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IDENTIFYING COVID'19 SEVERITY USING DEEP LEARNING MODELS FROM CHEST X-RAYS

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ABSTRACT

The contribution of Artificial Intelligence to the medical field in diagnosing various ailments have been triggered in the recent years and one such impact is the exposure of corona virus in the most reliable manner. Recently the familiar infection COVID 19 caused by coronavirus was first discovered in Wuhan in the end of the year which became major disaster for this century. The disease spread rapidly without control and the only remedy was preventive measures taken in advance. The examination depended on chest x-ray images which were processed to differentiate from pneumonia and other cold related diseases. This paper is related to the images identified as corona virus and the sternness of the disease is categorized into three classes. The images are segmented and classified using various deep learning techniques like Residual network, Exception model and Dense net model for comparison purposes. The best model is chosen from the accuracy produced with the given data sets. The deep learning Xception model proves to be the best with overall accuracy of 89% in identifying the disease using the chest x-ray images.

Keywords: *Artificial Intelligence, Corona Virus, COVID 19, X-Ray Images, Pneumonia, Deep Learning Techniques, Residual Network, Exception Model, Dense Net Model.*

1. INTRODUCTION

Almost in western and Asian countries there is suEarly during the year 2020 and till today the pandemic disease called corona is present world around terrifying the entire population. The recent statistics provides details about the affected inhabitants with confirmed cases and the victims of the disease. The significant measure to be taken is the detection of this virus at the earnest to break further spread and start the treatment procedure [1]. The new virus belongs to special type called Severe Acute Respiratory Syndrome (SARS) related to common cold. The detriment of this virus is the informal transmission by simple contact of the infected person and through contamination since the virus is alive for several hours. The symptoms are also more common like cold, cough, fever and tough breath similar to common cold or influenza confusing the medical experts to confirm whether the patient is affected by corona in the early stage. So proper diagnosing tests are required otherwise the situation will become fatal with unidentified illness.

The pandemic was introduced world around in three cycles called waves attacking the society from the outbreak of this disease starting from the mild stage to severe damage of the lungs finally resulting in death. The mortality rate could be controlled by prior action in identifying the diseased persons and their stage to support in the treatment measures. The research study presented here addressed the same by improved method presented here. Diagnosis was enabled by chest images since other methods like RT-PCR test failed to produce the results in short period and analysis was interrupted. By 2021 India was badly influenced and became the second country affected in the world. A simple survey provides the state wise details about the spread of the disease. Table 1 show the statistics report about the major infection phases in various states.

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Table 1. State Wise Report About Corona Virus

S.No	Category Types	State Name	Confirmed Cases (Sate wise in order)
1	Severe	Maharashtra, Delhi, Gujarat, Madhya Pradesh, Andhra Pradesh, Uttar Pradesh, West Bengal	7972474, 1934009, 1231483, 1044243, 2321379, 2090050, 2027901
2	Moderate	Tamil Nadu, Rajasthan, Punjab, Bihar	3473116, 1288328, 762755, 832581
3	Controlled	Kerala, Haryana, Jammu and Kashmir, Karnataka, Telangana	6634722, 1015501, 455006, 3968365, 800476

The reason for the infection is still in misperception and victims are in fluctuating number still in the country expecting proper assessment for the virus contamination. According to Union Health Ministry, India faced a maximum of 1,021 cases per day and the gradual decrease in thousands of the active circumstances was also experienced.

The need for the effective and consistent remedy leads to the deep learning approaches like CNN models to provide solution for the persistent infection by classifying corona affected patients from other normal persons [2]. The classification task is complex due to the similar features found in the images affected by cold or influenza also. So, extended architectures are used for classification with transfer learning methods to identify corona affected persons like Exception model and Dense net model along with residual model based on the convolutional neural network model. Automatic feature extraction is done in these deep learning models to enhance classification in earlier way.

