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NEURAL NETWORK AIDED OPTIMIZED AUTO ENCODER AND DECODER FOR DETECTION OF COVID-19 AND PNEUMONIA USING CT-SCAN

[1]SRINIVASA REDDY K, [2]P. VENKATESWARA RAO, [3]A.MALLIKARJUNA REDDY, [4] K SUDHEER REDDY, [5]DR. J. LAKSHMI NARAYANA, [6]SRI SILPAPADMANABHUNI

Professor, School of Computer Science and Engineering, VIT-AP
Assistant Professor, Department of Computer Science and Engineering, VNRVignana Jyothi Institute of Engineering and Technology
Associate Professor, Departmentof Computer Science and Engineering, Anurag University, Hyderabad
Professor, Department of Information Technology, Anurag University, Hyderabad,India
Professor, Department of ECE, Potti Sriramulu ChalavadiMallikarjuna Rao College of Engineering and Technology,Kothapet,Vijaywada

Associate Professor, Department of Computer Science and Engineering, Potti Sriramulu Chalavadi Mallikarjuna Rao College of Engineering and Technology,Kothapet,Vijaywada

Email: kondasreenu@gmail.com, venkateswararao_p@vnrvjiet.in, mallikarjunreddycse@cvsr.ac.in, sudheercse@gmail.com,drjln@pscmr.ac.in, silpa.padmanabhuni@gmail.com

ABSTRACT

Most of the countries in the world are now fighting against Covid-19 and many of the people are losing their life because of the less immunity or due to the late diagnostics and it is especially in the case of old age people and people with other medical issues. The concept of early detection of disease is really important in the case of the Covid-19 scenario because along with the infected people, the other people who are in close contact with the infected persons will also have life risk. During this pandemic, pneumonia and Covid-19 people suffers from almost the same symptoms. So, the proposed work designs an automated system that can perform multi-classification on general health, pneumonia and Covid-19 through Chest X-Rays by designing an optimized auto encoder- decoder network. Most of the earlier approaches which are used to perform the binary classification couldn't differentiate the Covid-19 and Pneumonia effectively because the traditional CNN extract the high level features, which are similar in case of COVID-19 & Pneumonia. These two have variations in the case of low level features. The major focus of this paper is to construct a hyper-parameterized auto encoder-decoder system that can help the user to detect level of lung infection. The level of infection helps the model to accurately classify the model. This method helps doctors and other medical-related people with the early diagnosis of disease.

Keywords: *Neural Networks, Augmentation, Auto Encoder Decoder, Latent Space Representation, Hyper-Parameters*

1. INTRODUCTION:

COVID-19 is an epidemic disease that made people across the globe fear their lives. The doctors perform identification of the disease by using the Positive PRC polymerase chain reaction (PCR) test. These test kits are available in a limited amount and it takes a lot of time to get the result. So, to overcome this problem our proposed system takes X-ray[1] as an input because research studies have proven that COVID-19 patients also suffer from a lung infection. Working on images and videos is getting much easier with the development of neural networks. Neural Networks take the input from original sources and generate the outputs by analyzing the relationships among the hidden patterns. COVID-19 is a highly infectious

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disease with difficult-to-predict characteristics. According to a study conducted by a Chinese team on COVID19, the majority of persons hospitalized in Wuhan, China, had anomalies in their chest X-rays, indicating bilateral involvement[2]. As a result, there is a strong need to develop a solution using less expensive methods to keep individuals out of quarantine. The data was gathered from a Chinese open source website called "Chester," which contains COVID-19, SARS, MERS, and ADRS chest x-rays. The healthy chest photos from the kaggle dataset can be used to train the system as shown in table 1. The detection of Covid-19 from chest X-ray using deep learning techniques plays a vital role in automation process and also reduces the cost of equipment because X-rays are less expensive than MRI and CT scan.To reduce the complexity involved in image classification and object detection, different CNN architectures are proposed. Auto encoders are famous for extracting the both high and low level images but the construction of encoder by checking every estimator of the neural network is difficult task which involves more resources and more combinations of estimators for checking the optimality. The proposed recognizes the best parameters that can design good encoder and good parameters for bottle neck using the optimization techniques. The efficiency of the network depends on some factors so there is a mechanism known as “Hyper-parameter optimization”. Hyper-parameters act as deciding thresholds for the betterment of values. The different hyper-parameter techniques are described in figure 1.

