Deep Learning Convolutional Network for Detection of COVID-19 from Images

Laheeb M. Ibrahim[1], Azweenn Abdulla[2], Mahadevan Supramaniam[3]

[1] Department of Software Engineering, College of Computer Science & Math,
University of Mosul, Mosul, Iraq
[2]School of Computer Science and Engineering, Taylor's University, Subang Jaya, Malaysia

Abstract
Currently, Covid-19 disease is considered as an infectious disease that spreads very quickly in society and needs effective and fast methods to detect disease. Whereas, the best way to detect disease is to use X-rays, and at the same time, the use of chest X-rays in detecting diseases is one of the biggest challenges. Whereas dealing with chest X-rays requires a special approach to extract the properties, a deep learning mechanism has been used because of its effective characteristics in extracting properties from X-rays and provides a promising solution by transferring knowledge from the tasks of identifying general objects to the tasks of the field. In this paper, a deep learning Convolution Neural Network (CNN) model with two architectures LeNet-5 and VGG-11 uses for Covid-19 diagnoses from chest X-ray images. The experimental findings demonstrated CNN's ability to detect COVID-19 cases from a robust Chest x-ray image from the Kaggle dataset. Good accuracy of 99.17% and 98.01% using VGG-11 and LeNet-5 was achieved in the detection of Covied-19.
Keywords:
Convolution neural network (CNN), LeNet-5 and VGG-11, Chest X- ray, Covid-19

1. Introduction

The Coronavirus disease (COVID-19) is a disease that has invaded the world and was discovered in China, at the end of 2019 [1-6]. COVID-19 infection spread from one person to another very quickly. Since January in 2019, cases of Covid-19 have increased, and the disease has been considered a global pandemic, and emergencies have been declared by the World Health Organization and several countries have reported recorded cases and deaths and as a result, the epidemic of Covid-19 posed a significant threat to international health. [1-6].

Since the COVID-19 disease was reported by the Chinese world in late January 2019 for the first time, the disease has spread all over the world rapidly and greatly and has become a source of international concern.Research performed by [4] has shown that the m ortality rate of COVID19 is 4.5 per cent worldwide. This implies that if 10 people are COVID-19 positive, they are more likely to infect 15–35 other people. Therefore, COVID-19 can infect a very large number of people in a few days unless intervention measures are implemented. Where the total number of people infected with COVID-19 worldwide is 56.631.555 and 1.345.577 deaths on 18th of November, 2020.

The diagnosis of Covid-19 disease is a big and growing problem in hospitals, because the symptoms of the disease are similar to the symptoms of respiratory diseases such as fever, cough, shortness of breath, as well as the daily and greatest increase in the number of patients diagnosed and suspected, where the standard diagnostic technique is the reverse transcription-polymerase chain reaction (RT-PCR) method [6-7], a laboratory procedure that interacts with other ribonucleic (RNA) and deoxyribonucleic acids (DNA) to determine the volume of specific ribonucleic acids using fluorescence. RT-PCR tests are performed on clinical research samples of nasal secretions. The samples are collected by inserting a swab into the nostril and gently moving it into the nasopharynx to collect secretions and identify COVID-19, in some cases, it produced negative test results even though the patients showed progression on follow-up chest computed tomography (CT) scans [6]. In fact, several studies [7-10] have recommended the use of CT scans and Chest X-rays owing to its availability in some countries. Thus, CT scans and Chest X-
rays have appeared as integral players in the preliminary detection and diagnosis of COVID-19.

The diagnosis of COVID-19 indications in the deeper portions of the lungs is much more effective using CT scans or X-rays [7]. However, due to the comparatively small number of radiologists compared to modern residents and the high amount of re-examination of infected persons who want to know the progression of their disease, they cannot solely solve the issue. In order to resolve the difficulties of CT scans and X-rays and to support radiologists, we need to increase the pace of the treatment and improve the speed of the procedure by designing diagnostic systems that utilize artificial intelligence (AI) tools to reduce the time and effort required to diagnosed the COVID-19-positive patients and evaluate the rate of disease development [8-10].

Radiological imaging is considered an important method for COVID-19 diagnosis [5]. Ai et al. [1] demonstrated the consistency of the radiological history

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of COVID-19-related pneumonia with the clinical nature of the disease. When examined by CT scans, almost all COVID-19 patients have exhibited similar features including ground-glass opacities in the early stages and pulmonary consolidation in the latter stages. In fact, the morphology and peripheral lung distribution can be rounded [1]. AI can be used to initially evaluate a COVID-19 patient as an alternative solution to traditional approaches that are time-Consumption and labour-intensive.

