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Deep Learning based Detection of Covid-19 using Chest X-Ray Images

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Abstract: A novel coronavirus spill over event has emerged as a pandemic affecting public health globally. Screening of large numbers of individuals is the need of the hour to curb the spread of disease in the community. Real - time PCR is a standard diagnostic tool being used for pathological testing. But the increasing number of false test results has opened the path for exploration of alternative testing tools. Chest X-Rays of COVID-19 patients have proved to be an important alternative indicator in COVID-19 screening. But again, accuracy depends upon radiological expertise. A diagnosis recommender system that can assist the doctor to examine the lung images of the patients will reduce the diagnostic burden of the doctor. Deep Learning techniques specifically Convolutional Neural Networks (CNN) have proven successful in medical imaging classification. Four different deep CNN architectures were investigated on images of chest X-Rays for diagnosis of COVID-19. These models have been pre-trained on the ImageNet database thereby reducing the need for large training sets as they have pre-trained weights. It was observed that CNN based architectures have the potential for diagnosis of COVID-19 disease.

Keywords: Covid-19, CNN, Corona Virus, X-Ray.

I. INTRODUCTION

COVID-19, the pandemic that has destabilized the world from every aspect, was first reported in December 2019 in Wuhan, China when patients with cases of unidentified pneumonia emerged and by the end of January 2020, it was declared as a pandemic by the World Health Organization. The virus responsible for the disease, named SARS-CoV-2, belongs to a family of coronaviruses that are zoonotic. Until SARS-CoV-2 surfaced, six types of coronaviruses were known to be able to harm humans by mainly targeting the respiratory system. Four cause mild symptoms while the other two had caused epidemics in the last two decades named SARS-CoV and MERS-CoV. Even though the mortality rates of these epidemics are much higher than that of COVID-19 (10% for SARS and 30-35% for MERS), the cumulative number of deaths for the latter has exceeded that of both the epidemics combined by many times. As of 21 July 2020, the total number of global cases and deaths exceed 14 million and 6.0 lakh respectively.

The range of typical onset symptoms of COVID-19 includes fever, dry cough, sore throat, myalgia, fatigue, dyspnea, a loss of taste and smell, and gastrointestinal symptoms. In more severe or progressed cases, pneumonia, development of fluid in the lungs, acute respiratory distress syndrome (ARDS), multi-organ failure, as well as death may occur. Elderly people or people exhibiting comorbid thus having a weak immune system are highly prone to both infection and severity. On the other hand, many carriers of the virus do not show any symptoms i.e., asymptomatic patients. This makes detection and containment of the virus even harder. With no specific treatment at hand, it is imperative that preventive measures such as social distancing, hygiene maintenance, and contact tracing are strictly followed and a system that can diagnose the disease as fast as possible is developed.

The gold standard for COVID-19 diagnosis is the reverse transcription-polymerase chain reaction (RT-PCR) which identifies the nucleotides of the virus from specimens extracted from a nasal swab or oropharyngeal swab. However, this method is tedious and time-consuming as the fastest turn-around time is at least 24 hours. Furthermore, given the rapid spread and hence increased rate of specimen collection required, the laboratories get loaded very easily. It is also laborious, relatively expensive, and has a low sensitivity (60%–70%) . False results may be produced due to specimen handling, stage of disease when the specimen is collected, or quality of specimen. Along with the long period of recovery, limited resources such as testing kits, hospital and ICU beds, ventilators, personal protective equipment (PPE) have overwhelmed the healthcare systems in most countries, thus forcing them to make selective decisions regarding testing, patient admission, ICU beds as well as the provision of ventilators.