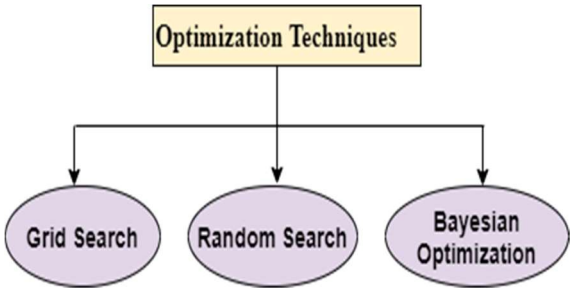

Figure 1: Classification TECHNIQUES IN Hyper Parameter Optimization

2. RELATED WORK:

The current research study explains about the novel pandemic that caused many loses in variant sectors round the globe. SARS-CoV-2 is the virus that was affected and have caused several deaths around 3v million according to [1]. By the author, many researchers have been working on identifying more about this deadly virus and have recommended few effective measures to standby it. A remarkable growth in pathogens has happened and many effective measures were being made to tackle with this pandemic. This article’s aim is to showcase a DL based COVID-19 identification over the data gathered from the X-ray and CT images. The objective in proposing this research article is to help the researchers by utilizing the current resources by making an in-depth study in training with ML for generating possible outcomes of the pandemic. The article presented a comparative study with the available researchers regarding COVID-19 and concluded that computer vision would be applicable in identifying the infected organs through the gathered data by comparing them to the healthy images.

This research study [3] focused on finding out the patients infected with COVID-19 by utilizing their radiographical reports because, the researchers have discovered that there would be a change in the patient’s lungs before and after they were infected when these scans were done at the early stages of their infection. Persuaded by this, this research was continued over the COVID-19 test cases by introducing a deep CNN framework designed developed especially for the identification of the infection through the chest X-ray pictures that were open and available for the public. Besides this, authors use an explain ability technique to examine how COVID-Net draws conclusions to not only obtain additional insights into significant elements affiliated with COVID instances, that can aid physicians in better inspection, but also to review COVID-Net in a transparent and accountable fashion to ensure that it is acting responsibly derived from existing information from the CXR pictures. The

research performed have shown a significant outcome in distinguishing among the normal, non-COVID and COVID-19 with a 94% of identifying the non-COVID19 category and 91% with COVID-19.

The primary motive of this paper is to develop a fast and automatic framework to diagnose the patients with COVID-19 using their CT images that is built on DL methods [4]. The researcher here has opted an innovative DL framework and a transfer training approach with a specified quantity designed for each DL structure to gain best outcomes. Extensive research has been done on two different pictorial datasets with CT scans of the patients with COVID-19. From the developer, their model had outperformed achieving higher results compared to the standard techniques.Many evaluation strategies were performed by gainingabout 99.4% of accuracy for the first dataset and92.9% for the second dataset respectively. For better understanding of the model and interpretation the developers had implemented visualization techniques for deeper explanations of the model. The model is said to be failed at identifying one of the infected lungs from the dataset. This means, the model could only identify the patients with heavy infection than identifying at the early stages.

According to [5], DL techniques could be applicable to the recent pandemic and could derive better results based on the patients'scanning images. In this study, a novel DCNN model named CoroNetwas implemented that could automatically identify the infected images from the chest X-ray images. Other architectures like Xceptionwere also performed over a pre-trained ImageNet dataset and trained over an end-to-end dataset by gathering the publicly available data. The developers say that their experimental outcomes have shown an overall accuracy of 89.6% and the preciseness of the model derived 93% with a recall rate of 98.2% According to the author, the developed model could also be applicable for larger amount of data as the currently underwent only over a smaller data with minimum possible pre processing and with deeper processing within the data the model is said to gain greater results and could be applicable to various other real time applications.

Due to the disease's rapid dissemination, [6] healthcare professionals are having trouble recognizing COVID-19 sufferers.The major priorities for developing a universal DL model are creating a coherent approach and maintaining privacy. This study presents a platform that uses blockchain-based collaborative intelligence to gather a limited quantity of data from various sources and build a universal Dl model. This solution verifies data and uses distributed training to build the machine worldwide while maintaining the organization's confidentiality. They initially presented a data normalization approach to cope with the variability of data obtained from multiple hospitals using various types of diagnostic equipment.To discover COVID-19 individuals, they utilized a Modular Network-based fragmentation and categorization. Finally, they devised a way for integrating BT with distributed training to interactively train a universal system while maintaining privacy. Furthermore, they had gathered genuine COVID-19 patient records that were available to the scientific community. The developed framework is said to attain 0.987 sensitivity as best compared to standard methods.

According to[7] implemented deep learning approaches on chest x-rays to detect covid. The author proposed pre-trained models for classification of images and applied fine tuning mechanisms for performing the feature extraction. In the pre-trained model, the last layer i.e., fully connected layer is customized with traditional SVM classification using linear kernel and obtained an accuracy of 94.7%. In this model, synthetic dataset combined from multiple data repositories is used. For extracting the deep features associated with the images, an ensemble architecture is proposed, it combines 5 pre-trained models and classification is performed by changing the kernel function of SVM and it is observed that among all the combination of ResNet-50 with linear kernel has obtained best

score. To fine tune the model, data augmentation technique with three major image manipulation operations is performed. The training with these newly created images has reduced loss function. To give end to end training, a 21-layered architecture is designed with all possible combination of layers.