In this paper, a healthcare system using deep learning "Convolution Neural Network (CNN)"model with two architectures LeNet-5 and VGG-11 to recognize COVID-19 cases and diagnose COVID-19 patients via chest X-ray images system.

The rest of this paper is organized as follows. The related works for COVID-19 detection methods are presented in Section 2. Section 3 presents the detailed system design. Sections 4 present the results and discussions, respectively. Section 5 concludes the paper and provides future research.

2. RELATED WORKS

Machine learning (ML) is used in a lot of areas, including image, signal recognition, diagnostic and information security...etc. [11]. In 2012, a new ML method called deep learning was developed, which is dependent on a CNN to perform classification tasks directly from images, texts or sounds. According to LeCun et al.[12], deep-learning models have high precision and may boost human performance in some instances.

A deep learning (CNN) algorithm was proposed in [9] Narin to diagnose COVID-19 patients that use 100 chest X-ray image data, half of whom are COVID-19 patients and half of which are healthy people. 3 CNN models ResNet-50, Inception-v3, and Inception-ResNet-v2 were analyzed using such a five-fold cross-validation and announced that ResNet-50 had the highest detection accuracy (98%).

In addition, Hemdan et al.[13] suggested a system called COVIDX-Net that could enable radiologists use X-rays to diagnosis COVID-19 patients. Using a sample of 50 X-ray images separated into two groups, they tested their framework: 25 COVID-19-positive images and 25 COVID-19-negative images. The images used were resized to pixels 224 to 224. Seven deep learning models are employed in the COVIDX-Net framework. Their evaluation results indicate that the VGG19 and DenseNet models delivered comparable performances with an F-score of 91% for COVID-19 cases.

Furthermore a classification scheme using multi-level thresholding and an SVM to identify COVID-19 in lung X-ray images was proposed by Hassanien et al. [14]. Their device was tested with a resolution of 512x512 pixels on 40 contrast-enhanced lung X-ray images (15 stable and 25 COVID-19-infected regions). Their method of classification reached a sensitivity of 95.76%, a precision of 99.7% and 97.48% accuracy.

Jiang et al.[15] matched RT-PCR against CT scans and studied 51 patients (29 males and 22 females) with the a background of endemic travel or residence and with serious symptoms of respiratory and fever due to unexplained causes. In a non-contrast chest CT scan for the identification of COVID-19, the authors obtained a sensitivity of 98% relative to the original RT-PCR sensitivity of 71%. Because of the lack of RT-PCR kits and a rising number of cases of COVID-19.

Meanwhile, Gozes et al. [16] employed a deep-learning approach to automatically identify COVID-19 patients and examine the disease burden quantification on CT scans using a dataset of CT scans from 157 foreign patients from China and the USA. Their proposed system analyses the CT scan at two distinct levels: subsystems A and B. Subsystem A performs a 3D analysis, and subsystem B performs a 2D analysis of each segment of the scan to identify and locate broader diffuse opacities, including ground-glass infiltrates (which have been clinically identified as representative of COVID-19). To evaluate their system, The authors applied Resnet-50-2 to subsystem B and obtained a 99.6% region under the curve. 98.2% and 92.2% respectively, were sensitivity and precision.

In [17] Fu suggested a ResNet-50 based classification scheme for the accepted COVID-19. A dataset of 60,427 CT scans from 918 patients was obtained by the authors; 14,944 of these CT scans were from 150 patients with COVID-19 and 15,133 from 154 patients with non-COVID-19 viral pneumonia. For several lung conditions, they did several studies. The precision, sensitivity and specificity obtained are 98.8%, 98.2%, and 98.9%.

3. PROPOSED HEALTHCARE MODEL

In this paper, we propose an automated intelligent system to detect Covid-19 disease and distinguish between people with Covid-19 disease and healthy people, based on X-rays. Where the intelligent system reads Chest x-rays to identify people with Covid-19 disease and reduces effort, time and the need for manual pre-processing steps, also, it is capable to reduce clinical errors and healthcare cost. The model is programmed by MATLAB R2020a, the model is briefly explained in the following steps, See Figure 1.

