Deep Learning Approaches for COVID – 19 Diagnosis

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Abstract

Coronavirus disease (Covid19) is a pandemic communicable disease that has a serious risk of speedy transmission. Identifying and isolating the affected person is the initiative mark to counter this virus. In regard to this matter, chest radiology images have been manifested to be a powerful screening approach of Covid19 positive patients. Many Artificial Intelligence based solutions have evolved for fast screening of radiological images and more precise in detecting Coronavirus disease. To make the proposed model more powerful, labeled chest X-ray datasets comprising two categories Covid19 and Non-Covid from kaggle uci repository data set are used in this work. To perform feature extraction, effective CNN structures, namely EfficientNet, VGG-16 and Densenet-121 with ImageNet pre-training weights are applied. The features produced are moved to custom fine-tuned top layers which are then followed by a group of model snapshots. In this study, the main objectives are to create database of Covid19 patients and to develop different Deep learning model for analysis of Covid19 pneumonia and then to train the deep learning models to get desired accuracy. A deep learning-based approach using Densenet-121 with ReLu activation function is proposed to effectively detect Covid19 patients X-ray images. The model is trained on Covid19 dataset which consisted of 2159 labelled X-ray images (576 images are of confirmed Covid19 patients and 1583 are of non-covid patients) and achieved overall accuracy of 95.04% in classifying the X-ray images and tested this model on Covid dataset containing 25 unidentified chest X-ray images. As a final step, we performed two-class classification of unidentified X-ray images as Covid and Normal using the proposed deep learning model.

Keywords1

Covid-19, deep learning, data set, radiological images, feature classification

1. Introduction

Covid19 is an extreme disease issue where a lot of humans lost their lives; even the complete globe is suffering due to this terrible virus sickness. In the past decade, numerous sorts of viruses (like Flu, MERS, SARS, and many others) existed just for some days and few months. Several scientists were working on such kinds of viruses. In the existing time, the complete world is laid low with Covid19 disorder, and the maximum essential factor is not a single USA scientist could come out with a vaccine (medicine) for the equal. At the same time, several extra predictions such as plasma remedy, X-ray pictures, and plenty of more came into limelight but the actual solution of this harmful sickness isn't discovered. Every day, human beings are losing their lives because of covid-19, and hence the diagnostic value of this dreadful disease may be too high within the context of a rustic, state, and sufferers. By early March 2020, X-ray images of wholesome human beings and Covid-19 infected people were to be had on line in one of kind repositories along with, Kaggle for analysis. Covid19 is a virus sickness that threatened people at a global stage and resulted in a virulent disease. To investigate

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Covid19 inflamed people with wholesome patients are important assignment. The dialysis of Covid19 inflamed patient's wishes greater precaution and should be treated beneath very strict tactic to lessen the risk of those people who are not yet contracted with Covid19. The novel corona virus disorder appeared first as a minor throat infection, and unexpectedly human beings faced issue in respiration. Medical imaging is another way of studying and predicting the results of Covid19 on the humans. Healthy humans and Covid19 infected patients could be inspected in parallel using Computerized Tomography images as well as chest X-ray snapshots. In order to contribute to an evaluation of Covid19, we amassed uploaded facts of X-ray photos of wholesome and Covid19 infected sufferers from different origins and then three different types of models (DenseNet, efficientNet and VGG) were applied. The data collected was analyzed using Convolutional Neural Network which is a machine learning tool. This work is largely centered on the use of Convolutional Neural Network model for classifying lung X-ray images of corona virus infected patients.

The most common place take a look at technique presently used for Covid19 analysis is a real time opposite transcription-polymerase chain reaction. Chest radiological imaging at the side of computed tomography and X-ray have important function in the timely analysis and remedy of this ailment. Because of low opposite transcription-polymerase chain response sensitivity of 65%–75%, despite the fact that terrible outcomes are received, signs and symptoms may be detected through examining radiological pictures of patients. Therefore, it is defined that CT is an acute method to find out Covid19 pneumonia, and may be considered as a screening device with contrary transcription-polymerase chain reaction. Computed tomography (CT) scan findings are located over a prolonged c language after the onslaught of symptoms, and patients generally take up a regular CT in the initial two days. In a take a look at on lung CT of patients who have survived Covid19 pneumonia, the most sizeable lung disease is found after ten days on the outbreak of symptoms.

The infected could be commissioned on occasion as Covid19 to healthful people due to a fake-terrible end result. In comparison with reverse transcription-polymerase chain reaction, the Thorax Computer Tomography is in all likelihood greater dependable, beneficial, and faster generation for the class and assessment of Covid19, especially to the infected (epidemic) region. Most hospitals possess CT-Image Screening; consequently, the Thorax CT photographs may be employed for the timely detection of Covid19 patients. However, the Covid19 type basing on the Thorax CT calls for a radiology professional, and loads of treasured time is misplaced. Therefore, automated evaluation of the Thorax CT pictures would be proper to store the precious time of the medical workers. This can even keep away from delays in beginning remedy [3].