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II. PAGE LAYOUT

Coronavirus (COVID-19) is a type of flu that appeared in Wuhan, China in December 2019. It is observed that it is much more contagious and lethal than the known seasonal flu. Deaths occur when the disease turns into pneumonia. People can be contagious before they develop symptoms, making it difficult to control the spread of the virus. Development of any vaccine can take twelve months according to the research conducted until the writing of this paper. Covid-19 disease caused by coronavirus has been declared a pandemic by the World Health Organization as of March 11. The total number of confirmed cases worldwide is 10,173,722 whereas the total number of active cases is 4,510,716 and the number of deaths from COVID-19 is 502,517 according to Coronavirus Resource Center at Johns Hopkins University of Medicine on 29 of June 2020. These statistics reveal that this novel coronavirus can be deadly with a 4.94% case fatality rate.

Early diagnosis of COVID-19 disease is of great importance for clinical treatment planning, patient monitoring and evaluation of treatment outcome. Looking at the current medical technological advances, COVID-19 disease diagnosis is typically based on swabs from the nose and throat. The major disadvantages of this procedure are that it is time consuming and susceptible to sampling error and therefore inefficient. These tests are known as reverse-transcription polymerase chain reactions (RT-PCR) and are confirmed that the sensitivity of tests is not high enough for early detection. It is possible to increase the diagnostic capabilities of physicians and reduce the time spent for accurate diagnosis with computer-assisted automatic detection and diagnosis systems. The purpose of these systems is to help experts make quick and accurate decisions. The motivation of this study is the early diagnosis of COVID-19 disease, the speed and high accuracy required for accurate detection and classification of COVID-19 disease. Automatic detection of COVID-19 disease from medical images is a critical component of the new generation of computer-assisted diagnostic (CAD) technologies and has emerged as an important area in recent years. X-rays is a widely used imaging method for the detection, classification and analysis of diseases caused by viruses.

Researchers who are always interested in artificial intelligence and sub-branches that aim to design more intelligent systems have modelled human thinking and decision making ability for the first time and presented a model that calculates the functioning of brain functions. It was emphasized that the way to design better performing neural networks depends on the establishment of deeper networks, hence the use of the term Deep Learning (DL) has been expanded to draw attention to the theoretical significance of the depths -. Within this important research field, Convolutional Neural Networks (CNN) are considered the basic architectural models in deep learning. These models are designed to learn from input data without user-specified features. CNNs are the developed and expanded versions of Artificial Neural Networks (ANN). The network deepening as a result of increasing the number of hidden layers in ANNs can be defined as CNN. This depth in the CNN was achieved by the use of 2-Dimensional filters. CNN has become a widely used method especially in researches such as medical image processing and disease diagnosis.

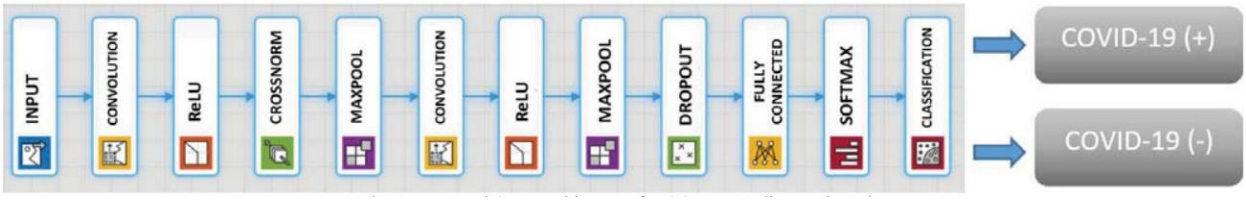

Fig. 1 Proposed CNN architecture for COVID-19 disease detection

In 2019, the Covid-19 virus has spread to various parts of the world [1,2] including Indonesia. This has led to the designation of Covid-19 as a global pandemic resulting in more than 29 million cases in September 2020. Covid-19 is considered as the evolving form of the virus so that no vaccine can treat or prevent the transmission of the virus yet. Therefore, people mostly rely on Rapid Test as a method to detect whether someone is infected with Covid-19 or not. Some research studies on Covid-19 reveal that women are less likely to be infected with Covid-19 than men. Additionally, another research also discovers that the mortality rate in children aged 0-9 years caused by Covid-19 has not been found. There are several indications to find out whether someone has been infected by the virus, such as fever, cough, and respiratory symptoms. Several worse things may also happen such as pneumonia, septic shock, acute respiratory syndrome, multi-organ failure, and even death. Furthermore, someone who has a history of pneumonia can be infected by the Covid-19 virus more quickly than someone who does not have a history of respiratory problems. Rapid test, as an alternative to detecting Covid-19, is currently considered problematic to carry out since the diagnostic system is not available in all places. Given the limitations of Covid-19 testing, other alternative diagnostic measures are urgently needed. Therefore, the automatic detection instrument, such as the application of X-ray scans, is needed to analyze the patient's lungs and to detect whether someone has been infected by the virus or not.