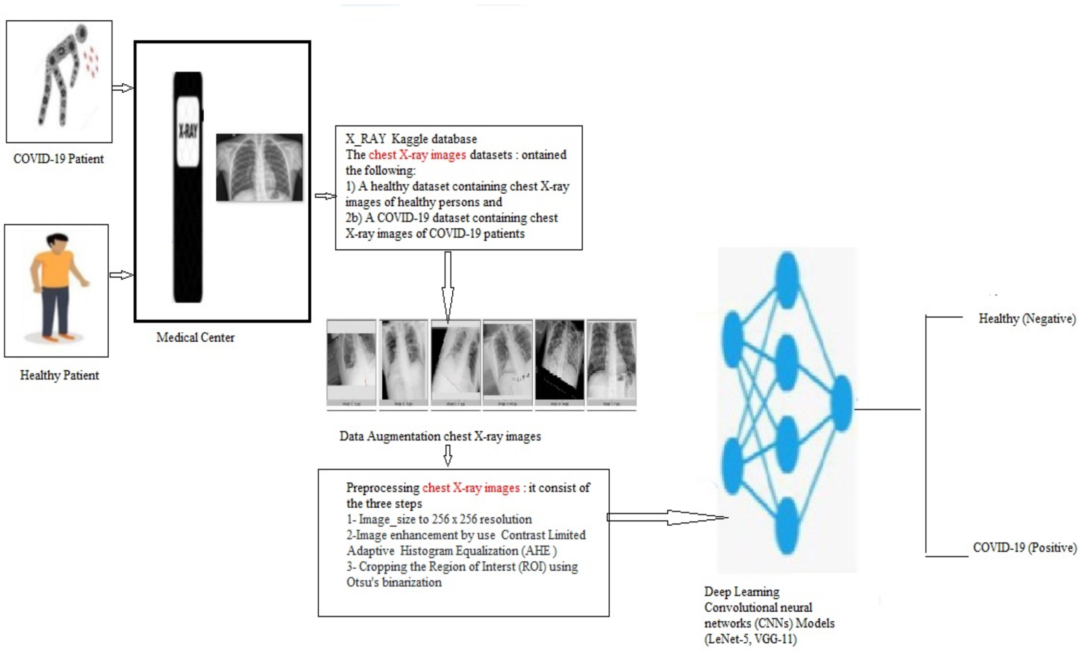


Figure 1. Architecture of the proposed work

Step 1: **Patient dataset**: The Dataset consist from an electronic medical record (EMR). EMR contains medical and treatment history of patients, e.g., patient information, medical information, chest X-ray images …etc. The chest X-ray images datasets were used in the evaluation contained the following: a) A healthy dataset containing chest X-ray images of healthy persons. b) A COVID-19 dataset containing chest X-ray images of COVID-19 patients.

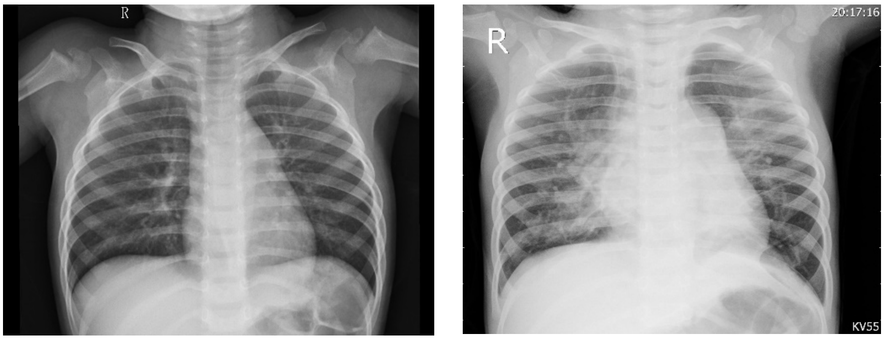
The original dataset was obtained from the Kaggle dataset, [18,19], and its total number of images is 128, as presented in Table 1 and owing to the limited availability of chest X-ray images, we generated our dataset using data augmentation as in [11]. Data augmentation is an AI method for increasing the size and the diversity of labeled training sets by generating different iterations of the samples in a dataset. Data augmentation methods are commonly used in ML to address class imbalance problems, reduce over fitting in deep learning, and improve convergence, which ultimately contributes to better results. The total number of images in the dataset became 1000 after applying augmentation, as in [11]

Table 1 Kaggle Dataset [11]

Original dataset (without augmentation)		Augmented dataset	
X-ray images	***Number***	***X-ray images***	***Number***
Healthy	***58***	Healthy	***500***
COVID-19	70	COVID-19	500
Total	128	Total	1000

Step 2: Preprocessing chest X-ray images: it consist of the following steps:

- **Color mode**: The images will be converted to gray scale. See Figure 2.