Deep Learning (DL) is the maximum efficient approach which could be employed in life science. It is a quick and green technique for predicting numerous ailments with an awesome rate of accuracy. They are especially skilled fashions to categorize the inputs into distinctive classes favored by using the programmers. In the field of medicine, they may be used to stumble on coronary heart troubles, tumors using photo evaluation, diagnosing most cancers, and plenty of other applications. Furthermore it can be employed to distinguish the CT experiment patient images not inflamed with Covid19 as negative or infected that is positive. A self-advanced version CTnet-10 got created with an accuracy of 80.1 %. To enhance the accuracy, we furthermore handed the X-ray experiment picture via a couple of pre-existing fashions. It was found that the Densnet121 model is nice to categorize the pics as Covid19 nice or poor because it gave a greater accuracy of 95 %. The X-ray test image is exceeded through a Densnet121 version that categorizes the X-ray test into Covid19 positive or Normal.

2. Related work

Originating from the Wuhan city of China, Covid19 has widespread in almost all countries across the globe. Therefore there is a need for an automatic version [6] to diagnose Covid19 with less execution time and less complexity. Since the ailment has transmitted, there aren't always relevant facts to enforce a correct Covid19 predicting version. However technology is a blessing that makes it feasible. Effective strategies relied on scientific imaging using artificial intelligence (AI) have addressed to aid human beings in requisite time. Detection of Covid19 has become vital in human beings at an early level to make it less infectious. To add on, Neural networks (NNs) have given favorable results in medical imaging. Therefore, in this part of the work, a deep learning based methodology is used for photograph type to discover Covid19 the usage of chest X-ray photos. A Convolutional Neural Network

classifier has been used to categorize the regular-healthy photos from the Covid19 images, the usage of transfer learning. Early stopping is employed to beautify the proposed Dense Net accuracy. Performance metrics such as Precision, F1 score, and Recall are evaluated. An automatic comparative evaluation amongst more than one optimizer, Loss function, and LR Scheduler is executed to attain the maximum accuracy appropriate for the proposed gadget.

Explainable deep mastering framework for differential prognosis of Covid19 the use of chest X-rays. Covid19 has emerged as an international disaster with remarkable socio-economic challenges in the lives and livelihoods of human beings [1]. The lack of vaccination for Covid19 has laid down speedy checking out of the populace instrumental on the way to include the exponential upward thrust in the case of contamination. Scarcity of reverse transcription-polymerase chain reaction test kits and lag in attaining test outcomes calls for substitute strategies of fast and true prognosis. Hence this paper advocates an unique deep mastering-primarily based answer the use of chest X-rays which could assist in speedy triaging of Covid19 sufferers. The proposed answer makes use of image enhancement, and segmentation, and uses a altered stacked ensemble version along with four Convolutional Neural Network base-inexperienced persons alongside Naive Bayes as meta-learner to categorize chest X-rays into 3 training viz. Covid19, pneumonia, and every day. Powerful pruning techniques as brought in this proposed work consequences in surged model overall performance, generalize potential, and reduced model complexity. We comprise explain capacity in our project through the use of Grad-CAM visualization to be able to set up consider inside the clinical AI system. The proposed key may be employed as one element of affected person assessment in conjunction with gold preferred scientific and laboratory checking out.

Early investigation of the coronavirus sickness in 2019 (Covid19) is vital for oppressing this pandemic [6]. Covid19 is spreading swiftly everywhere in the international. There isn't any vaccine obtainable for this virus but quick and precise Covid19 screening is feasible by the usage of computed tomography scan pics. This manuscript specializes in distinguishing the CT test snap shots of Covid19 and non- Covid19 CT the use of one of a kind deep gaining knowledge of strategies. A self-evolved model named CTnet-10 become intended for the Covid19 analysis, having 82.1% accuracy.

3. Proposed methodology

The proposed Deep Learning system includes three parts:

1. Covid19 dataset.
2. Feature extraction in multiple hidden layers.
3. Classification of output layer.
4. Covid19 dataset

The initial step is the training of the information which are essential for facts mining throughout statistics understanding, information preparation. The below data encompass clinical information, which includes clinical reports, statistics, pictures and other diverse kinds of facts which could be converted into data that could be deduced by a machine. Feature extraction in a couple of hidden layers. The proposed Deep Learning device consists mainly of three parts- Automatic lungseparation, suppression of non-lung area, and Covid19 diagnostic and prognostic analysis.

- Automatic lung separation:
- Regularly used chest X-ray photos include some non-lung areas (heart, muscle) as well as blank space outdoor frame. To investigate on lung region, a completely automatic Deep Learning model (DenseNet121) is used to phase lung regions in lung X-ray photos.
- Suppression of non-lung region:
- On completion of the above mentioned process, a few non-lung organs or tissues (for example, Heart and Backbone) within the lung may additionally present. Hence, a non-lung location suppression operation is proposed to quench the intensities of non-lung regions of the lung.
- Deep Learning model for Covid19 diagnosis and prognosis:
- Once the non-lung vicinity suppression operation is accomplished, the standardized lung changed into sent to the Covid19Net for diagnostic and prognostic analysis.
- This Deep Learning version used a Dense Net-like structure, which include dense blocks, in which each dense block become numerous tacks of convolution, batch normalization

and ReLu activation layers.