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Many researchers give their best effort to fight the COVID-19. Due to the massive number of infected people, various approach have been conducted to tackle the pandemic, including in the machine learning communities. Detecting COVID-19 based on the chest Xray images is one of the efforts that have been made by many researchers and are still doing. Several strategies have been implemented to detect COVID-19 using deep learning approach. In the early phase of the pandemic, the number of available data is limited, therefore, there are constrained that should be resolved. To overcome the limitation of available data several strategies were used, such as transfer learning. Various models have been tested and got promising results. Some of the models are ResNet50 [17, 18], Xception and InceptionV3 and Coronet. Rahimzadeh and Attar implement Xception model for Covid19 detection using 15085 images. Their model shows an average accuracy of 91.31% . Yadav et.al and Makris et al implement InceptionV3 model for the Covid19 detection. Yadav et.al used 30000 training data images and the model achieve accuracy of up to 93.77% . On the other hand, Makris et al used much smaller in the number of data, 336 images, and the accuracy drop to 54.41% . Khan et.al proposed a deep neural network based on Xception model, called CoroNet, to detect Covid 19. Their experiment used 1251 images and the overall accuracy of the model is 89.6%.

The previous models show that they need a lot of number of images for training. Makris et al used a relatively small number of images; however, its performance is significantly lower than the models used large number of images. Therefore, this research proposed a modified Xception that work with small number of images training.

Training deep neural network is challenging. It can be sensitive to the initial weight and the learning algorithm configuration. One aspect of the challenges is the changes of the input distribution to layers in the network when weights are updated. The changes is called internal covariate shift. It may cause the learning algorithm fail to reach the target and longer the training phase. In this research, a modified deep neural network model, called FCovNet, is proposed for COVID-19 detection based on chest X-ray images.

Computer science in artificial intelligence (AI) is one type of technological advancement shown by machines. Unlike the natural intelligence displayed by humans, the term "artificial intelligence" is often used to define machines that mimic the "cognitive" functions related to the human mind, such as "learning" and "problem-solving". In contrast to traditional machine learning methods that require hand extraction features from the input, artificial intelligence performs a deep learning method by studying the features derived from certain data.

The Convolutional Neural Networks (CNN) algorithm is an “artificial intelligence” with a deep learning method that is quite superior to other models. That is to say, CNN is likely to be the dominant method in the processing tasks of computer vision. The objective of this research is to explore the feasibility of CLAHE and CNN's basic performance with some primary deployment scenarios and transfer learning trials. The dataset used is 200 X-ray chest images. To be specific, the dataset used consists of 100 normal X-ray images and 100 Covid-19 X-ray images.

Pneumonia is one of the lung’s deadly diseases. The pneumonia diagnosis involves a set of chest radiographs interpreted by a radiologist. However, a diagnosis that is assisted by humans has its limitations such as the availability of experts, fees, and other issues. In the current X-ray chest image of the Covid-19 patients, the researchers add the non-Covid pneumonia dataset so that the number of datasets used can be obtained with maximum accuracy. In other words, in this research, the dataset used contains normal X-ray chest images and Covid-19 X-rays chest images.

