E-ISSN 2581 – 7957
P-ISSN 2277 – 3916

CVR Journal of Science and Technology, Volume 21, December 2021
DOI: 10.32377/cvrjst2117

Screening and Classification of Covid-19 from Lung Images using Deep Learning Models

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Abstract: **The world is facing human mankind issues which made people quarantine. Real-Time Reverse Transcription Polymerase Chain Reaction (RT-PCR) detection of viral RNA from nasopharyngeal swab has a relatively low positive rate for the early-stage detection of COVID-19. The Computed Tomography is the first imaging technique that plays an important role in the early diagnosis of COVID-19 and their manifestations had their characteristics that are different from other non-COVID diseases like Influenza-A viral pneumonia. So this survey is trained to determine an early screening model to distinguish COVID-19 from healthy cases and Influenza-A viral pneumonia using 2D and 3D deep learning techniques algorithms like Inception-V3, Xception, ResNet, ResNeXt, etc., Further proceeding into the design, the candidate regions were first segmented using these deep learning models from the CT images by applying filter layers such as convolutional layer pooling layer other dense layers depending on the model selected and activation functions such as a sigmoid function or ReLU function and then these were categorized into COVID-19, influenza-A viral pneumonia and healthy groups with the best accuracy results and the promising screening.**

Index Terms: COVID-19, Deep Learning, CT images, Convolutional Neural Networks, Screening.

I. INTRODUCTION

At the end of the 2019, there was an outbreak of novel coronavirus disease 2019 pneumonia (COVID-19) [1] in Wuhan, Hubei Province, China. The health authorities did investigation inorder to characterize and control the disease and summarize the clinical characteristics indicating the common symptoms fever, cough, myalgia, fatigue etc., and some people ended up with lifetime diseases. Due to this some patients had pneumonia, the lung CT examination showed abnormalities and complications including acute respiratory distress syndrome, acute heart injury and secondary infections and observed the evidence of one person to another person transmission of COVID-19 through droplets or aerosols when an infected person coughs talks or sneezes. Now the covid-19 has reported different variants of it. It is spreading alot more than previous waves and is very dangerous as different mutations come together to form another mutant and the study tells the severity increases with the increase in the number of mutations.

As the situations are getting more worse day-by-day, the virus should be detected and diagnosed very early and accurately helps in controlling the spread of the disease .The manual method of detection of COVID-19 in human can be done using RT-PCR test i.e the detection of viral RNA from sputum or nasopharyngeal swab that resulted a low positive rate in the very early stage. However, the CT scan images were collected from the patients with the COVID-19 disease, who had their own characteristics different from other viral pneumonia diseases. So the RT-PCR testing has been replaced with the lung CT scan image detection as early diagnostic criteria for COVID-19.

There is rapid development in computer technology where digital image processing has been widely applied in the medical field including image segmentation, image enhancement for medical detection. Deep Learning technologies such as Convolutional Neural Network[2] have substantial applications in medical image processing.And deep learning models usage and applications have drastic impact on the efficiency of predicting , testing or classifying etc.

The objective of this study is finding the different models to early diagnose the disease from the CT lung images or the X-ray chest images and then classify the diagnosed images into different categories i.e either COVID-19 or healthy using binary classification and COVID-19 or Pneumonia or healthy using multiclass classification more accurately.

Generally, a deep learning model involves different workflow steps.

1. Collecting the data
2. Data preprocessing
3. Choose the model
4. Train the model
5. Evaluate the model.

As part of this study, the first step is to find the data related and to gather the data that is to be given as input to the network. And the data is preprocessed using different image processing techniques [3]. The preprocessing is a method to perform some operations on the low quality image to improve the quality of the image or extracting the useful information from the images and the feature extractions [4] are to be done. The next step is to select the deep learning model that works efficiently and gives the state-of-art results. Then training the model is the most important step in the process flow where complete evaluation is based on how the model is trained and the best model that is selected to train the data. The training model is a dataset that is used to train the model that takes the input data to correlate with the output data against the sample output which is used in modifying the model. This is known as the “Model fitting”. The final step involves the evaluation of the model that has been trained. The model will be tested in this step against the training and validation dataset with

Received on 24-07-2021, Revised on 21-08-2021, Accepted on 26-09-2021.

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DOI: 10.32377/cvrjst2117

the unused dataset. Some metrics are used to measure the performance of the model.