(a) Healthy (b) Coronavirus Infected

Figure 2. Chest X-ray images: (a) Healthy (b) Coronavirus Infected

- **Image size**: To resize images to after they are read from disk. Since the pipeline processes batches of images that must all have the same size, the image is resized to 256 x 256 pixels.

- **Image enhancement**: To diagnosis a Covid-19 based on Chest x-ray, it must be enhanced using Adaptive Histogram Equalization (AHE) by improve contrast in images uses them to redistribute the lightness values of the image. See Figure 3.

- **Image Segmentation**: The chest x-ray images are segmented using Otsu's method by returns a single intensity threshold that separate pixels into two classes, foreground and background. The mathematical equations and algorithm of Otsu's method are discussed in [20]. See figure 4.

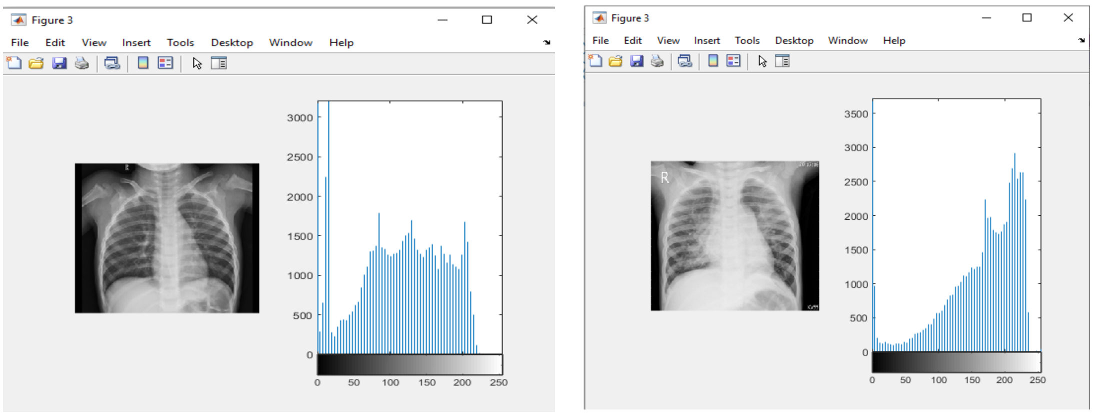


Figure 3. Chest X-ray images enhancement using Adaptive Histogram Equalization (AHE): (a) Healthy (b) Coronavirus Infected

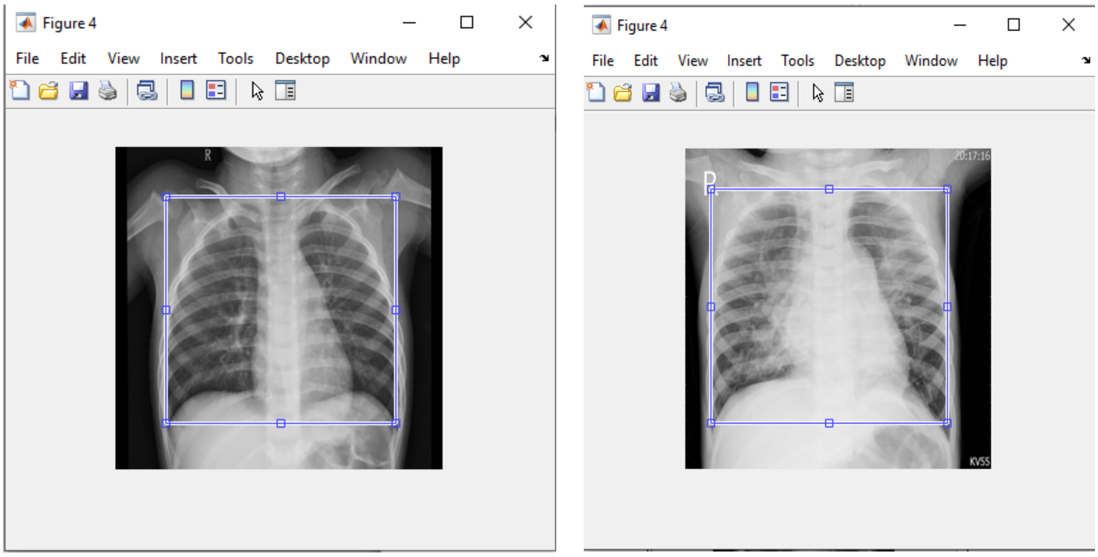


Figure 4. Chest X-ray images enhancement cropping the Region of Interst (ROI) using Otsu's : (a) Healthy (b) Coronavirus Infected