Neural Network (NN) is a basic algorithm system that is often used at present. Neural Network (NN) mechanism is inspired by the learning process of the humans’ brain. The perceptron is one of the primary systems of NN that was first proposed by Rosenblatt. Convolutional Neural Network (CNN) is a developmental variation of Neural Network (NN) suggested by Weasel and Hubel after observing the visual cortex of cats in 1968. The visual cortex generally possesses a small area formed from a cell that is sensitive to the point specified in the visual field. That is to say, the cell within the cortex can be activated only in a particular shape and orientation.

The basic structures of CNN are essentially like the structures of NN in general. They consist of some similar aspects, such as input, hidden, and output layers. Meanwhile, every layer on CNN generally contains several parts such as activation, convolution, and pooling. The condition of each layer is set regarding the spatial grid structure in which a small area on the previous layer specifies any value in the feature.

An Adaptive Histogram Equalization (AHE) is a procedure used to enhance the image contrast by increasing the local contrast of the image. The local contrast is acquired by forming a symmetrical grid on the image so-called region size. The issue of excessive contrast enhancement in AHE can be solved by 0using CLAHE that assigns a limit value to the histogram. This value is called the clip boundary which represents the maximum height of a histogram.

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Convolutional Neural Network (CNN) is a development of Multilayer Perceptron (MLP) designed to process two-dimensional data. CNN is involved in the Deep Neural Network since it has a high network depth. It is also widely applied to process the image data. In the case of image classification, MLP is not suitable to use due to its incapability to store the spatial information of the image data. Besides, it also considers each pixel to be an independent feature resulting in poor outcomes.
CNN was established under the name of NeoCognitron proposed by Kunihiko Fukushima, a researcher from the NHK Broadcasting Science Research Laboratories, Kinuta, Setagaya, Tokyo, Japan. The concept was then finalized by Yann LeChun, a researcher from AT&T Bell Laboratories in Holmdel, New Jersey, USA. The CNN model with the name LeNet was successfully applied by LeChun in his research on numbers and handwriting recognition.

The X-ray detection of Covid-19 patients on their chests using Contrast Limited Adaptive Histogram Equalization (CLAHE) and Convolutional Neural Networks (CNN) was carried out through several stages as illustrated in Fig. 2.

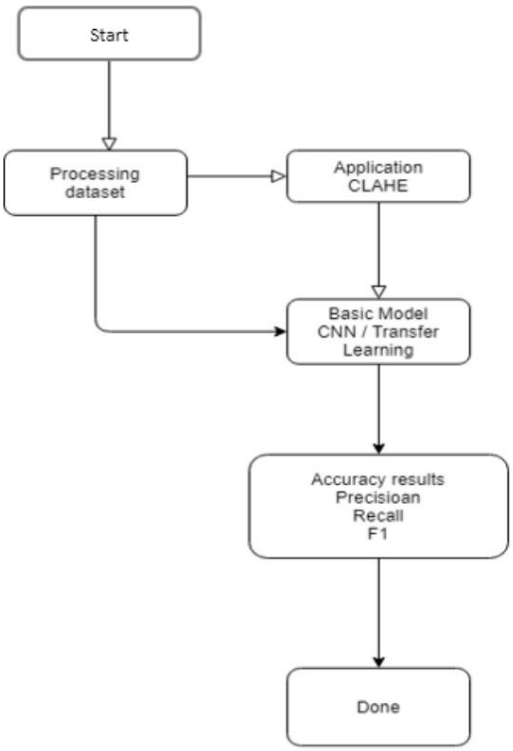

Fig. 2. Flowchart of research

The chest X-rays of the patients contain information that determines whether the person is COVID-19. In this article, chest x-rays of the patients were classified as COVID-19, healthy and viral pneumonia. The data set includes chest X-ray images of 219 COVID-19 patients, 219 healthy patients and 219 viral pneumonia patients. This means a total of 657 images. Figure 1 shows sample chest X-ray images from the data set.