Fig. 1, is the generic process flowchart of our deep learning survey.

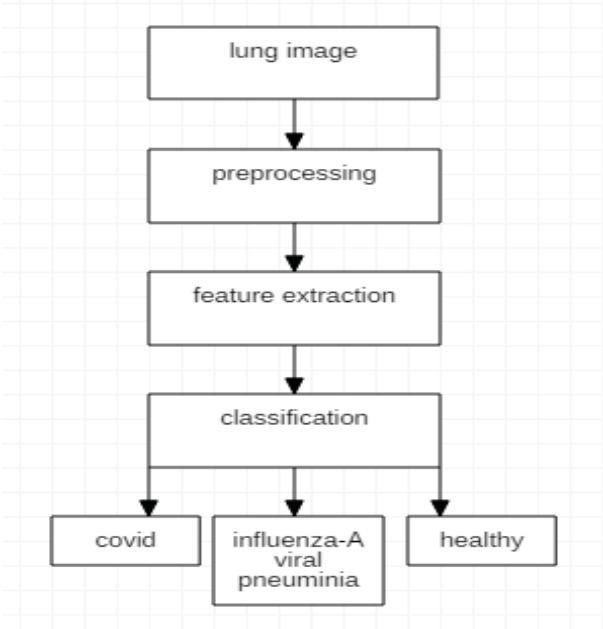

Figure 1. Generic process flowchart

The input we consider is either the lung CT scan image dataset or the chest X-ray image dataset from any open-source datasets. Further, the data is preprocessed to remove the noise from the data or to collect the important information from the images. The feature extraction is done to reduce the redundant or the unwanted features and extract the required characteristics which are most essential for classification. The final stage of the process is to classify the data using the selected deep learning models into binary classification (COVID-19 or healthy) or multiclass classification (COVID-19, pneumonia, healthy) with the best performance measures after training and model fitting the data.

Fig. 2, is the different types of CT lung images affected with COVID-19, Pneumonia and healthy.

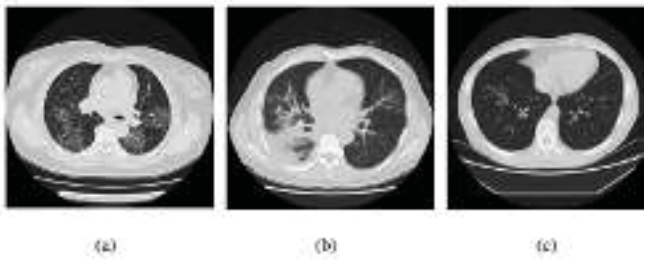

Figure 2. (a)CT lung image with COVID-19 (b) CT lung image with other pneumonia (c) healthy CT lung image

II. Related Literature

There were many models like Inception, ResNet, Transfer Learning, Deep Convolutional Neural Networks, Xception Networks, AlexNet etc., which are widely used in image classification, object recognition with best performances. In this section some of the existing techniques were explained.

A. Residual Network , Location Attention Mechanism:

(Xiaowei Xu, feb2020) aimed to develop an early screening model to detect and classify the COVID-19 from other pneumonia and healthy images in the early stage efficiently.

The data of total 618 Traverse Section CT samples from First Affiliated hospital of Zhejiang University were collected where 219 from 110 patients of COVID-19 , 224 from 224 patients with Pneumonia and 175 from healthy people. Of them 528 samples i.e 85.4% were used for training and remaining 189 samples i.e 14.6% were used for testing.

Fig. 3, is the process flow chart of this study where first the collected CT image dataset is used as input which were preprocessed to extract the pulmonary regions based on the HU values and is normalized to pixel value.

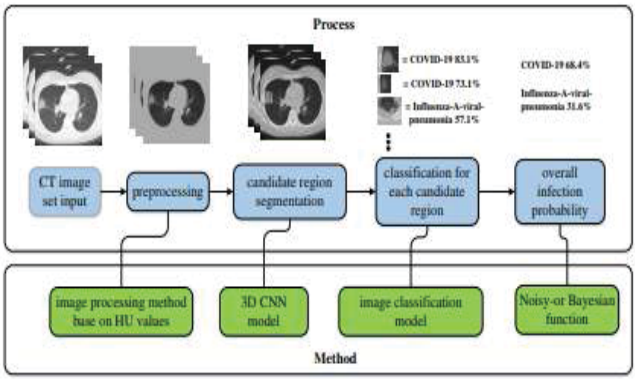

Figure 3. Process flowchart of model

The preprocessed images are then segmented using 3D CNN model i.e VNET based segmentation model called VNET-IR-RPN (VNET Inception ResNet Regional Proposal Network) [5] to separate the candidate regions ~ candidate patches from the images. Moreover, this is the model used for both segmentation and classification, but only segmented data were preserved.