From[9] ensembles MobileNet and SqueezeNet model by customizing the classification layers using "SVM". MobileNet is famous for segmentation process because of its dense layers and SqueezeNet is famous for classification because of its fire layers. It also implements AlexNet to reduce the cost of model. The fire layers acts as compressors and expansions depending on the requirement of the processing application. It also separable filters for compression phase and expansion phase which helps the model to define the hyper plane accurately and to convert the non-linear transformations into linear transformations. To handle the noises in image and low quality images, it reconstructs the entire image with the help of fuzzy logic technique and tries to reduce the distance between the pixels and improvement of color is performed by summing the elements of the pixel windows. Since the summing up of value increases the pixel value, the quality of image improves at low cost.

The researchers[10] designed Xception deep learning model to detect and analyze the chest x-ray images. In this algorithm, the pre-processing is implemented as a combination of traditional and data augmentation techniques then it is passed as input to the Xception model, which is a pre-trained model, the major advantage of this architecture is it has the capability to concatenate the layers and it also needs very less number of parameters to train. It uses Leaky ReLu activation function for performing inferences from the last dense layer but it implements softmax function to perform classification.

Sources[11] implemented fusion technique integrated with deep learning. Instead of normal images, this model fused HOG processed images with CNN and is passed as input to the neural network. In HOG step, it iteratively selects bins in different regions of image. Feature extraction is the crucial step in any of the image processing applications, in this model to preserve edges, it implements MAD filtering technique. It computes the fusion vector one is based on HOG and other is computed using CNN. These two vectors are added to form a new vector and a threshold limit is initialized, to ignore the unwanted features. The first serial fusion produces a vector of 1X7694 but the last feature vector reduces the dimension to 1X1183. It uses wavelet shed segmentation to identify the infected part in lung and then classify the images based on the level of intensity. It computes the fusion vector one is based on HOG and other is computed using CNN.

Authors have [12] proposed fast AI which is based on pre-trained ResNet to classify the chest x-ray images of covid patients. In fast AI, transfer learning helps the model to work with huge amount of data to produce more accurate systems than the models which work on smaller datasets. In this model, to enhance the training phase, it has implemented ImageNet, in which batch size is adjusted to 32 for 20 epochs. For performing feature extraction, it fine tunes the VGGNET-16 pre-trained model. The callback mechanism in fast AI helps the utilities of training phase to execute quickly and also performs customization of data blocks. All the weights assigned to ImageNet are fixed and it applies Residual operations on the down sample images. It reduces 7X7 size to 1X1 by continuously reiterating the layers with dynamic size variation of CNN.

According to the works on [8][13], the authors haveimplemented deep learning techniques on radiography images for automating the covid detection process. The model implemented transfer learning to avoid the training process from scratch. Out of the two mechanisms available in transfer learning, the model has choosen second approach in which pre-trained model is utilized for solving the classification problem. During this process, the researcher has customized VGGNET containing 16 layers as 13 layers has been maintained the same but the last

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3 fully connected layers are implemented for performing multi classification like covid, pneumonia, and normal. To perform feature extraction, it implements dense layer and reduces the feature vector size to 1X1X4096, which highly acceptable and trainable and it also avoids the problem of overfitting by implementing dropout by passing necessary threshold values basing on the maxpooling layers implemented.

The work of authors[14] proposed computation of uncertainty estimation process, which is considered as vital parameter in CT images. Any deviation from the results can make the radiologists to conclude in the wrong information. So, this model implemented semi supervised technique known as "MixMatch", using unlabeled data because these type of data are not controlled by the training and any missing information will not harm them. The computation of post-hoc capacity impacts the re-training of the deep learning model. So, more attention is given to this parameter. In this model, softmax is implemented as activation function and any class with highest prediction rate is considered as proxy element and mentioned as over confident output neuron. This problem is addressed by adding temperature as decision making parameter to activation function.

The researchers [15] have compared the working scenario of different pre-trained models on two types of dataset. In one dataset, they worked on chest X-ray and in second dataset; they work on CT scan images. The researchers implemented machine-driven generation algorithm in which MosMed technique creates an augmented data because of which the diversity of images increases and it is less expensive than transfer learning. The model has its uniqueness to identify the white pneumonia region by using glass opacity technique and its efficiency is computed with the help of mathematical notation known as "NCP and CP grouping". The entire dataset is divided into n batches and based on the progression learning rate of the image is computed and it is utilized to mixup the data to create fusion images using forward propagation. It also implements backward propagation while classifying the images.

The authors [16] have designed a novel approach known as "Squeeze Excitation Block" as a layer that can be immersed in CNN. The researcher also proposed mish activation function to optimize the convergence factors. In general traditional approaches researcher's implements pre-defined neural network layers but here the researcher combined max-pooling layer with SEB layer to extract the features and reduces the dimensions layer by layer using HAAR transformations. Since the model implements ResNet and VGGNet during classification process, it reduces number of trainable parameters. The combination of neurons and wavelet transformations can drastically reduces the number of layers by eliminating utilization of batch normalization layers.