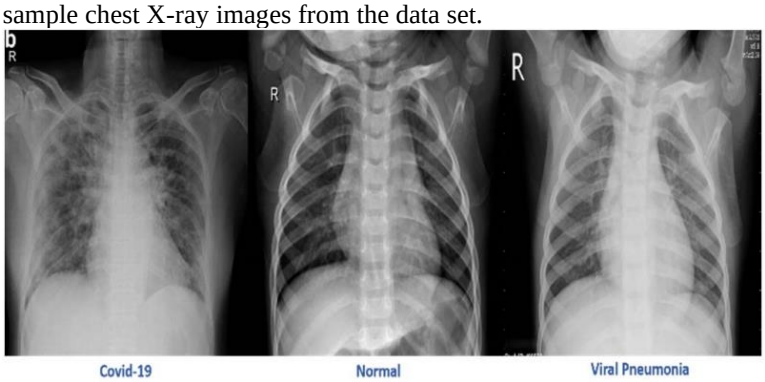

Fig. 3. Data set samples.

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Confusion matrix is used to evaluate the performance of deep learning models. Confusion matrix is a matrix in which target predictions and actual values are compared to evaluate the classification performance used in deep learning algorithms. The criteria used in the evaluation of the classification results except the confusion matrix are as follows:

- Accuracy: It is the main evaluation element in the study. It is the ratio of the total number of correct predictions to the number of predictions tested.
- Precision: It is the ratio of the number of positive real value classified as positive value to the total of those classified as positive value.
- Recall: It is the ratio of the number of positive real value classified as positive value to all positive real value.
- F-Score: Its value shows the harmonic mean of the recall and precision values. One of the ways to increase the accuracy rate in the study is by data augmentation. The over-fit problem of the deep learning model stands out in small data sets. Which means a low accuracy rate. We rotate the images in the data set by 15 degrees clockwise or counter clockwise to increase the accuracy. Thus, the data set has been expanded.