Then the classification model was designed inorder to differentiate the infections by finding the relative-distance-from-edge that gives the location of the patches on the image. This is known as Location attention classification mechanism. First the minimum distance is measured from the mask to the center of the patch. Next, the diagonal of the minimum circumscribed rectangle of the image is obtained. Finally the relative distance from the edge is achieved by dividing steps 1 and 2.

The final step is finding the overall infection probability using the Noisy-or Bayesian function which classifies the image into one of the three categories considering the infection probability rate.

Fig. 4, is the Network Structure where two CNN classification models i.e ResNet based network and Location attention mechanism in fully connected layer were used by concatenating to improve the accuracy.

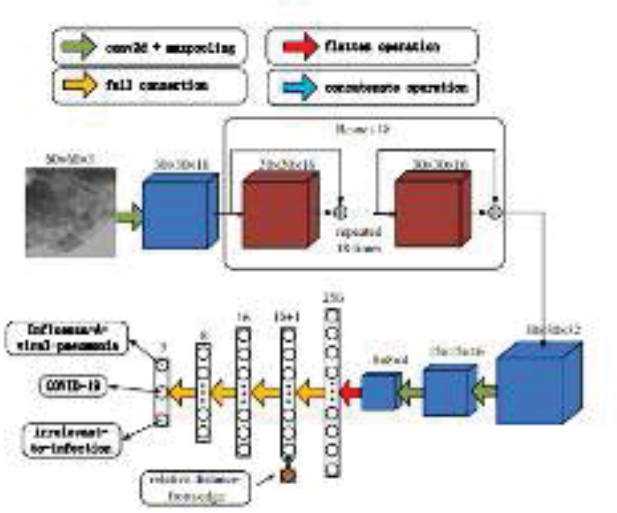

Figure 4. Network Structure

The ResNet model is used for feature extraction and pooling layers to prevent overfitting of the data by dimensionality reduction. Then the output is flattened to 256 dimension vector and then using Location attention mechanism it is again reduced to 16 dimension vector followed by three fully connected layers with the confidence scores are classified into any of the classes i.e COVID-19 or Pneumonia or healthy images with the overall accuracy rate of 86.7%.

The profit of using this model is, as the layers are increased using VNET-IR-RPN for segmentation and both ResNet and Location attention mechanism for classification leads to increase in accuracy and efficiency.

The major drawback in here is, it takes more time to train and evaluate the model as there were many layers for process.

B. Transfer Learning , Ensemble Classifier:

(M.Qjidaa, Y. Mechbal, A. Ben-fares jun 2020) aimed to develop an intelligent clinical decision support system to early diagnose COVID-19[6] from chest X-ray images easily accessible for the people in rural and remote areas.

The total of 566 X-ray images of COVID-19, pneumonia and healthy classes were collected from two open sources with public access. Of them 70% of the sample containing all the three classes were used for training and the remaining 30% of data was used for testing. As the data was collected was improper as it was collected from two different sources, it was subjected to preprocessing and augmentation.

I. **CNN and Transfer Learning:** The steps involved are first, several pre-trained neural networks where the classifier selects the network with the highest accuracy rate which transforms inputs into vectors. Then taking the advantage of these pre-trained models an ensemble model is built which outperforms all the remaining pre-trained models with the best performance.

II. **Pre-trained Neural Networks :** Using different pre-trained models –VGG16, VGG19, MobileNet, Inception V3, Xception, InceptionResNetV2, DenseNet121 as shown in Fig. 5, gives the output with the maximum prediction using Ensemble classification.