The work proposed in [17], the authors havedesigned framework known as "EfficientNetB0", in which multiple pre-trained models are ensembled. The amount of data is increased by combining GANs and data augmentation technique and pipelined transfer learning takes care of classification process. Instead of activation function, the model has designed activation maps for both optimization and visualization of results. Image training is performed using VGGNet-16 and ResNet-50. To identify low level features, proposed framework is implemented and in the fine tune process the first layers of pre-trained models recognizes generalized features and backbone model helps to extract specific features. Grad-CAM activation maps help the model to exhibit the infected part using the concept of ROI.

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Table 1: Mechanisms Implemented in Previous Research

S.No	Authors	Algorithm	Advantage	Limitations/ Future Work	Accuracy
1	AmjadRehman	Machine learning algorithms	The author explained the usage and importance of data science in identifying the COVID-19	A practical study was not implemented.	91
2	Linda Wang	COVID – Net.	The method also makes predictions to make deeper conclusions into critical factors related to COVID.	In future, deeper enhancements could be included for finding the risks included, survival statistics, predicting risk status etc.,	93
3	HammamAlshazly	SqueezeNet and ShuffleNet	The model is said to outperform the early methods.	The model could only predict heavily infected images but not theidentify the early predictions.	99.4
4	AsifIqbal Khan	CoroNet	Computationally less expensive.	The performance can be improved better if the training data became available.	89.6
5	Rajesh Kumar	Blockchain	Private data was collected and experimented for this research. This method could collaboratively train the universal model with federated learning.	Working of the model for more number of attributes and huge data is not explained.	98.7
6	Ismael	Fine tuned for feature extraction. Pre-trained with linear SVM	Fine tunedResNet helps in deep training on the data available. Instead of local texture identification techniques, learning algorithms performs much more faster	It consists of limited images and the cubic kernel function need deep neural network for better performance	94.7
7	Rachna Jain	Xception Model	A deeply separable layer helps in reduction of training epochs.	The validation of data is performed well and it gives wrong output for real world data	97.97
8	Nur-A-Alam	Fusion based CNN	It efficiently handles speckle noise and low resolution images and it also reduce the	Implementation of k-fold validation can	98.36

			error rate during feature selection process	improve the efficiency of the model	
9	Mohammad Khalid	Transfer Learning	Usage of transfer learning has reduced the training time over large dataset.	Data pre-processing is not taken care before passing it to the neural networks	92.53
10	TahminaZebin	Backbone Neural Network	Ensemble mechanism reduces the complexity of model and also produces the accurate results for validation data	The utilization of pipeling technique increases training cost and time	96.8

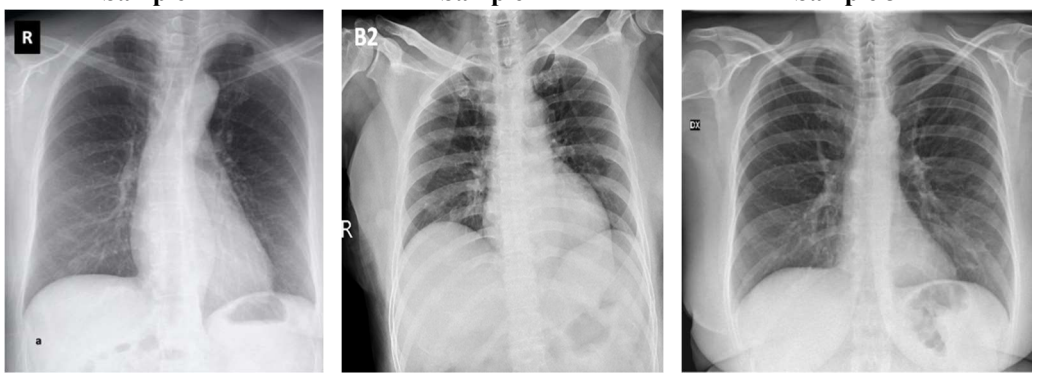
Problem Statement: The proposed research should include a mechanism that can identify the level of infection in the images. Most of the mechanisms don't pre-process the images with an intention that CNN layers have the capability for automation of pre-processing technique. So, the proposed model should design a layer that can normalize the elements of the image pixels. One more standard approach to differentiate the X-rays images is using either cross fold validation so that every epoch can get the training on every different possible class available in the dataset or by induction of random noise in the images. Transfer learning approaches are best for the models where, the classification involves in general images but for the medical images, it doesn't suit. So, the model needs to re-train the weights of fine tune layers to customize the freeze portions.