- After an iterative training technique within the Covid19 dataset, the Covid19 Net can expect the opportunity of the enter affected person being infected with Covid19, this possibility turned into described as Deep Learning score in this work. To find the prognostic price of the Deep Learning features, we extract the Deep Learning feature from the Covid19Net for prognostic evaluation.

Classification of output layer:

In end result evaluation, usual lung X-ray photographs have been compared with Covid19 affected people and categorized as whether the output is Covid affected sufferers, or Normal healthful character [4]. In clinical research specifically for essential illnesses consisting of Covid19, it's far extensively important to reduce the false high-quality and false bad results inside the modeling method. False negatives for obvious motive sought to be minimal as a way to not misclassify any Covid19 positive patient as a Covid19 negative may additionally harm our society loads. Also, it is also important to decrease the variety of false positives as a Covid19 negative to classify as Covid19 positive can also cause unnecessary emotional disruption for a man or woman. It sincerely suggests that the proposed method offers false negative and false positive rate. Thus, the proposed version can be fine opportunity of rapid Covid19.

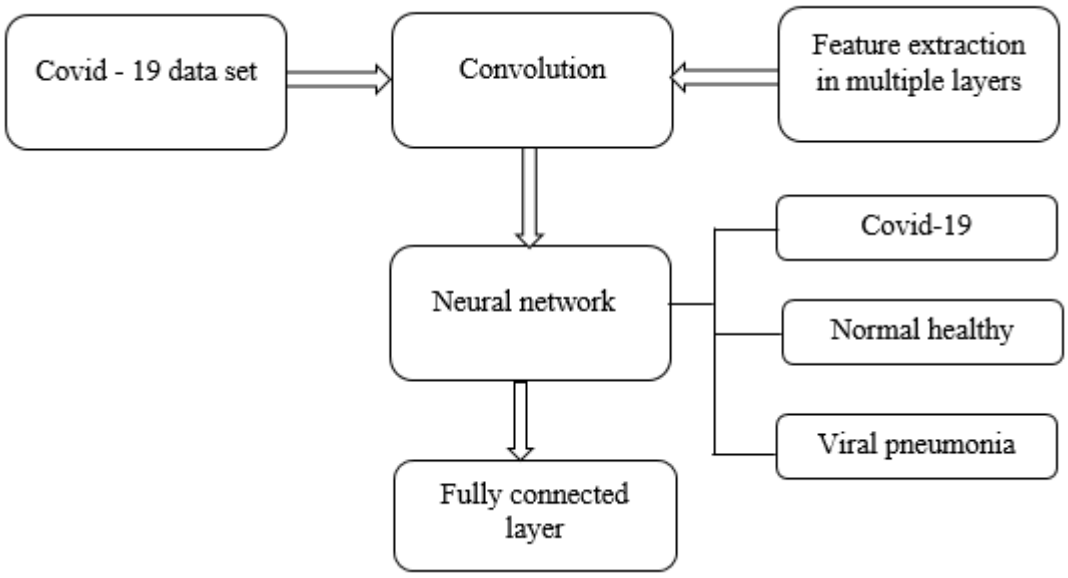

Figure 1: Block diagram of showing the illustration of methodology for Covid19 diagnosis

4. Deep learning techniques

The architecture of DenseNet-121 is employed as an inspiration for the Deep Learning Model. Dense Net on opposite to well-known belief, need less parameters when compared to conventional Convolutional Neural Networks due to the fact they do no longer require studying nonessential feature maps. A few of ResNet variations have proven that the number of layers is not improving the ResNet performance and hence they may be discarded. ResNet have several parameters due to the fact each layer will have its private weights to understand whilst DenseNet layers are narrow; hence they show new characteristic-maps in insignificant numbers [5].

One more trouble here is educating them due to the formerly expressed information and gradients. Because each and every layer could link to gradients via the loss characteristic and real picture, then DenseNet clear up this hassle. A basic change with ResNet is rather than involving characteristic-maps, they may be concatenated. The significant idea of DenseNet is reusing feature, that leads to highly compact versions. Convolutional Neural Networks in view that no feature-maps are repeated. When

Convolutional Neural Networks cross deeper, they run into problems.

The purpose at the back of is drawing of facts from inside layer to outer layer (in addition to the gradient in the contrary course) gets see you later that it can vanish right even before passing in addition facet. DenseNet makes this interconnection much facile through really connecting each and every layer immediately with every other layer. DenseNet employs the community's ability by reusing capabilities. As imparted, DenseNet which is a kind of convolutional neural community makes use of dense blocks to hyperlink all the layers (with corresponding characteristic-map sizes) without delay to each other, leading to dense connections among layers. The definition of DenseNet states: the denser the connection in the model, the better is the performance. Each and every layer in DenseNet gets extra enter throughout every preceding layer and transmits its feature-maps to the next layers.