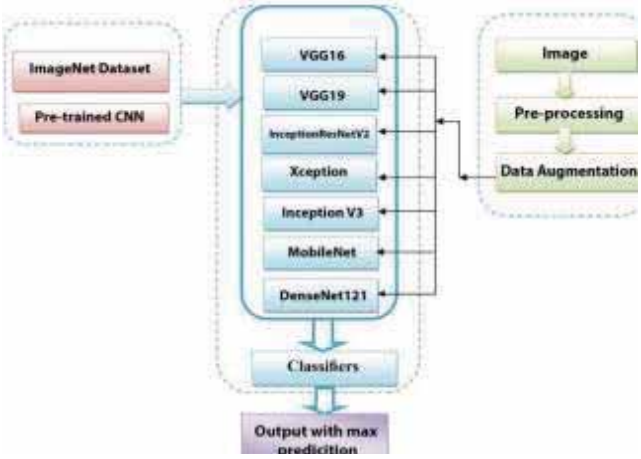

Figure 5. Model process

a) VGG16, VGG19: VGG network is a pre-trained image recognition model that has upto 19 layers where as VGG16 is one of the VGG network that has 16 layers and VGG19 has 19 layers deep. These are used as the pre-trained models in this survey.

b) MobileNet: It has depthwise separable convolutions to construct lightweight deep convolution neural network that is efficient for mobile applications. It is used as pre-trained model with trainable and non trainable layers in this survey.

c) InceptionV3, InceptionResNetV2: It is a Convolution Neural Network of the Inception family. This model InceptionV3 is developed of many improvements i.e label smoothing, batch normalization and widely used in image recognition and classification with depth of 48 layers and InceptionResNetV2 is the concatenation of both Inception and Residual network has residual connections helps in increasing accuracy. These are used as the pre-trained models with trainable and non-trainable layers.

d) Xception: It is an extreme version of Inception which was improvised in many aspects and is used as another pre-trained model.

e) DenseNet121: It is a Convolution Neural Network that connects to the layers that are deeper in the network i.e first layer is connected to 2^{nd} , 3^{rd} , 4^{th} layers and second layer is connected to 3^{rd} , 4^{th} , 5^{th} layers etc., so on and this is selected as the pre-trained model in this survey .

III. **Ensemble Classification:** It is the learning algorithm that constructs the classifier and then classifies the data using the maximum of the predictions. It is developed by combining several models that help in predicting with the highest of the pre-trained model's accuracy and efficiency. As shown in Fig. 6, in this study, the Ensemble

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DOI: 10.32377/cvrjst2117

classification is used to merge the prediction of all the seven pre-trained models with the prediction vectors as output and takes the majority voting as the final prediction class with the overall accuracy of 98% in this study.

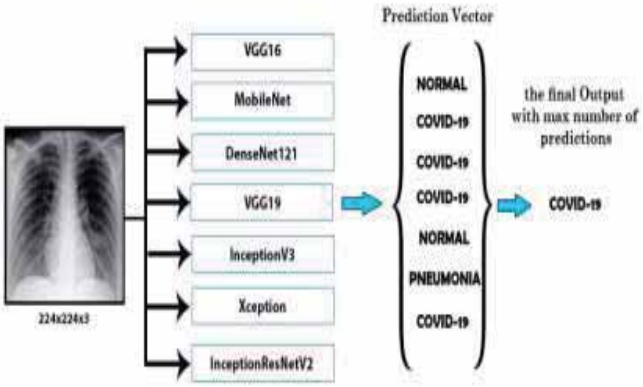

Figure 6. Ensemble Classification

The advantage of applying the Ensemble method on the different pre-trained models classifies with the best accuracy and efficiency.

The major drawback is although it improves the accuracy and efficiency, it costs more to create, train and deploy the model and sometimes new observations can confuse the model in classification.

C. Deep CNN using InceptionV3:

(Sohaib Asif, Yi Wenhui, Hou Jin sep2020) [7] aimed to detect the COVID-19 pneumonia patients automatically using X-ray images using Deep Convolutional Neural Network model by maximizing the accuracy and efficiency. This deep learning model was built so that it could extract the graphical features of COVID-19 that makes the work easier in classifying data into COVID-19, normal and pneumonia classes.

Total of 864 COVID-19, 1345 pneumonia and 1341 healthy X-ray images were collected. As the model selected works good for the large datasets, so the data was subjected to preprocessing and augmentation inorder to increase the dataset.

Transfer Learning: The transfer learning is used on smaller data set as this model is based on the concept of reusability i.e learns from the previous data. It is transfer learning best use. Whereas it does not work well with the large dataset as it is difficult for the experts to collect the data, label it which takes lots of time effort and cost.

InceptionV3: So InceptionV3 is used in this study as it works best on a large dataset. Fig. 7 is the InceptionV3 architecture that performs convolution, pooling, softmax and fully connected processes. It is a pre-trained Neural Network where one block can be used as the initial layer of the next block. It involves two steps where it uses the feature extraction of convolution neural network and the classification uses the softmax and fully connected layers.