3. MATERIALS AND METHODS:

The proposed model works on the public dataset available at [14]. Since it contains three cases namely healthy, covid-19, and pneumonia, the model has decided to implement a multi classifier and the sample representations for each case is shown in figure 2 and the statistics are provided in Table 2.

Name **Sample 1** **Sample 2** **Sample 3**

Covid-19



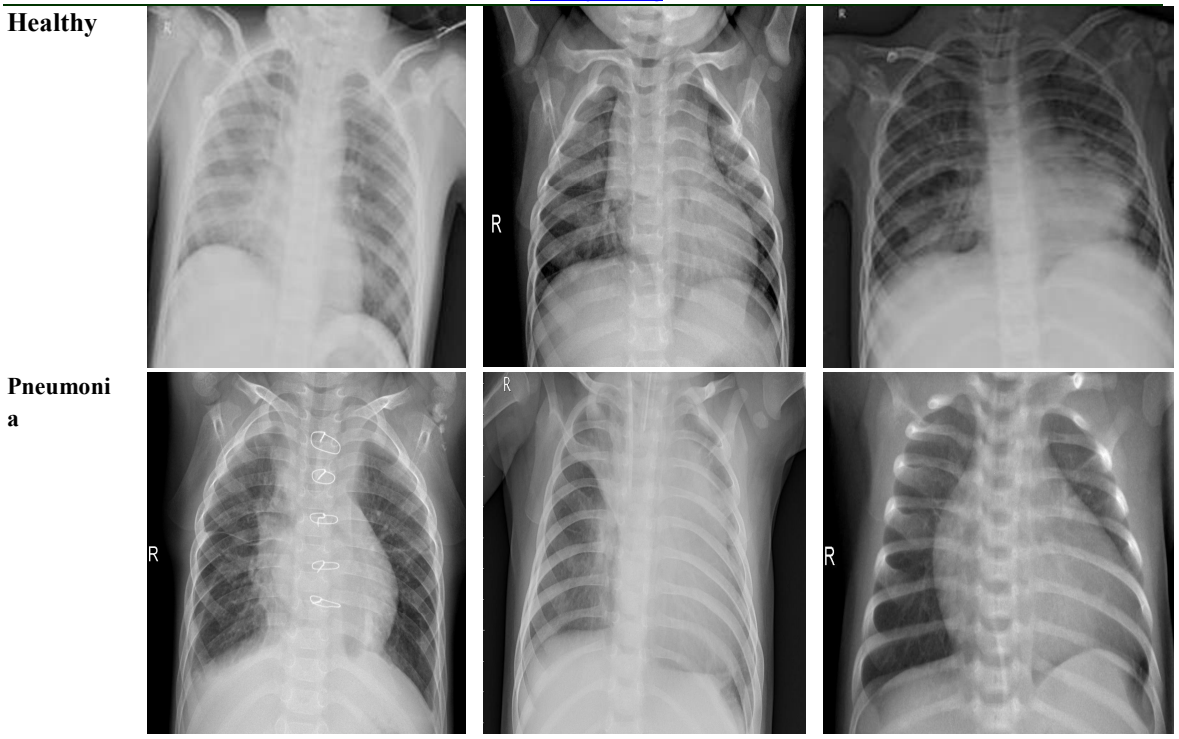


Figure 2: Samples Of All The Three Cases Present In The Dataset: Covid-19, Healthy, And Pneumonia

Table 2: Statistics on the images present in train and test datasets

	Covid -19	Healthy	Pneumonia	Count
Train Images	874	806	112	1793
Test Images	90	84	50	224
Total Images	964	890	162	**2017**

By observing the above sample data figures and statistics, the system has decided to perform two major operations as part of the pre-processing operation. First, it deals with resizing[18]all the images to the same size, because neural networks can work smoothly with the same size images as input. Second, from the statistics, the model tries to increase the number of images by performing basic manipulations on the image as described in table 3.

Table 3: Manipulation Operations on Image

S.No	Operation Name	Value	Description
1	Scaling	1/255	To make all the images ofthesame size
2	Shift (Horizontal & Vertical)	30%	It shifts the image pixel values in both the directions
3	Horizontal Flip	True	It transforms the horizontal pixels into vertical pixels
4	Zoom	50%	The nearest neighbors values are replicated so that most of the values gets intensified

After applying these operations, the new images created are shown in figure 3. These are utilized in online mode for further processing.

