall accuracy achieved is 94.5%.
- Removing irrelevant region, normalizing image contrast-to-noise ratio.

AD. Automated Deep Transfer Learning-Based Approach for Detection of COVID-19 Infection in Chest X-rays[27]

In the following paper, the authors describe the lesser sensitivity of RT-PCR with overhead of time consumptions.

The paper compares between X-ray and CT scans, X-rays takes more advantages than CT-scans which includes:

- Faster results
- Lesser ionisation than CT-scans.
- More availability
- Cost friendly.

But manual testing is very time consuming so to tackle this, the paper proposes the need for automatic testing using deep learning-based approaches. Such approaches can train over the weights of networks on large datasets as well fine tuned in smaller datasets. In this paper, deep transfer learning methods have been discussed and performances were analysed on the basis of f-measures, sensitivity, specificity and kappa statistics.

Moreover, it discusses that in the near future various initial parameters can be tuned by various approaches to provide better results.

III. GAP ANALYSIS

After going through the literature survey many models have been built to classify X-Ray images into COVID or NORMAL. But, some or the other models have flaws like training the images on deep neural architecture which led to less accuracy, high false positive or high false negative rates. Some of the studies focused on data augmentation, used pre-trained architectures like VGG-16, VGG-19, NobileNet-V2, Inception ResNet-V2, Xception, etc. but all some of them failed to overcome the problem of classification.

Type of Model	Accuracy
COVID-Light	98.86%
COVID-CAPS	98.3%
ResNet	98%
CVDNet	97.20%
ResNet+SVM	95.38%
VGG-19	93.48%
COVID-Net	93.3%
MobileNetv2	92.85%
ResNet50 + VGG+ CNN	91.24%

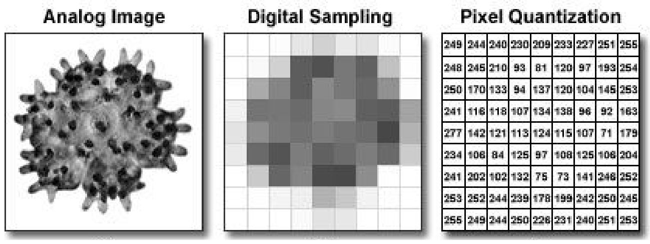
Table 1. Accuracy comparison of implemented models in the literature.

Some of the studies completely hit the level of accuracy. But, our model "COVID-Light" beats the accuracy of these models with accuracy 98.86% (see Table 1).
Our approach to reach this accuracy is simple and produces better testing accuracy. Let's discuss the steps involved to reach the final classification result. Steps involved are-
Step 1: Downloaded the dataset from Kaggle named as COVID-19 Radiography Database. Randomly visualized the dataset to know what is present exactly in the dataset.
Step 2: We have built the binary classifier to predict the outcome as (0-NORMAL, 1-COVID-19) so we used only COVID-19 and NORMAL images from the dataset.

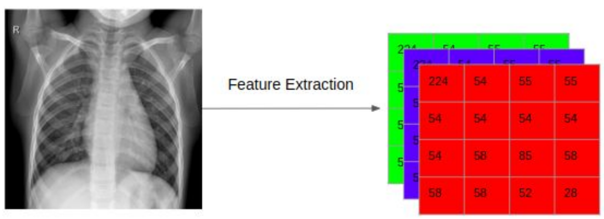
Step 3: In the next steps the images are resized into 224-by-224 using the OpenCV python library. The original image present in the dataset has size 1024-by-1024 pixels (see Fig. 3).

Fig. 3. Size Reduction

Step 4: In the next step we converted the features of images into numerical values and stored into the Numpy arrays. Numpy makes the feature learning easy as it supports large and multi-dimensional arrays(see Fig. 4)



(a)



(b)

Fig. 4. (a)Image Preprocessing, (b)Feature Extraction

Step 5: The next step involves the normalization process on the values of the Numpy array created in the previous step to bring the values into the same scale. The final data is split into training and test set in the ratio of 8:2 (Training set 80% and Test set 20%).

Step 6: A 2-dimensional convolution neural network has been used to classify X-Ray images into one of binary classes (0-NORMAL, 1-COVID). We used a CNN Sequential model with the activation function named 'RELU'(Rectified Linear Unit), Softmax, MaxPooling, Dropout, and Flatten for training the model.

Step 7: The next step involves the training of the CNN model. The data is then fit into the model with

Number of Epochs = 20

Number of Steps per Epochs = 28

Test Accuracy after fitting the model = 98.86%.