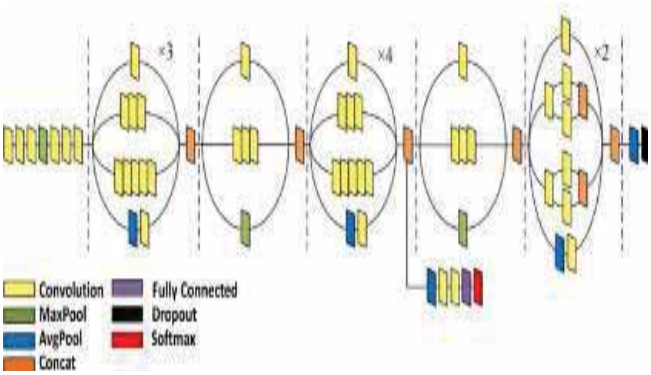

Figure 7. Inception Blocks

The step-by-step procedure of the classification of InceptionV3 model architecture is as shown in Fig. 8.

i. Recursively performs convolutions and pooling
ii. Then applies dropout and fully connections where the image is classified according to the training class labels.

Convolution is the process of extracting the features of the input image in which each pixel is responsible to produce the output. It is a feature extraction process.

Pooling layer is used to remove the noise from the obtained features. These are of two types: Average pooling and Max pooling.

The dropout is used inorder to avoid the over-fitting of data, Then the fully connected layer is applied to final classify the data.

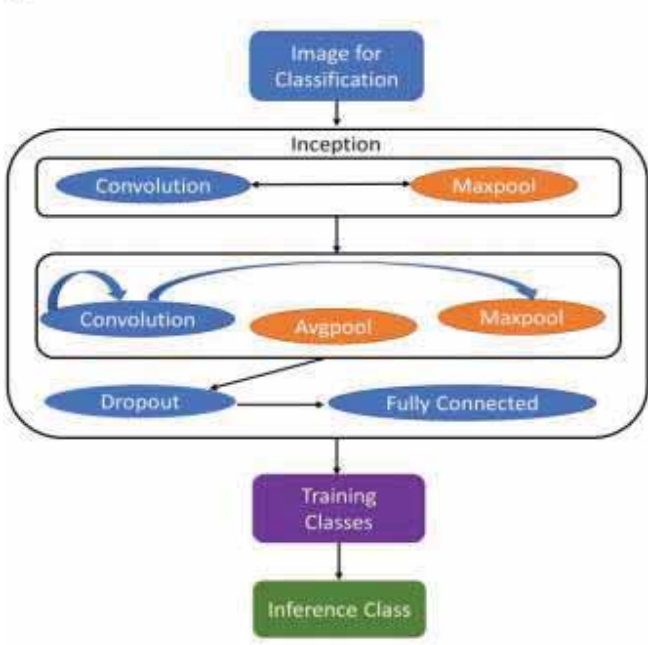

Figure 8. InceptionV3 model Architecture

The full schematic diagram of the model Deep CNN based InceptionV3 implied to classify the data into three classes i.e COVID-19, pneumonia and healthy as shown in the Fig. 9.

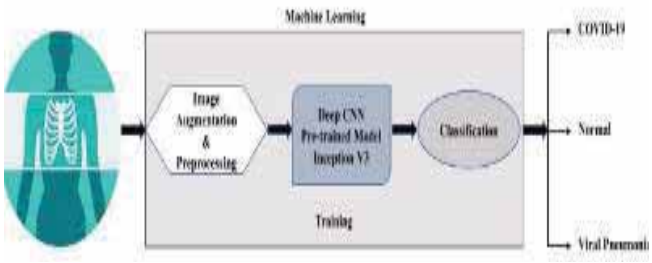

Figure 9. Schematic diagram of model

The X-ray images are used as the input images for the model. The images were augmented and preprocessed. The pre-trained model Deep Convolutional Neural Network based InceptionV3 is used for training the model having applied all the layers. After training the model, the data is classified according to the training models as COVID-19, pneumonia and healthy classes. This model then gives out the classified class that outperformed the existing models with the accuracy of more than 98%.
This is the algorithm for the model classification:

Step 1: Start
Step 2: Create list of images // Start training the model
Step 3: Provide a directory for storing the bottleneck value of each image
Step 4: Provide inference to the images // to create bottleneck values
Step 5: Create folder for all images of bottleneck values
Step 6: Generate bottleneck values for each individual image
Step7: Create new softmax layers and fully connected layers// end of training
Step 8: Test new image // input chest x-ray image to get the result
Step 9: Finish

Algorithm for classification

As the network used is deep Convolutional Neural Network where a model block is used iteratively with different layers embedded for feature extraction and denoising is the best advantage that helps in increasing the accuracy and the model outperformed than the other existing models.