The proposed model aims at processing of chest x-ray images to identify corona affected persons from normal people using deep learning techniques. The images are preprocessed using standard method suitable for segmentation. After segmentation the regions affected by corona are separated and given as input for classification. In sorting based on features extracted automatically the images are divided into three groups as mild, moderate and severe. The results derived are compared for accuracy to find the best model for processing of x-ray images. The work presented here limits on to perform analysis of existing methods and comparisons and does not involve in drug design or analysis in medical perspective like organ analysis.

2. MATERIALS AND METHODS

Research carried out to identify the epidemic disease in different areas using various images is discussed in this section. Work combined both artificial intelligence with big data analysis for classifying computed tomography chest images to detect corona [3]. Segmentation of lesion to spot the contaminations along with the density is implemented using the Infnet architecture. For classification Resnet block is used to separate normal with abnormal images. An model proposed with efficient module based on adversarial network for segmentation automatically separates areas of ground glass with consolidation and pleural effusion for detailed information with additional data set for multitask learning [4]. Segmentation and classification is done mechanically using chest CT scan images. DWT-PCA based feature extraction method is used from the segmented images and classified using machine learning method like Random Forest for accuracy [5]. Hybrid method namely improved whale optimization algorithm is used and compared with other methods like WOA, SSA and SCA [15].

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Classification of CXR and CT images were discussed using deep learning algorithms especially CNN models for detection of corona virus [6]. Significant research publications are carried through these two suggested images based on DL classification. In the proposed methodology reverse transcription polymerase chain reaction along with x-ray and CT scan images are used to detect corona [7]. For classification deep convolutional neural network model is used for analysis with data augmentation of chest x-ray images among high workload conditions [13], [14]. Classification of images used CNN model namely Mobile net V2 model for high accuracy compared with other models enriched by histogram equalization method, spectrum, grays and normalized using NCLAHE method using VGG 19 and Residual net 101 methods are used for next accuracy in classification [8]. Finally, Wilcoxon signed rank test method was done to check the statistical importance.

Based on the one another existing model with various classification simulations with 3D computed tomography data sets from different countries were the targeted data sets with multiple factors affected like patient demographics and image procurement or renovation causing oscillation in the results [9]. A comparison with x-ray and CT scan images is done using deep learning networks for accurate results. Both the images showed best performance with the CNN model for diagnosing corona virus earlier and in fast manner [10].

3. Architectural framework of COVID detection System

The proposed system uses popular and cost effective chest x-ray images for classification of corona virus. Here the images are preprocessed and segmented and then later on images were classified using deep learning models. The overall architecture of the proposed work is described as block diagram in Fig.1.

3.1 Data Acquirement

The data collection used for processing chest x-ray images are retrieved from many sources from 2019 up to date. The on line foundations are available in Kaggle data set and the link is also provided [11]. The other open resource is the CORD- 19 data set with [12] more than 1,67,000 images covering corona, SARS-CoV-2 and other cold related diseases. The other data repository operated by John Hopkins center for corona images named as Novel coronavirus visual dashboard provides numerous images for processing. There are nearly 60 data sets available worldwide in the website data. World updating images regarding corona virus infection. The daily and weekly data are provided in the formats suitable for downloading from media like CSV, XML and JSON.

Fig.1. Overall Architecture Of The Proposed Model

3.2 Data Preprocessing

Preprocessing of data is an important step in image processing as it provides clean images so that it can be used for classification purpose. As CNN models require same sized images for fully connected layer the images need to be formatted to standard size as they are collected from different sources both online and real. Standard dimension reduces the training time and improve the inference speed. There are many stages in preprocessing but the proposed model includes which is explained below in several sub-sections (3.2.1 to 3.2.5).