Each and every layer gets collective information from the layers which are on top of it and this is the exact idea of concatenation which is being used. To maximize computation reusing among the classifiers, incorporating a couple of classifiers into a super and deep convolutional neural community and inter-connects them with dense connectivity for powerful and efficient image category. With the arrival of convolutional neural network, deep learning is capable in excelling the current methodologies for functions together with segmentation and category. For maximum scientific imaging responsibilities, convolutional neural networks are at present state of the art, motivating us to research the effectiveness of those for Covid19 detection using X-ray experiment Images. The efficiency of convolutional neural network architectures in medical imaging, the following state of the art general architectures is used because the guideline for the proposed pipeline: VGG-16, DenseNet121, and EfficientNet. The baseline models are cut back at the final FC layer and the following layers had been combined to every baseline model:

- Average pooling method with a pool size of (7,7)
- Flattening layers
- Dense layer consisting of 128 hidden units and ReLu AF
- Dropout layer (dropout ratio of 0.5)
- Dense layer with three hidden units and softmax AF

The enter photo size for each of the base learners is 224. A not unusual disadvantage of those standard architectures is their leaning to over suit the training set. To cope with this downside, we appoint a dropout of 0.5 and L2 (Lasso) regularization of 1e-three. Stochastic gradient descent optimizer is employed with preliminary getting to know charge of 1e-4, and 0.95 of momentum. The cross-entropy loss function is applied for educating the baseline fashions that are largely used for multi-elegance class assignment.

4.1 Densenet 121

In resemblance with this study, our purpose for the class of Covid19 lung X-ray photographs into Covid19 positive and negative photographs. A convolutional neural network classifier is developed to diagnose Covid19 ailment the use of chest X-ray snap shots [5]. Also, a deep getting to know PyTorch library and torch vision are employed, which a pre-trained statistic is learning version which has a highest of manage across overfitting and it further improves the optimization of consequences from the beginning.

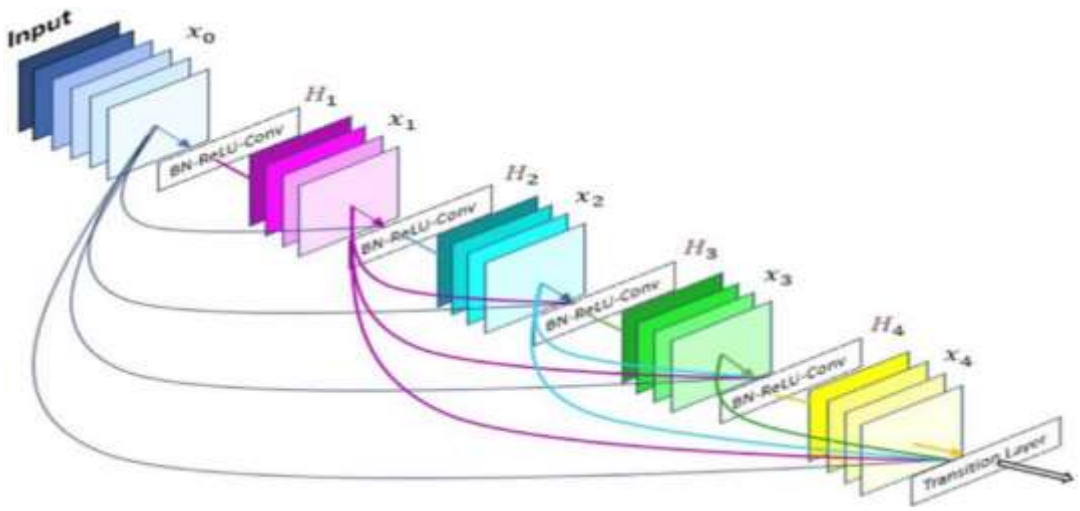

Figure 2: Block diagram of DenseNet

As proven in Fig. 2 shows the DenseNet block diagram which marks a five-layer dense block owing an increase rate of k = 4. The wide variety 121 in DenseNet121 suggests the entire quantity of layers within the neural network [7]. A traditional mix of DenseNet121 is blend of diverse layers which constitutes:

- Five convolutional and pooling layers
- Three transition layers (6, 12, and 24)
- One classification layer (sixteen)
- Dense Blocks (1 × 1; 3 × 3 convolutions).

DenseNet instigates feature reprocess and decreases the parameter which complements the accuracy of version for diagnosing Covid19 the usage of chest X-ray pictures. After the blend function process, the end outcome of the previous layer will be an enter for the second one layer. The blended manner consists of a non-linear activation layer, pooling layer, batch normalization and convolution layer [5]. Also, a deep studying library named PyTorch and torch vision are used, that are pre-educated record is gaining knowledge of version which has a highest of control throughout over fitting and it also improves the optimization of consequences from the first actual. After the composite characteristic operation, the previous layer result will be an enter for the next layer. The mixed process consists of a nonlinear activation layer, pooling layers, batch normalization and convolution layers. The different models that were examined are DenseNet-121, and VGG-16. The VGG-16 came out superior with 94% accuracy. Fifty-two % in comparison with rest of the deep learning methods. Automated prognosis of Covid19 from the CT experiment snap shots can be utilized by the medical workers as a short as well as green technique for the screening of Covid19.