But the drawback is that it uses a lot of parameters and takes a lot more memory to run the training model followed by testing.

D. Concatenation of Xception and ResNet50V2:

(Mohammad Rahimzadeh, Abolfazl Attar May2020) aimed to apply the deep learning methods to achieve best results in detection of COVID-19, healthy , pneumonia classes . The model is developed in such a way that it works better on unbalanced dataset also.

The dataset is collected from two open sources of chest X-ray images with 180 images from 118 COVID-19 cases, 42 from 25 pneumonia cases from the first source. And 6012 cases with pneumonia, 8851 normal cases from another source. All the data were combined into a single dataset. After that, the dataset is balanced to achieve good results for training and evaluation.

Networks: The Xception model is concatenated with the ResNet50V2 model in this study. Xception model is a pre-trained model which is the extreme version of the Inception model that has the depth-wise convolutional layers and point-wise convolutional layers. This model has given the best performance above all the networks that are existing using ImageNet dataset. ResNet50V2 is also a pre-trained network that consists of skip connections which tend to use the important layers and skips some of the layers that are not needed inorder to decrease the time of training and evaluation.

As shown in the Fig. 10, an architecture of concatenated models Xception and ResNet50V2 [8] , the dataset collected is used as the input for the concatenated model which is used parallely for deep feature extraction and these concatenated features are further connected to the convolutional layer with filters, using kernel and padding applied to it using no activation function helped in the extraction of valuable semantic features from the spatial points of all channels. Then the fully connected layer is added to flatten the channels, dropout layer is used to remove all the unwanted features followed by the classifier that classified the data into COVID-19, pneumonia or healthy classes with an outperformed accuracy rate of 99.50%.

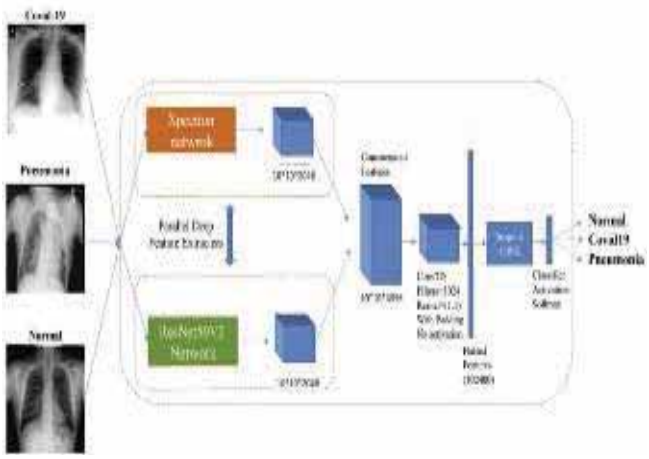

Figure 10. Architecture of model

As the Xception model has the depthwise convolutions and ResNet50V2 has skip connections, concatenating both have their unique features gives best results.

E. Deep CNN using DeTraC:

(Asmaa Abbas, Mohammed M. Abdelsamea sep2020) aimed to develop a deep convolutional neural Network called DeTraC to classify the COVID-19 chest X-ray images that has the speciality of removing the irregularities present in the data by exploring the class boundaries using decomposition mechanism.

The dataset is the package of 80 samples of healthy images, 105 samples of COVID-19 and 11 samples of pneumonia.

DeTraC: It is abbreviated as Decomposition Transfer Learning Composition [9] and there are steps involved in this model to classify the data into COVID-19 pneumonia or

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healthy classes. This model is used in order of decomposition followed by transfer learning and composition of the data.

The class decomposition is used in splitting up the data and takes the data that is required by considering the features taking the decision boundaries into consideration inorder to enhance the properties of the data and then the performance of the model.