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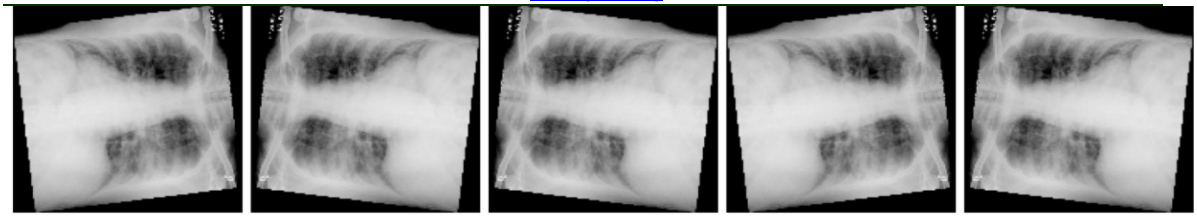

Figure 3: New Images Creations Using Image Operations

The proposed algorithm uses auto-encoders and decoders [16] to extract the features since they are good at handling dimensionality reduction, which is kind of unsupervised machine learning and mainly deals with noisy data. Suppose the units in the hidden layers get all the features from the previous layer because of the fully connected network[19] then it may suffer from a bottleneck problem. So to avoid this auto-encoder tries to learn features from the existing structure and creates a compressed vector representation then using the auto decoder it again reconstructs the input image. The auto-encoders are popular for understandably presenting the features. The architecture for the auto-encoder using CNN is represented in figure 4

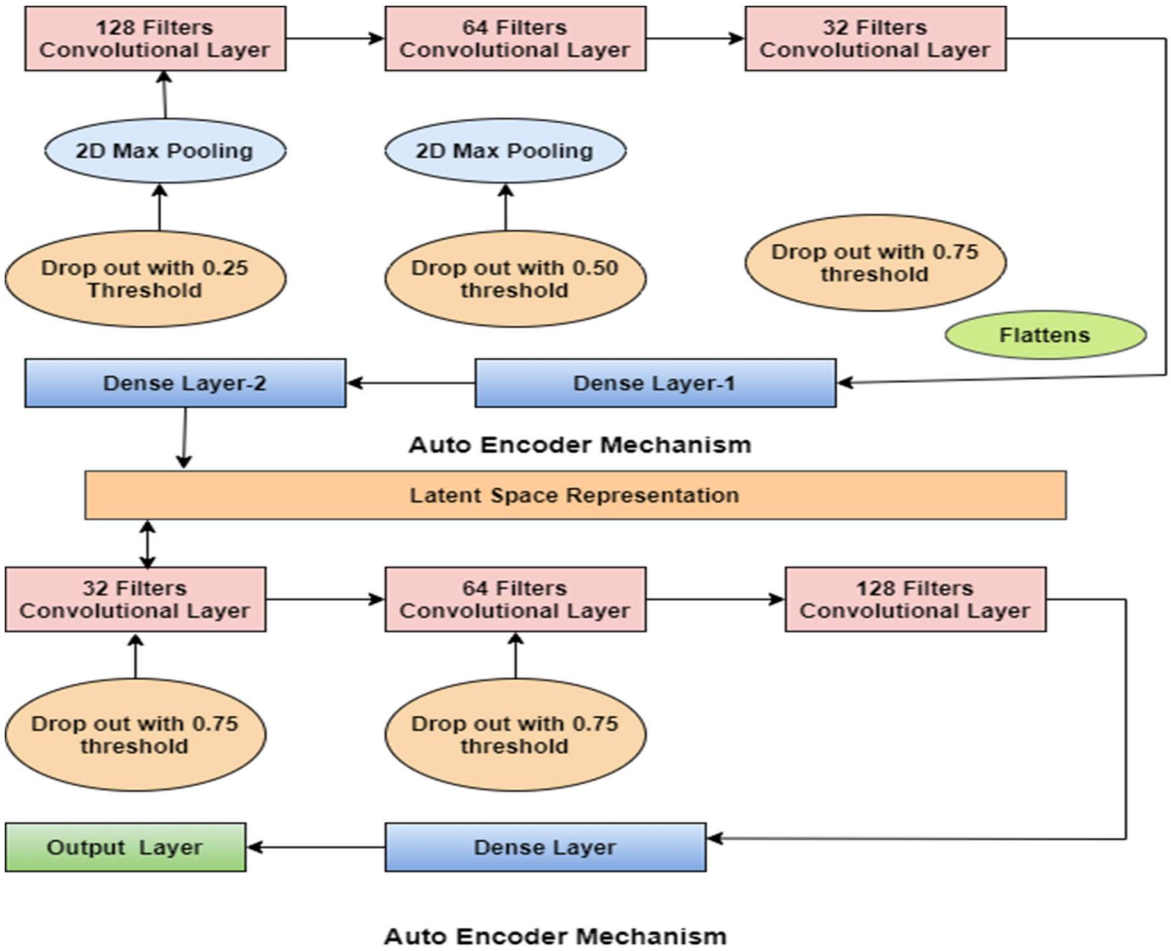

Figure 4: 5-Layered Architecture for Auto Encoder Decoder Mechanism

These images are passed as input to the neural network layer to extract the features of top layers and are presented in figure 5.