4.2 VGG-16

VGG-sixteen is a convolutional network that is sixteen layers deep by using the usage of this version we got accuracy of 91.6% with loss of 4.42%. The entered snap shots have been fed to the visible geometry institution-sixteen (VGG16) model with a measurement of 150x150x3. This model has nineteen layers, with five convolutional blocks; each block together with two or three convolutional layers and five max pooling layers, eventually finishing with two fully connected (FC) and a softmax layer. Softmax layer was replaced with sigmoid layer for two-class classification. This model was trained with rms (root mean square) propagation and iteration of 13 epochs. Photo augmentation was further attempted on the equal model and the model was trained for about 30 epochs. Fig. 3 depicts the accuracy and loss graph of the VGG16 [6].

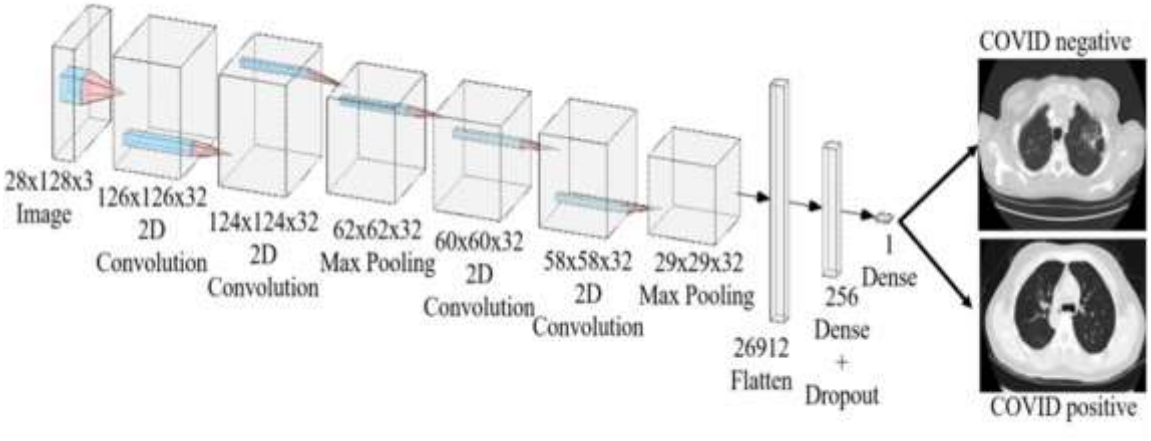

Figure 3: Block diagram of VGG-16

The Fig. 3 shows Configuration of version of VGG16. The version become with an enter picture of dimension 224x224x3. There are five convolutional blocks. Later it surmounts through any one of the convolutional layers and dimension of 224x224x64. It then passes via a subsequent pooling and convolutional layer of size 112x112x128. It further passes via pooling layers of sizes 56x56x128, 28x28x512 respectively. In addition it is passed via the consecutive layer of size 14x14x512, and a pooling layer of dimension 7x7x512. It is furthermore handed through 25088 neurons of the flattened layer, that's consecutively surpassed via a Fully Connected layer of 4096 neurons, where the dropout layer was employed in every layer. Further progressing it through an individual neuron through sigmoid and linear activation functions, the X-ray experiment photographs are labeled as Covid19 positive or as negative.

A Deep Learning algorithm is employed for feature extraction from lung X-ray images of patients more precisely in order the model that can detect pneumonia more accurately. Fig. 1 exhibits the block diagram.

The steps given below provide information of the work done along with a flowchart.

- Collection of X-ray lung images are taken from Kaggle's uci repository dataset of lung X-ray images of Covid19 is used for the project.
- Data processing is done after collecting dataset of X-ray lung images, the noise present in X-ray images is extracted or cleared. Once this is accomplished, the data is resized to desired shape.
- Feature extraction is done.
- DensNet121, VGG16, and Efficient Net Convolutional Neural Network models are employed to create a model for pneumonia prediction.
- Data is split in the ratio of 80:20 as training and testing sets respectively. This data is given to the Convolutional Neural Network.
- After building the model, the test dataset is given for prediction.

5. Results and Discussion

The data (Covid19images) is been collected from Kaggle uci repository dataset [8]. The Covid19 X-ray dataset consists of the images of the patients that had tested positive.