3.2.1. **Resizing of images**

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The first step in processing of X-ray images is to rescale the images into uniform shape and dimension with standard aspect ratio suitable for deep learning network. The images are given the square shape favorable for the network models. There are two phases in resizing either zoom the given image to the larger size or compact the large image to the given size. Pixel relation method is used to shrink or enlarge the image using function Resize method and interpolation model is used for rescaling the images to the standard size. Using the neighboring pixel location and their relation with the pixel intensity values these methods are implemented. Inter area method is used to compact the images to the regular size while inter linear interpolation method is used to enlarge the image without disturbing the resolution of the images. The images resized are shown with original image in Fig.2.

Fig.2. Resizing Of Images

3.2.2 Data Normalization

Another important aspect of preprocessing is the normalization of the x-ray images so that range of pixel values in all the input images is in equal series. All pixel value of the images belongs to standard distribution. The normalization is done by dividing the pixel values by the maximum value that pixel can acquire. To avoid poor contrast and deviated angle of the images normalization is done to enhance the convergence of the image and achieve positive values.

3.2.3 Segmentation of Images

Segmentation is primarily used in processing of lung images to partition the given image based on the pixel properties into numerous regions or segments, facilitating only vital parts to be highlighted in the image. Especially for recognizing the diseased region in the image, segmentation is carried out to classify the pixels based on some attributes like shape, color, contour etc. To point out the region of interest images are segmented to extract the region affected by disease. The segmented image is used for classification purpose to identify the stage the image belongs whether mild, moderate or severe. The segmentation method used for corona affected image is based on mask segmentation with AND operator.

3.2.4. Segmentation using Mask with AND operator

The proposed model aims at classifying the given images affected by corona infection to identify the stage of the patients for further investigations. For this purpose, the diseased portion in the images are deviated using morphological operators. The region of interest is asymmetrical to be cropped so bitwise operations and masking method is applied for segmenting purpose. First using bitwise operations mask is constructed and using the mask segmentation is carried out for the images. The sequence of steps for the proposed basic algorithm for segmenting lung images follows in Table 2. The lung x-ray images are preprocessed and segmented to extract the affected portion for further usage of images. The images after segmentation are given as input for automatic feature extraction and classification using deep learning techniques.

3.2.5. Segmentation Result

The lung images are segmented using the proposed algorithm and first mask is produced for each image. Using the mask, region of interest is cropped from the input image to produce the required output. Segmentation is done for every image to produce the output along with mask is given as Fig.3

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Table 2: Algorithm Sequence Of COID'19 Detection

Input: Image (X-ray)
Output: COVID detection
Step 1: The image to be segmented is acquired from the data set and preprocessed to the required size for handling. Step 2: For segmenting bitwise operations are used which function in binary manner that is each pixel value is represented either as zero or non- zero. Step 3: First mask is created for every input image comprising of only the affected portions from the given lung image. Step 4: Mask is used to center only the diseased regions that are to be removed from the image. For the lung images rectangular masks are used. Step 5: Masking applies effects to a single image and creates new image from the old covering only the diseased regions. Step 6: There are two input images, one is the original and other is the mask for the original image and bitwise AND operation is performed with these two input images to produce one output image. Step 7: For both the input images the pixel intensity values are compared. If both the values are equal the pixel is selected otherwise the pixel is not considered. Step 8: AND operation is performed with both the input images and the pixels are checked whether their value is equal to 0 or greater than 0. When both the pixel values are greater than 0 bitwise operation is performed with AND operation true. Step 9: While AND operation is true segmentation is performed matching the mask with the input image. The regions are deviated accordingly producing the output segmented image. Step 10: Finally the lung images are segmented with only the affected portions which are used for c classification purpose.