The proposed model design is found to be efficient in classifying COVID-19 and NORMAL patients. The use of CNN model for classification made the process more convenient and efficient.

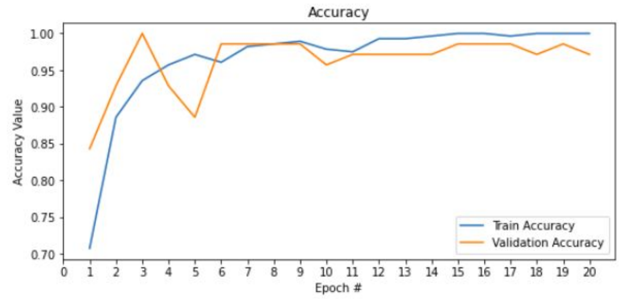
IV. SIGNIFICANCE OF WORK

COVID-Light overcomes all the flaws present in the literature study. COVID-Light is has the training accuracy of 99.31%(see Fig. 5) and testing accuracy achieved is 98.86%. The training of the CNN model. The data is then fit into the model with

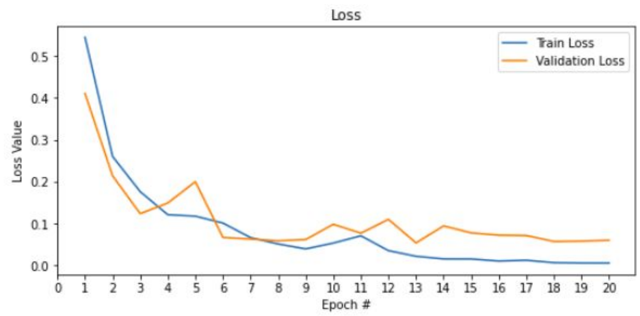
Number of Epochs = 20

Number of Steps per Epochs = 28

Test Accuracy after fitting the model = 98.86%.



(a)



(b)

Fig. 5 (a)Accuracy Graph and (b)Loss Graph

After going through the confusion matrix, which clearly describes the model performance.

True positive = 217

False positive = 2

False negative = 1

True negative = 218

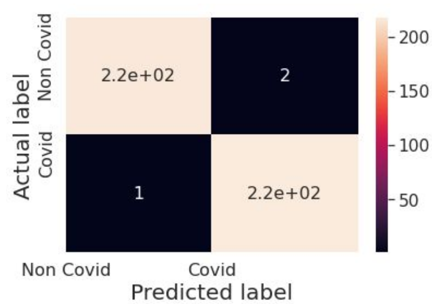


Fig. 6. Confusion Matrix completely describes the finding observed during the training of the model.

	precision	recall	f1-score	support
Class 0	1.00	0.98	0.99	47
Class 1	0.98	1.00	0.99	41
accuracy			0.99	88
macro avg	0.99	0.99	0.99	88
weighted avg	0.99	0.99	0.99	88

Table. 2. Classification Report

The model also has low False Positive and False Negative Rates respectively(0.9%, 0.4%). For both the classes(0-NORMAL, 1-COVID-19) precision are(1.00, 0.98) , recall(0.98, 1) and f1-scores(0.99, 0.99).The classification report is the evidence of the above findings (see Table 2).

On considering the available dataset this model will definitely perform better. But, to increase its integrity and scalability of the model we will work in adding following features-

- We will work on increasing the COVID-19 images which could be contributed towards addition to the dataset.
- Our future will contribute to develop a model which will help to find out how severe is the current patient condition and percentage of lungs damaged. Accordingly he can be recommended to be hospitalized.
- We will perform further testing to get better results about its negative sides as it can be used by the radiologists for testing purposes.

V. CONCLUSION

The aim of this project was to classify the input X-Ray image into binary class(0-NORMAL, 1-COVID). Due to availability of small sized dataset building a model was a tough task as sometimes the model was overfitted or under fitted which lead to high False Positive and high False Negative Rates. We have built this model keeping in mind the above stated problems. The built model is lightweight and can be trained again in less time whenever the size of the dataset increases. The model also has low False Positive and False Negative Rates respectively(.9%, .4%). For both the classes(0-NORMAL, 1-COVID-19) precision are(1.00, 0.98) , recall(0.98, 1) and f1-scores(0.99, 0.99). The test accuracy achieved by the model is 98.86%. But since we have managed to obtain a decent model with decent accuracy, it can be concluded that the model will definitely perform better if trained on a bigger dataset. This model is enough to diagnose COVID-19 in the early stage. The support with the Web Application built on Flask is user friendly and scalable.

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