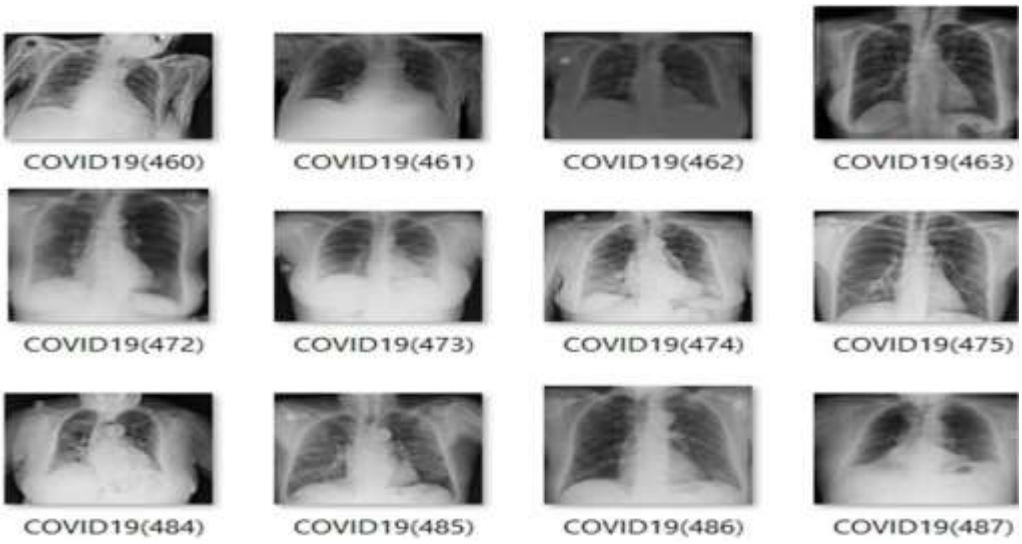

Figure 4: Covid19 X-ray Images

From a total of 2159 X-ray scan of 1500 patients, 576 images are of confirmed Covid19 patients and 1583 are of non-covid patients. To train a model the images are split into 80:10:10 training, validation and test set. The images in Fig. 4- 5 are involved to train the model for detecting the Covid19. The Fig.4 shows the Covid19 images which we have used to train the model. In our work, we have used three models for training and below graph shows the accuracy and loss of DenseNet, VGG-16, and efficient Net. 576 X-ray images are of confirmed Covid19 patients are used to train the Convolutional Neural Network models. These images are used for detection of Covid19 X-ray images.

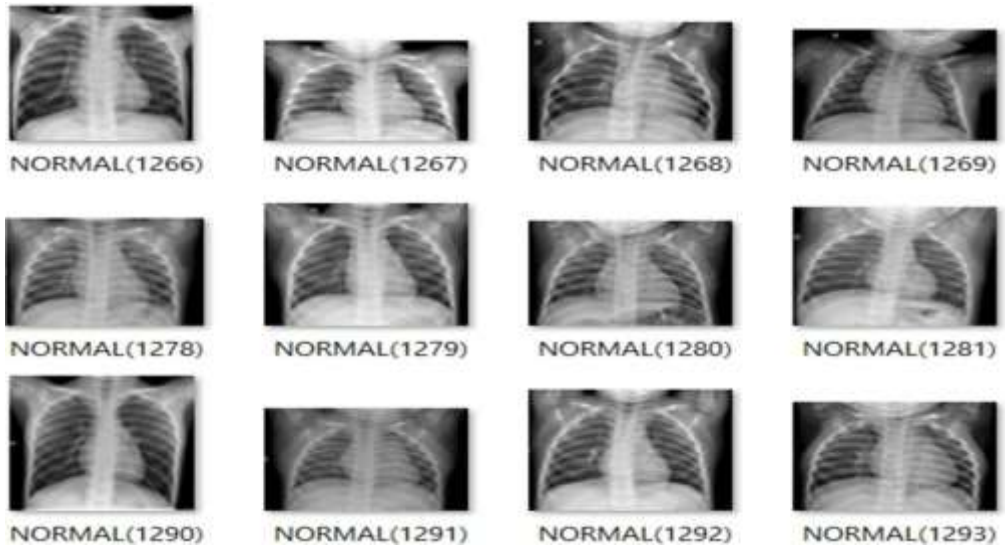

Figure 5: Normal X-ray images

The Fig. 5 shows the normal images which we have used to train the model for Normal X-ray images. 1583 X-ray images are of non-covid patients that are used to train the Convolutional Neural Network models. These images are used for detection of Normal X-ray images. So, total of 2159 labelled X-ray lung images of 1500 patients are used for training the model. Out of 2159 labeled X-ray lung images 576 X-ray images are of confirmed Covid19 patients and 1583 are of non-covid patients.

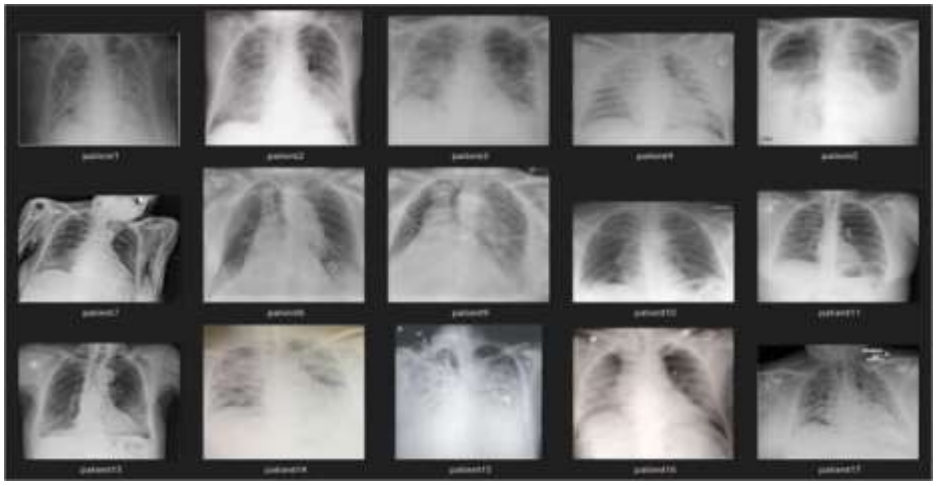

Figure 6: Covid19 and Normal X-ray images

Fig. 6 shows Covid19 and Normal X-ray images which have to segregate as Covid and Normal by the trained model. 25 unidentified X-ray images are given for testing purpose such that the model will segregate the X-ray images as covid and normal images.