Fig.3. Segmentation Result With Mask

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4. CLASSIFICATION TECHNIQUES AND BASICS OF EXISTING MODELS

Classification is the process of grouping the images into several varieties or classes for easy implementation and sorting of given images into predefined classes. Deep learning methods are used for both feature extraction and classification of lung images into three predominant groups namely mild, moderate and severe classes. Feature extraction converts the essential attributes into numerical data suitable for classification. Redundant data are eliminated pointing only vital entities needed for organizing the data. The final step in processing of images is the classification based on the extracted features and their similarities enabling to classify the given images. The proposed model experiments three deep learning methods for classification and they are Dense net model, Exception model and Residual network model. The experimental analysis is performed for three models and the accuracy is calculated by comparing the result of all three models.

4.1 **Dense net model**

For deep convolutional neural network model, densely connected networks are suitable when the network depth is raised to certain extent. The problem faced by CNN architecture is the vanishing gradient values for deeper network which is solved by the DenseNet model by connecting each layer with one another directly. By this multiple connections gradient flow is confirmed with needed information. The architecture of DenseNet is described using the block diagram as Fig.4.

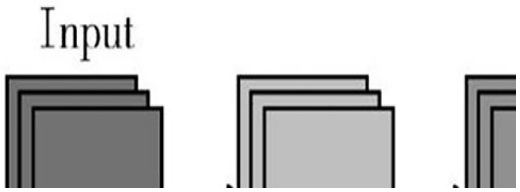

Fig.4. Block Diagram Of Densenet Model

Another Image Classification model similar to Residual Network is the densely connected network with the dissimilarity that the model takes input as all the formerly connected outputs for the next layer as shown in the above figure. This is possible by applying combination of operations like convolution or pooling layers, batch normalization with an activation function. The equation is given as:

$$X_L = H_L([X_0, X_1, \ldots X_{L-1}]) \quad (1)$$

Dense Nets concatenate the output feature maps of the layer with the input of the next layer to allow maximum information travel between the layers. The basic building block of this network includes two vital blocks namely Dense blocks and the transition layers along with basic convolutional operations and pooling layers. They are explained in brief below:

Convolution operation – First convolution block is implemented in the model with batch normalization and activation function. Then the actual conv2D layer is executed.
Dense block – Each dense block consists of a pre specified number of layers and the feature maps produced by all the layers from top to bottom creating an explosion. To avoid such situation dense block is created to store all the feature maps.
Transition Layer – The output of the selected dense block is produced to the transition layer which is followed by max pooling layer to decrease the size of the feature maps.

The architecture of the proposed model to identify corona affected persons using chest x-ray images is developed and shown as Fig. 5.

Using transfer learning approach the proposed model for detecting virus affected patients is established and three stages are classified using Dense Net model. The pillars used for this model are explained below.
-First the segmented image is given as input to the proposed model. Followed by Convolution and max pooling operation which is pre-defined in the model.
-Next there is a combination of dense block and transition layers where the feature maps of the previous layers are accumulated. In dense block convolution operation takes place and in transition layer pooling operation is done to reduce the size of the feature maps.
-Finally the feature maps are sent to the dense layers where there is reduction from 128 to 64, 32 and three attributes are filtered for three classes.
-The last layer Sigmoid is used for classification of the given input image whether it belongs to mild, moderate or severe class.

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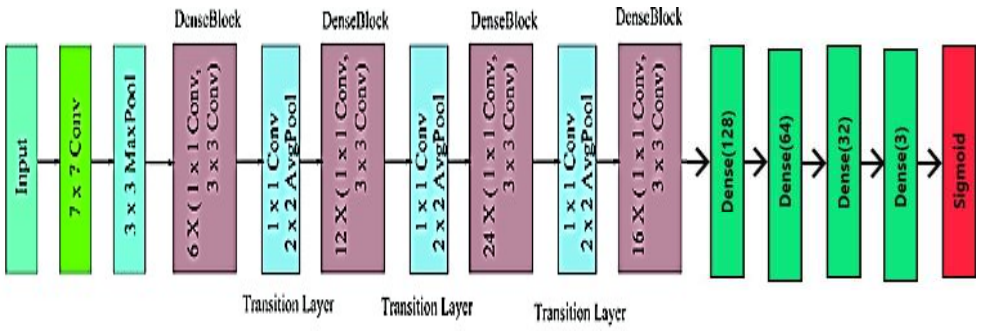

Fig.5. Architecture Of Proposed Dense Net Model

Dense Net model is used for classification of x-ray images to identify corona affected persons and their stages. The accuracy is compared with other two CNN models discussed in the next sections.