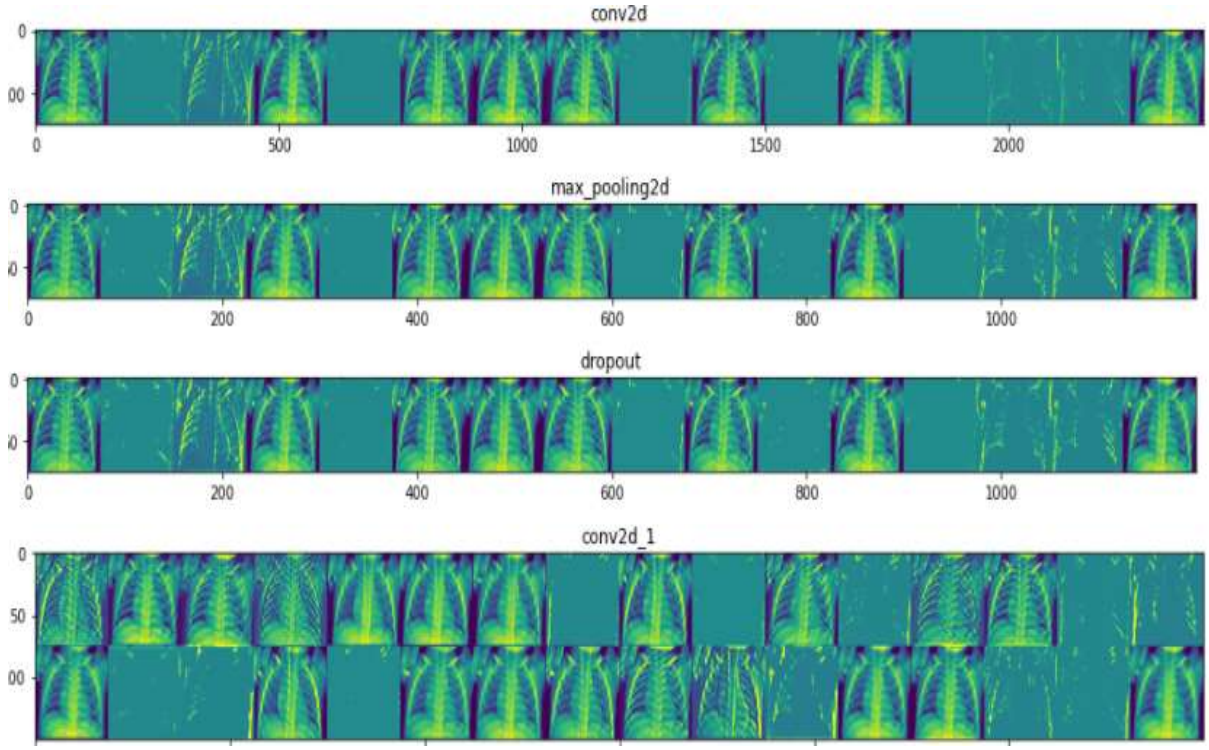

Figure 5: Presentation of extracted features using Neural Networks

The proposed model has applied Bayesian Optimization[20-27] to decide the Hyper Parameters of the neural networks. The obtained performance for the model with different combinations of the parameters is described in table 4.

Table 4: Hyper-parameters turning using Bayesian Optimization

S.No	Parameter	Value	Description
1	Learning Rate (LR)	0.003	The time needed by the network to learn the patterns from the hidden layers and get acquainted with configuration. The lesser rate always helps in training [28,29]
2	Weight Decay	0.01	When the number of features increases then the model and its training becomes complex. By adding all the features to the loss function sometimes it might result in zero. So, the training model assumes a value and multiple with

			feature value, it claims it as "Weight Decay".
3	Batch Size	32	It defines the number of samples with which the model should work in the process of training [30].
4	Loss Function	Multi-Class Entropy	It calculates the probability distribution and tries to minimize the difference between the actual class and the predicted class[31-32].
5	Optimizer	RMSProp	The major advantage of RMSProp is it can easily immerse with newly updated weights
6	Number of Epochs	350	It represents the number of times the complete process has to take place.

4. EXPERIMENTAL RESULTS:

The proposed system performs better than the previous by doing the multi-classification[21] task and it is reported in the following confusion matrix represented in table 5.

Table 5: Multi-Classification Confusion Matrix Table For Optimized Neural Network

		Predicted Values			Count
		Pneumonia	**Healthy**	**Covid-19**	
Actual values	**Pneumonia**	12	2	0	14
	Healthy	1	103	1	105
	Covid-19	0	0	105	105
	Count	13	105	106	**224**

In the computation of the confusion matrix, the accuracy calculation remains the same as of the binary classification, which is represented in equation 1

$$accuracy\_multi = \frac{T_{PP}+T_{HH}+T_{CC}}{Total\ Count} \text{ - (1)}$$

$$= \frac{12+103+10}{224} = \mathbf{98.12\%}$$

Where T_{PP} denotes the true label value for pneumonia

T_{HH}denotes the true label value for healthy

T_{CC}denotes the true label value for covid-19

The precision and recall computation is computed by weighted average per class. The metric "per class" computation is shown in equation 2 and equation 3.