The transfer learning is to transfer the insights gained from the previous model to the next model. This has three steps Shallow tuning, deep tuning, Fine tuning. Of them Shallow tuning takes only the last data parameters to merge with the new data whereas the deep tuning retains all the data parameters and Fine tuning trains more layers till the performance is achieved.

Composition is making up the data together that was decomposed inorder to increase the quality and improve the performance of the data.

The DeTraC architecture consists of three phases where in the first phase, the data is trained with the DeTraC model then the training is done using the Gradient Descent optimization. Finally, the class composition is applied to the data as shown in the Fig. 11.

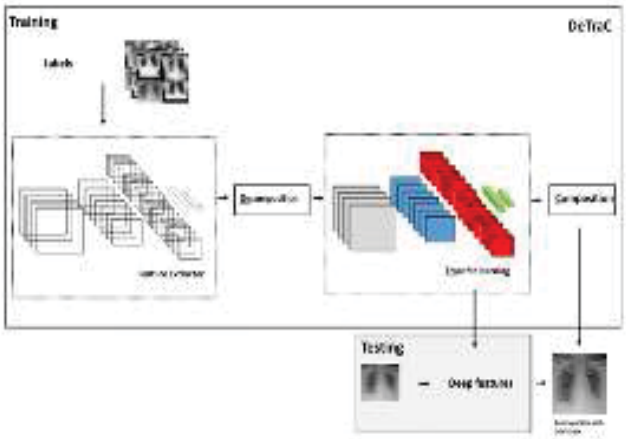

Figure 11. Architecture of DeTraC

In this class composition, a 2D feature space is considered from principal component analysis outputs consists of a number of classes where K-means clustering is further applied to divide each class into different subclasses where each class is associated with the centroid near to it based on Euclidean distance metrics. After the clustering is finished, each class is again divided into different subclasses as a new dataset. For the class decomposition AlexNet pre-trained model with shallow learning mode is used to extract the features of the classes.

In Transfer learning, the final classification layer from the class decomposition is considered and then the fine tuning is applied on the parameters adopted.

In the class composition, the subclasses that are segregated will be assembled back to actual classes as to produce the final prediction based on the actual classes with the accuracy rate of 97.35%. All the stages were explained in the algorithm as shown.

Algorithm: Procedural steps of DeTraC for COVID-19 detection.

1: Procedure

- Input:
  -CXR image set divided into training and testing sets.
  -Ground truth tables.
- Output:
  -Predicted labels.

Stage 1 Class Decomposition:

-Use an ImageNet pre-trained CNN model (e.g. AlexNet) as a feature extractor to construct a deep feature space from input CXR images.
-Apply PCA on the deep feature space for dimension reduction.
-Use reduced feature space of the input CXR images to decompose original classes into a number of decomposed classes.

Stage 2 Transfer Learning:

-Adapt the final classification layer of an ImageNet pre-trained CNN model to the decomposed classes.
-Fine-tune parameter of the adopted pre-trained CNN model.

Stage 3 Class Composition:

-Calculate the predicted labels associated to the decomposed classes.
-Refine the final classification using error-correction criteria.

Algorithm for DeTraC

This work deals with the most challenging problem i.e data irregularities and also fine-tuning is used in transfer learning helps in resulting the best output.

III. Results

This section describes the results of all the papers that have been included for the review. And the graphical representation and the tabular formats of the results for the respective models used.

Fig. 12 is the loss and accuracy curves for the two models belong to the first paper i.e Residual Network, Location attention mechanism. The graph is a comparison between the loss and accuracy ResNet+ Location-Attention and ResNet alone. The model with Location-Attention performed well with the accuracy better than the model without Location-Attention mechanism with the increase in the epochs. The loss values or the accuracy values did not increase or decrease suddenly. The models also converged without any over fitting.

The Precision, Recall and F1-score were also calculated for all the categories COVID-19, Pneumonia, and Healthy ct images which resulted in 90% recall , 93.1% precision, and 91.5% F1-score with the overall accuracy rate of 86.7%.