4. 2 Xception Model

Another CNN architecture based on transfer learning used for image classification is the Xception model which is the extreme version of the Inception model V3 having 71 layers deep used for classification of nearly 1,000 images. The working principle is reverse of the Inception model where the filters are first applied on the depth map and the input space is finally compressed using 1 x 1 convolutions. This process is also named as depth wise separable convolutions without non linearity function which are implemented in this proposed model. The architecture of this model contains three parts namely entry flow, middle flow and the exit flow through which the data streams. The depth-wise separable convolution contains two operations.

They are
1.Depth-wise convolution – It is the channel wise n x n convolution that is spatial based on the number of channels.
2.Point-wise convolution – It is the original 1 x 1 convolution to change the measurement.
The basic architecture of the proposed model is given as block diagram in Fig.6

The main architecture for the proposed model to identify corona infection is constructed as follows

- First step the input image of predefined size 299 x 299 is taken as first layer in the proposed model
- Three convolution steps namely A, B, C are implemented two, three and eight times as three stages. In all the three stages both convolution operation along with max pooling layers are carried out except B block.
- Finally the global average pooling layer functions to extract the features need for classification.
- Dense layers are added in the last layers for flattening the values thus reducing the attributes form 2048 to 3 attributes representing the three required classes.
- Sigmoid classifier is used for the final classification of given input image into any of the three classes.

Using the proposed Xception model for classification, chest x-ray images are classified into three stages.

4.3. Residual Network Model

The proposed model based on CNN architecture to classify the images into various stages is the Residual neural network model constructed using transfer learning suitable for chest images. The vanishing gradient problem based on Chain rule of Calculus is realised in deeper networks during back propagation is solved using the Resnet model with skip connections. This model is called ResNet 50 model based on the fifty layers available in this model. Here the input value is appended with the output along with the input function so small values are obliterated in this model. The formula used is:

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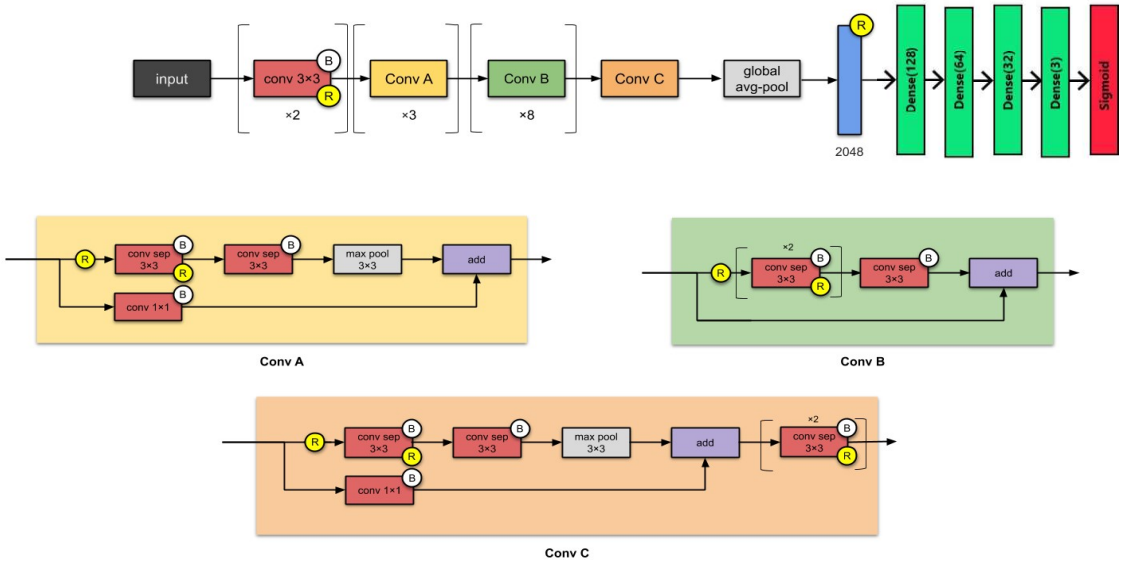