$$percision\_per\_class = \frac{true\ value\ for\ tha\ \ particular\ class}{total\ count\ of\ predicted\ class\ value} \text{ - (2)}$$

Precision_per_pneumonia=$\frac{12}{14}$ =0.857

Precision_per_healthy=$\frac{103}{105}$ =0.980

Precision_per_covid-19=$\frac{105}{106}$ = 0.990

The weighted average of precision= ∑percentage of i^{th} class actual total* precision of i^{th} class

$$= \frac{14}{224}*0.857+\frac{105}{224}$$

* 0.98+$\frac{105}{224}$* 0.99 = **95.9%**

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$$recall\_per\_class = \frac{true\ value\ for\ that\ particular\ class}{total\ count\ of\ actual\ class\ value} \text{ - (3)}$$

Recall_per_pneumonia=$\frac{12}{13}$ =0.923

Recall_per_healthy=$\frac{103}{105}$ =0.980

Recall_per_covid-19=$\frac{105}{105}$ = 1

The weighted average of recall= ∑percentage of i^{th} class predicted total* precision of i^{th} class

$= \frac{13}{224}$*0.923+$\frac{105}{224}$ * 0.98+$\frac{106}{224}$* 1= **96.69%**

The proposed model compares the simple auto encoder-decoder with a hyper parameterized network and it is observed that the optimized network has good evaluation. The values are illustrated in table 6.

Table 6: Comparative Study On Different Neural Networks

	Accuracy	Recall	Precision	F-score
Convolution Neural Network	70%	69.6 %	67.8%	70.11 %
SimpleAuto Encoder Decoder	85.6%	82.3 %	84.1%	95.7 %
Optimized Auto Encoder Decoder	98.12%	96.69 %	95.9%	96.24 %

The comparative study graph representation is shown in figure 6. In Figure 6, X-axis represents the metrics that are needed to evaluate the model and Y- axis represents their measure in terms of percentages. In terms of all metrics, it is clearly evident that encoders are better than simple CNN but with the optimized parameters of the encoders, the proposed model has exhibited much better than the traditional encoder. In terms of accuracy alone, it is clear that from simple CNN to Optimized encoder the performance is improved by nearly +20%, which is highly remarkable.

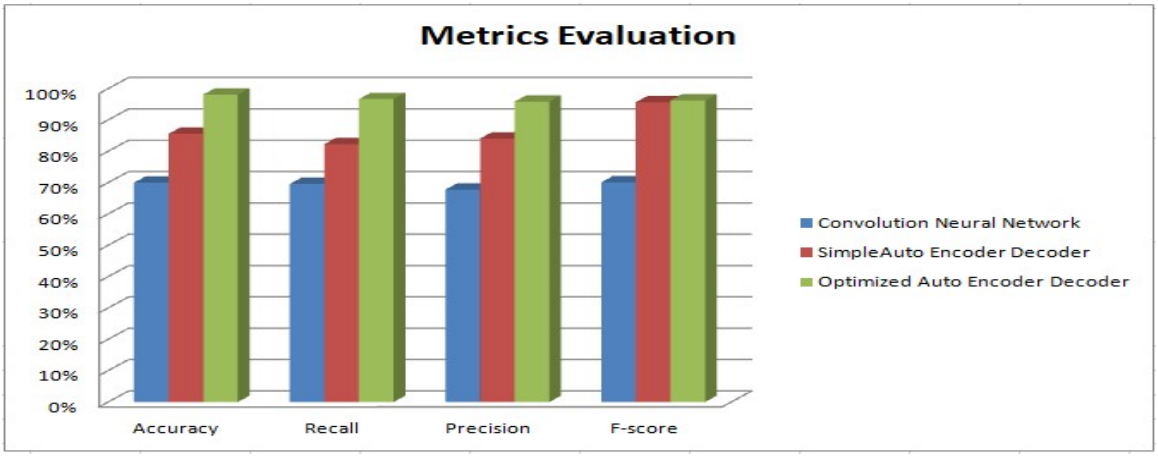

Figure 6: Graphical Representation Of Performance Metrics

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5. CONCLUSION:

This automated multi-classification model has obtained an accuracy of "98.12%" for classifying the images into three categories namely covid-19, pneumonia, and healthy. The model has tried to improve the performance by defining the important parameters in different combinations. The precision and recall metrics show that the system correctly the true labels accurately and better than the other systems. The proposed system has very low loss values in each iteration so the model can efficiently predict the COVID-19 but the system has observed from the visualization graph, at a certain interval of time the system has reached 100% accuracy, which represents the system may suffer from overfitting problem. Many models suffer from overfitting because of the noisy data, So to address this issue researchers can design good fine tuned transfer learning techniques which help the model to get sufficient training.

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