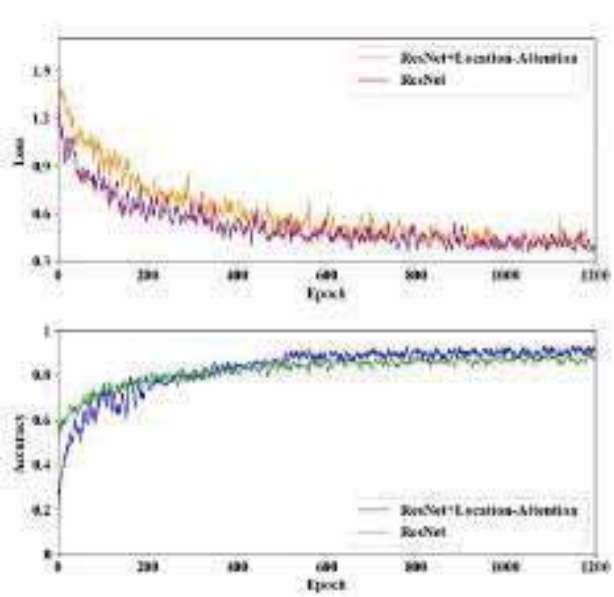

Figure 12. Graph of Loss and Accuracy between ResNet+ Location-Attention and ResNet

Table 1 is the results of all the models and the Ensemble methods for the model Transfer learning and Ensemble classifier. The test accuracy is calculated with the learning rate of 0.001 reduced for every 4 epochs, model configured for every 60 iterations. As shown, VGG-16 and VGG-19 accuracy is high 96.88 and 95.31. But after combining the entire models using the Ensemble classifier, the accuracy precision recall and F1-score increased as 98, 98.66, 98.33 and 98.30.

TABLE I.
RESULT TABLE FOR ALL THE MODELS AND ENSEMBLE CLASSIFIER

Model	Precision (%)	Recall (%)	F1-score (%)	Test Accuracy (%)
VGG-16	91.66	90	90	96.88
VGG-19	96.60	97	96	95.31
Inception ResNetV2	96	95.66	95.66	89.06
Xception	95.66	95	95.33	95.31
InceptionV3	92.33	93	92.66	92.66
MobileNet	92	89.66	90.33	89.06
DenseNet121	97	97.21	97.66	92
Ensemble Method	98.66	98.33	98.30	98

Fig. 13 is the training accuracy and cross entropy measured for the model Deep CNN using InceptionV3. The accuracy and Cross entropy are found for 4000 steps. Where the model has given the accuracy of 96% for 4000 steps for the training set and for the validation the model has given the accuracy of about 95.2%. Coming to cross entropy, the model has given the low cross entropy with the increase in the number of steps. The overall accuracy achieved with the DeepCNN using InceptionV3 model is 98%.

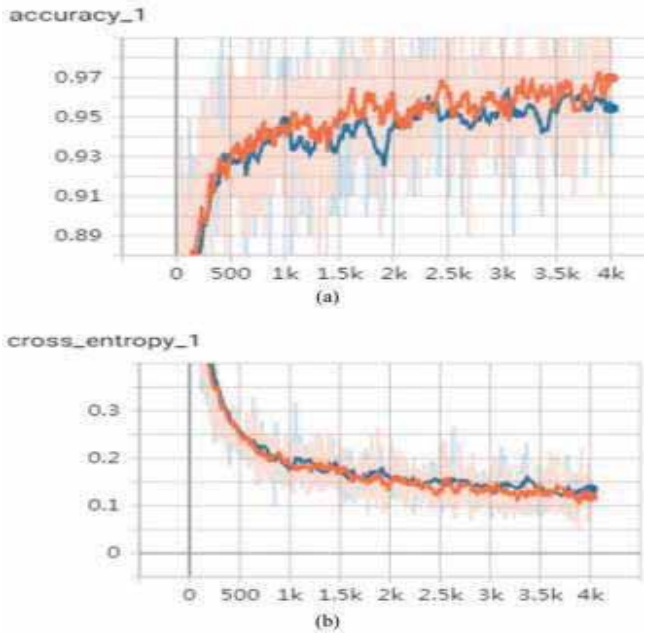

Figure 13. Visual of Accuracy and Cross Entropy.

There are some models that have an accuracy rate of 93.1% and 99.50%. But the difference is some of the models performed well for smaller data sets and some of the models performed well for larger data sets. Overall results were very accurate and efficient for all the models that were discussed in the paper.

IV. CONCLUSIONS

Among all the manual existing methods, Deep learning methods are very efficient in early detection and the classification of the COVID-19 from the Chest CT, X-ray images. This study is completely about the different deep learning techniques used with the different datasets collected from various open sources. The existing models have performed well with the data collected giving the best accuracy. And the advantages and the disadvantages were also explained after each model. With the processed datasets and the efficient models, the detection and classification would be more efficient.

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