Fig.6. Basic Architecture Of Xception Model

$$Y = F(X) + X \quad (2)$$

where Y is the output value, X is the input and F(X) is the function of the input value. The basic building blocks of residual model are the two important functions namely Identity of block and Convolutional block. Based on the condition whether the size of the input image is equal to the output image the two functions are used. If two images sizes are equal, Identity block is used otherwise, convolution block with additional 1 x 1 convolutions is used.

5. PROPOSED ARCHITECTURE:

The proposed architecture for classifying x-ray images of corona affected persons is executed and described as block diagram in Fig.7. The sequential flow is presented as steps below:

-First the input image is taken as the first step in the proposed model. Next convolution layer [7 x 7] with 64 filters and stride 2 is used which is fixed for the residual model.

-Batch normalization with activation function is implemented next followed by the max pooling layer.

-Next Convolution block is applied four times intercepted by Identity block.

-If input size equal to output, Identity block is performed otherwise Convolution block is performed. In Convolution block additional 1 x 1 convolution is performed to match the output size.

-In Identity block Convolution [1 x 1, 3 x 3, 1 x 1] are performed along with batch normalization and activation function.

-Finally global average pooling function is performed to get the feature values extracted for classification.

-Then dense layers are added and the values are reduced from 128 to 64, 32 and finally 3 attributes representing final three classes.

-The final value is given to sigmoid classifier for classification of three classes namely mild, moderate and severe.

Thus lung images are classified using three standard CNN based models and their accuracy is compared in the next section.

6. RESULTS AND DISCUSSION

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The chest x-ray images are analyzed to detect the occurrence of corona disease and the degree of the spread also identified by three stages namely mild, moderate and severe. For this classification totally 300 images are considered which are equally collected from three classes. Three deep learning models namely dense net, xception and residual network models are used for classification. More accuracy nearly 89% is achieved by xception model whereas residual model produced accuracy up to 80% and dense net model proves accuracy by 69% which is the least accuracy. Experimental analysis is done for all the three models using measurements like precision, F1 score and accuracy. The output results measures are summarized and presented in Table 3.