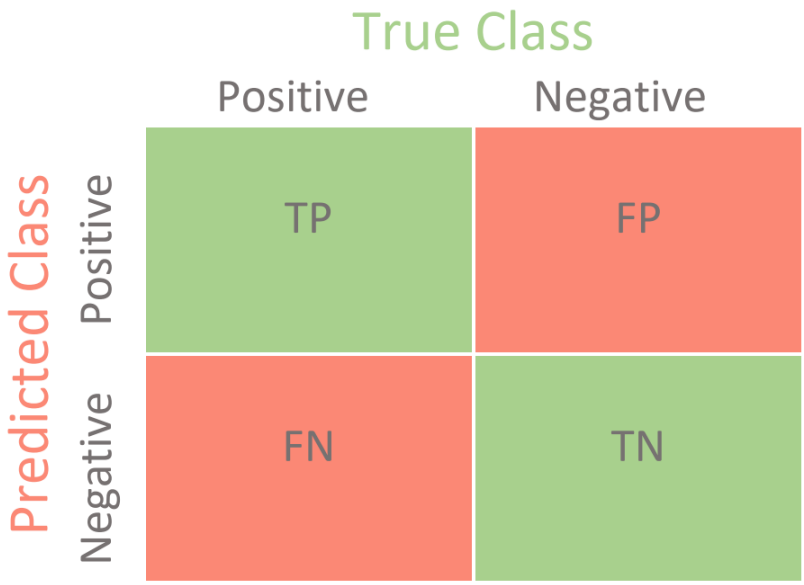

Fig. 4. Confusion Matrix

Deep learning algorithms have become more and more popular after the competition organized by Imagenet in 2012. It has started to be used more in academic research. Convolutional neural network (CNN) is one of the deep learning networks used for computer vision. The CNN algorithm was created by taking inspiration from the visual center of animals. CNNs are structures designed to take images as input and are used effectively in computer vision. CNN consists of one or more convolutional layers and one or more fully connected layers, such as a standard multilayer neural network. These; Convolution, Relu, Pooling, Flattening, and Fully Connected layers. The convolution layer is the main block of CNN. The layer is responsible for perceiving the features of the images. Some filters are applied to the picture to extract the high and low-level features in the images. Filters usually contain multidimensional matrices and pixels. The feature map, which is the last matrix obtained as a result of the applied filters, is shaped according to the filters used. After the Convolution layer, the order is in the nonlinear layer. Since the activation process is done in this layer, it can be called the Relu layer. The relu activation function sets the negative values from the feature map to 0. The task of this layer is to reduce the sheer size of the representation and the number of parameters and calculations within the network. In this way, incompatibility in the network is checked. The main purpose here is to reduce the number of parameters we have and to keep the most critical parameters and to reduce the number of entries for the next layer. This reduces the computational cost for subsequent layers and prevents memorization. In the flattening layer, the main purpose is to prepare data for the last layer, Fully Connected layer. It converts matrices from Convolutional and Pooling layers into a one-dimensional array . The last layer, the Fully Connected Layer, takes the data from the Flattening layer and performs the learning process through the Neural network.

As the name suggests, VGG-16 consists of 16 layers, and VGG-19 consists of 19 layers. Both of were the basis of the Visual Geometry Group (VGG). The group won the first and second places in the ImageNet Challenge 2014. Small filters (3x3) are used in convolution layers in VGG16. VGG16 consists of 13 convolution layers and 3 fully layers in Figure 3.

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There are 5 pooling layers of 2x2 size. The last layer contains the softmax layer. The input data coming with the softmax layer are classified. Relu is used as the activation function. VGG19 consists of 16 convolution layers and 3 fully connected layers in Figure 3. As seen in Figure 3, VGG19 has five pool layers like VGG16 and as the last layer, both have a softmax layer. VGG16 contains 138 million parameters, while VGG19 contains approximately 144 million parameters. The disadvantage of both VGG models is that they consume a lot of memory. VGG16 and VGG19 schemes are given in Figure 3.

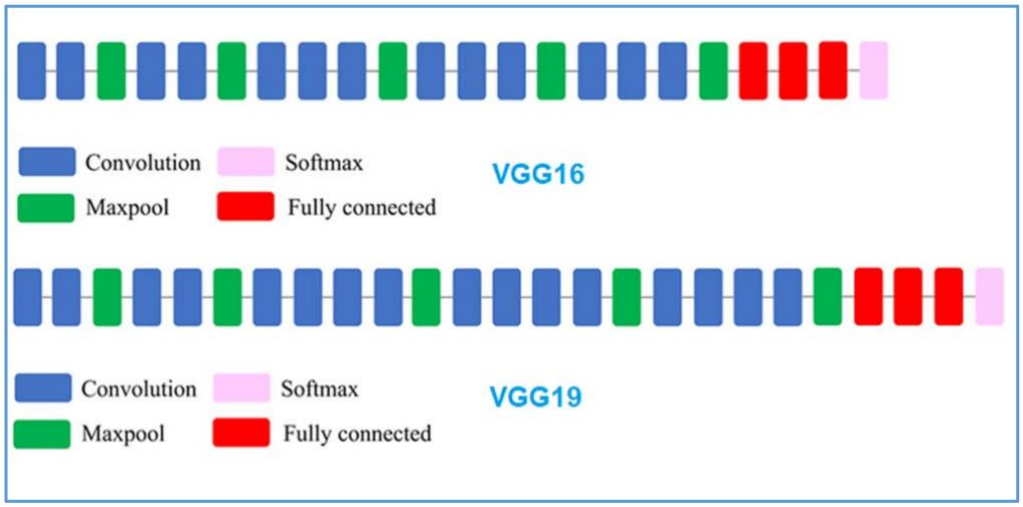

Fig. 5. VGG16 and VGG19 scheme

Medical images are very often contaminated by noises due to increasing forms of intrusion. Therefore, a visual assessment of them could become more challenging. Several pre-processing techniques can be applied to enhance the information the image generates for the unaided eye or to use it as feedback for algorithms.