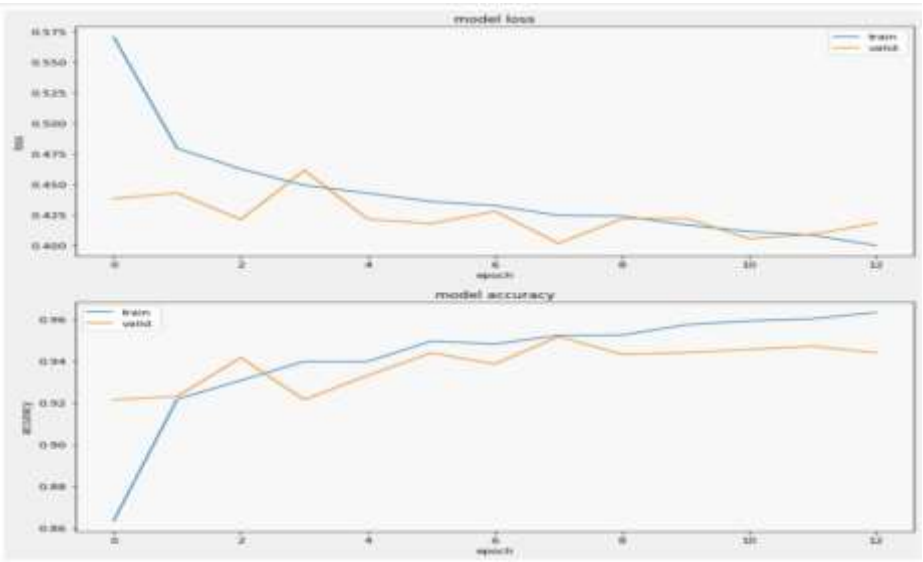

Figure 7: DenseNet121: Accuracy and loss graph

Fig. 7 exhibits the accuracy and the loss graph of DenseNet121 Convolutional Neural Network. The DenseNet CNN model was trained for 13 epochs to classify X-ray images. Each pre-trained model was trained on gray scale images. The blue line in the graph indicates the loss and accuracy of DenseNe model for the training dataset. The red line in the graph indicates the loss and accuracy of DenseNet model for the validation data set.

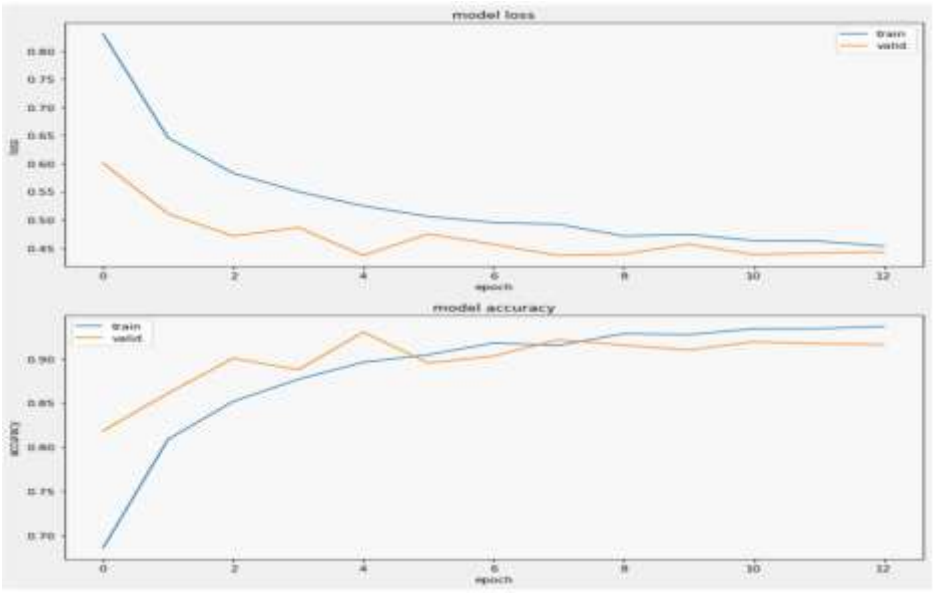

Figure 8: VGG-16: Accuracy and loss graph

Fig.8 displays the accuracy and the loss graph of VGG-16 Convolutional Neural Network. The VGG-16 CNN model was trained for 13 epochs to classify X-ray images. Each pre-trained model was trained on gray scale images. The blue line in the graph indicates the loss and accuracy of VGG-16model for the training dataset. The red line in the graph indicates the loss and accuracy of VGG-16 model for the validation data set.