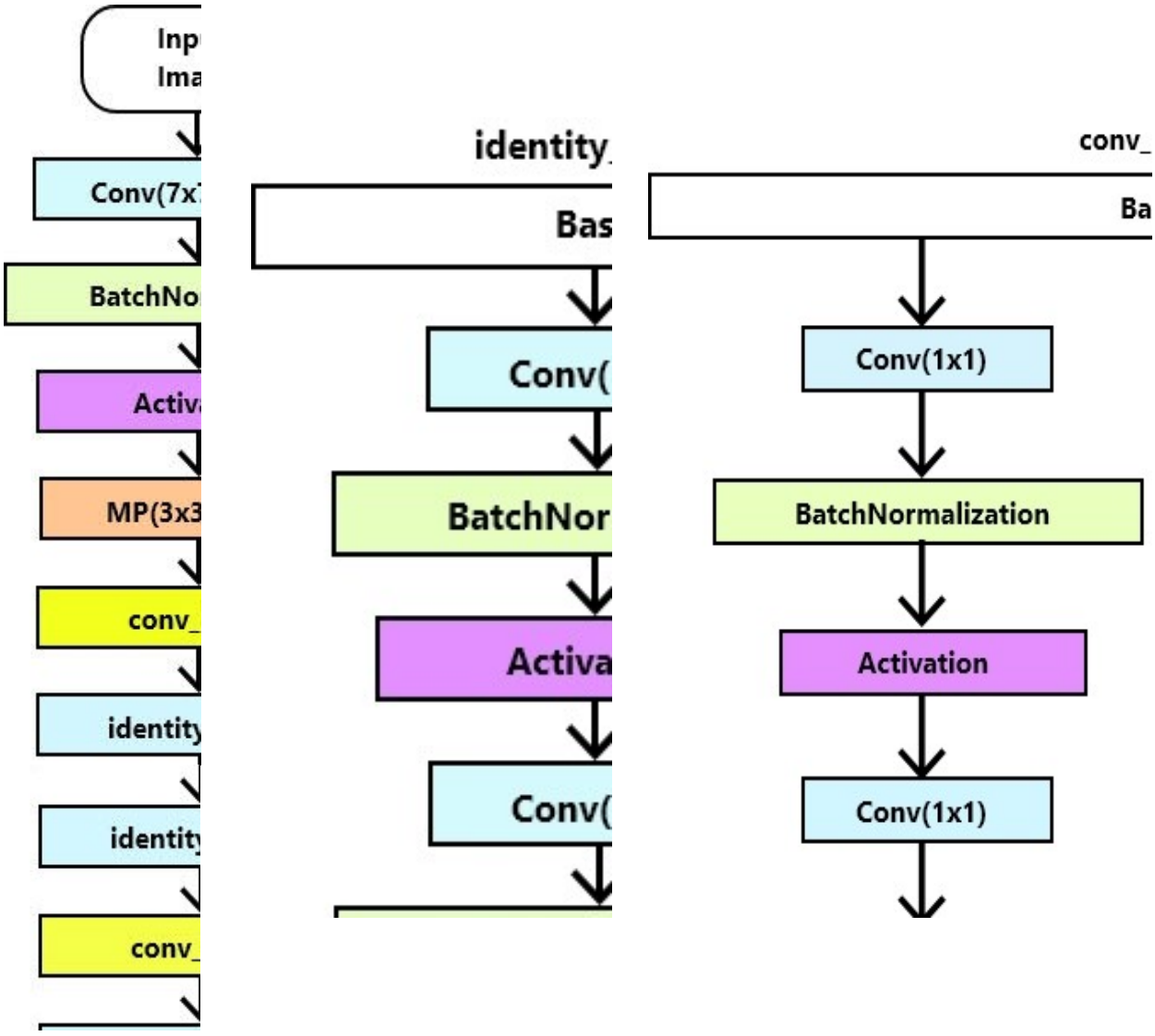

Fig.7. Block Diagram Of Residual Network Model

Table 2. Performance Analysis For Classification

S.NO	METHOD	STAGES	PRECISION (%)	F1 SCORE (%)	ACCURACY (%)
1	Dense net	Severe	1.00	47.00	69
		Moderate	99.01	87.12	
		Mild	50.12	67.30	
2	Xception	Severe	90.12	82.03	89
		Moderate	97.01	98.32	
		Mild	79.45	85.31	
3	ResNet	Severe	64.00	77.23	80
		Moderate	94.51	96.00	
		Mild	98.30	59.43	

6. CONCLUSION

For detection of corona virus infection x-ray images are used for processing with deep learning models to achieve the best accuracy. For this purpose, the images are first acquired from the standard data set. Next the images are cleaned and segmented using mask method with AND operator. The segmented images are finally classified into three stages namely mild, moderate and severe using three deep learning models namely Dense net, Residual network and Xception model. Out of the three models Xception net proves to be the best model for classification by showing accuracy up to 89%. This model shows more accuracy and thus can be used for other type of images also. Future usage can be done for other lung infections using this model. The more important restriction for future model proposed by the system is on the severity and recovery time with other combinations of the diseases.

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