Firstly, the data samples are resized to 150×150, 224×224 pixels, and are converted to grayscale images. Each image is then merged into 3 channels resulting in an input shape of 150×150×3 and 224×224×3 for different DCNN models. Furthermore, the dataset is normalized using standardization. Standardization, in machine learning algorithms, helps to stabilize the model as well as increases the speed of training. Additionally, the labels of the dataset are one-hot encoded where each class is converted into a binary feature. Doing so helps machine learning algorithms understand the format of input and thus perform better. Data augmentation is a method widely used in DL that helps to generate the number of samples required. Since our dataset is relatively small, we apply some image augmentation techniques to artificially increase the size of our training data. To increase variation within our small database, we have applied image augmentations by gripping Keras ImageDataGenerator during training such as randomly rotating the images by 10˚, randomly zooming images by a range of 0.9 to 1.1, as well as translating the images with respect to height and width proportional to a range of -0.1 to 0.1.

Convolutional Neural Network (CNN) is a class of machine learning neural network which specializes in image segmentation and inspection. It consists of two parts which are the most distinctive features of CNN. Starting with the first part, it comprises of the main learning method. The input images fed to the learner consist of the smallest units which bring out the accuracy. CNN consists of several layers and the first part uses the convolutional layer which acts on a specific region and not all over. It extracts the distinctions from raw input and transforms that layer to the preceding layer. Next, the pooling layer learns from the previous layer and proceeds to reduce the process complexity. In the second part, the fully connected layer executes the features learned from all the previous layers giving the desired categorized outputs.

In our research, we opted for 2-D CNN architecture which delivers a better faster approach towards feature extraction. It contains a total of 11 layers where the training is executed, with 4 convolutional which work at 4 different filter sizes each incrementing by a product of 2, followed with 4 pooling layers or otherwise called the max-pooling layer which halves the parameters used, followed by a flattening layer, a fully connected or dense layer and finally a softmax. All models are built over a stride of 1 with a kernel size of 3×3, all of which are running under the Rectified Linear Unit (ReLU) activation function. Figure 3 demonstrates our overall architecture of the proposed DCNN models used for the classification of COVID-19 in chest X ray images.

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The first 2-D convolutional layer comprises of 32 filters, keeping all the other parameters the same as mentioned above. This also goes for the next 3 convolutional layers which contain 64, 128, and 256 filters respectively. After ReLU execution of the first convolutional layer comes the max-pooling layer with a pool-size of 3×3 and the same stride number of 1. Here, within the pool size, the layer selects the neurons containing the maximum activation number, splitting the parameters in return, all the while keeping the padding unchanged to have the inputs and outputs in the same dimensions. To solve the overfitting problem of the network, a 0.5 dropout is included after the max pool layer in order to randomly shut down 50% of the neurons. This dropout comes after the third convolutional layer is executed. The second, third, and fourth convolutional layers with different filters are then executed simultaneously. The output has a multi-dimensional feature vector and for it to be fed to the fully connected layer, it must be transformed into a 2-D feature vector which is done by the following flattening layer. Now, with the converted output fed to the dense or fully-connected layer of 512 units, it conjoins each neuron of the preceding with the succeeding layer. This is further followed by another dropout layer to re-evaluate the overfitting issue and finally passed on to the last layer where the softmax activation function is utilized in the classification of input data giving an output in the size of 3.

III.DISCUSSIONS AND CONCLUSIONS

In this research, a modified deep neural network is proposed. The proposed model is based on the Xception models followed by two stacks of two dense layer and batch normalization in the end layer of the model. The dense layer and batch normalization is used to avoid overfitting in the model.

The proposed model is used to detect COVID 19 based on the chest Xray images. There are three categories of the data in the dataset, normal, pneumonia and pneumonia caused by COVID-19. In order to evaluate the performance of the proposed model, it is compared with the Resnet50, Inception V3 and Xception on the COVID-19 dataset. The number of data training is 618.

The experiment result reveals that, the proposed has better performance in most cases compare to the other model used in this research. It has higher acuracy and lower loss in both training and validation data. The model is able to identify the normal, pneumonia and pneumonia caused by COVID-19 with higher accuracy than the other methods used in the experiments. However, the layes addition leads to longer training time

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