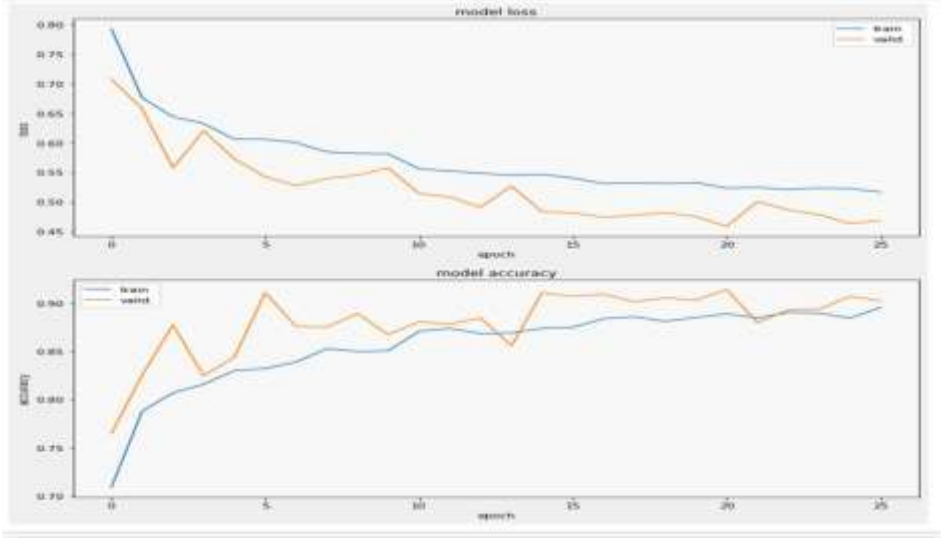

Figure 9: EfficientNet: Accuracy and loss graph

Fig.9 depicts the accuracy and the loss graph of EfficientNet Convolutional Neural Network. The EfficientNet Convolutional Neural Network model was trained for 26 epochs to classify X-ray images. Each pre-trained model was trained on gray scale images. The blue line in the graph indicates the loss and accuracy of EfficientNet model for the training dataset. The red line in the graph indicates the loss and accuracy of EfficientNet model for the validation data set.

Table1

Results of three different models

Model	Accuracy	Loss
VGG-16	91.6%	4.42%
EfficientNet	90.2%	4.68%
DenseNet	94.4%	4.18%

6. Conclusion

As mentioned earlier, the detection and analysis of Covid19 through Deep Learning strategies with low cost and less complexity are the essential steps in averting the disease and the development of the pandemic. With the integration of Deep Learning algorithms and equipments used in radiology centers in the upcoming years, it will likely be feasible to comprehend a quicker, less expensive, and more secure prognosis of this ailment. The application of such techniques in fast diagnostic choice-making of Covid19 are regularly a robust device for radiologists to scale back human error and may help them to shape choices in sensitive situations and at the height of the ailment. This particular study helps the idea that Deep Learning algorithms are one of the favorable way for optimizing healthcare and maximizing the effects of diagnostic and therapeutic processes. Even though Deep Learning is one of the numbers of the principal effective computing tools in analysis of pneumonia, particularly Covid19, we need to take care to circumvent overfitting and to enhance the generalizability and effectiveness of Covid19 Deep Learning diagnostic fashions, these fashions should be trained on large, heterogeneous datasets to enfold all of the obtainable facts area.

7. References

[1] Agnes S.A., Anitha J, and Peter J.D, "Automatic lung segmentation in low-dose chest CT scans using convolutional deep and wide network (CDWN) Neural Computing and Applications", (2018).pp.15845–15855.doi:10.1007/s00521-018-3877-3

[2] Nihad Karim Chowdhury, Muhammad Ashad Kabir, Md.Muhtadir Rahman, and Noortaz Rezoana, "ECOVNET a highly effective ensemble based deep learning model for detecting Covid-19", (2021).doi:10.7717/peerj-cs.551

[3] Jamshidi M, Lalbakhsh A, Talla J, Peroutka Z, Hadjilooei F, and Lalbakhsh Petal, "Artificial intelligence and COVID-19:Deep learning approaches for diagnosis and treatment", IEEE Access,(2015).pp.109581–109595.doi:10.1109/ACCESS.2020.3001973

[4] Jiayang Chen, and Kay choong, "Artificial Intelligence for COVID-19: Rapid Review", (2020).doi:preprints.jmir.org/preprint/21476

[5] Tavishee Chauhan, Hemant Palivela, and Sarveshmani Tiwari, "Optimization and fine tuning of DenseNet model for classification of COVID-19 cases in medical imaging", (2021).doi:10.1016/j.jjimei.2021.100020

[6] VruddhiShah, RinkalKeniya, Akanksha, Shridharani, Manav Punjabi, Jainam Shah, and Ninad Mehendale, "Diagnosis of COVID-19 using CT scan images and deep learning techniques".(2021) doi:https://doi.org/10.1038/s41598-021-93832-2

[7] https://www.tensorflow.org/tutorials/quickstart/beginner

[8] https://www.kaggle.com/prashant268/chest-xray-covid19-pneumonon