Step 3: Diagnosis Covid-19 Disease: CNN is used in this paper to diagnose Covid-19 disease since CNN have a series of algorithms that extract several features from the input data set, where CNN composed of two components responsible for extracting and classifying features. [21-23]. Features are automatically derived from CNN objects using hidden layers from 10 to 100 layers, a shape is learned from the first hidden layer, and the most complicated shape of an object is learned at the last hidden layer. For object detection tasks using deep learning models, this automated extraction of features contributes to high precision. There are many CNN architectures like LetNet-5,VGG-11, VGG-16,GoogleNet, AlexNet…etc. In this paper LetNet-5 and VGG-11 are uses to recognized Covid-19 Patient from Non-patient

LeNet-5: LeNet-5, suggested by Yann LeCun for optical character recognition in 1998, is one of the classic CNN models [21, 23]. Seven layers are the number of layers in LeNet-5, and there are also pooling and convolution layers in the LeNet-5 architecture, preceded by a flattening convolution layer and two fully connected layers, at the end of its design , there is a Softmax classifier.

VGG-11: VGG-11 is a CNN model proposed in 2014 by Simonyan and Zisserman [21, 24] to examine the impact of convolutionary depth on its accuracy in the issue of image recognition. Two architectures have been used for image segmentation and recognition: VGG-11 [25], VGG-16 [26] and VGG-19 [11], respectively. VGG-11's architecture consists of eight convolutional layers and three entirely interconnected layers, accompanied by a single layer of Softmax.

Convolutional neural network have the following [20-27]

1. **Convolution layer :** The first layer in CNN is the Convolution layer, which is responsible for extracting features from the input data by using the convolution filter (kernel). The convilution filter used to extract the weights from the input image is used to extract the weights by slipping the size 3 x 3 filter over an input image matrix at step1. Multiplication of the element-wise matrix and summation of the result is performed for any step. In the proposed work, 32 with phase size 16 is a convolution filter size for the convolution layers. Stride determines the amount of pixel changes over the input matrix, and we have chosen one stride at a time to pass the filters one pixel at a time.
2. **Activate function:** Activation functions are being used to decide whether or not a neuron can be triggered, checking whether the input obtained by a neuron is "relevant." For further activity, the relevant information is then transferred to the next stage. ReLU activation function is used in proposed work because ReLU is nonlinear activate function, ReLU in training faster than another activate functions like sigmoid , tanh , etc. [27] The output of ReLU is a constant variable which returns 0 if the input is a negative integer, otherwise the output is equal to the input. ReLU assigns all negative inputs to zero, which means missing a large number of nodes that will never be included in potential training. The ReLU as in Eq. (1):

ReLU(x) = max(0, x), (1)

Where x denotes the input to a neuron

3. **Regularization (Normalization):** After the convolution layer and before the activation function, regularization is implemented. In the proposed mode, by subtracting the average of the lots and dividing by the standard deviation, input batches were standardized. The uniform batch was then resized and moved.

4. **Pooling layer :** In CNN, the pooling layer is used to limit the computing cost of the CNN network and scale the data by acting on each input slice separately. The x-pooling is calculated every 2 ?? 2 regions in a deep slice in the proposed model. It is possible to determine the performance dimension of the max-pooling operation as in Eq. (2)

n_{out} = floor {(n_{in} –f) / s } + 1 (2)

where n_{in} , f and s Represents the input image dimension, the size of the filter, and the size of the stride, respectively.

5. **Fully connected layer (FC):** To produce output from data generated from the Convolution layer, the fully connected layer is used. In FC layers, neurons are bound in one layer to each neuron in another layer. The efficiency of its classification depends on the features derived from the previous layers. Due to the different activation functions used in this sheet, the classifier's output can be diverse. In the proposed work, the Softmax activation function was used.

6. **Output layer:** The Softmax activation function output is simply the normalized exponential likelihood of class observations, in which each input is split by the exponential number. In this paper analysis results in a vector of length 2, where each scalar is likely to belong to one of the 2 patient or stable types of Covid-19. In the Softmax layer, the likelihood of each class can be expressed as in Eq. (3):

$$\sigma\,(x)_j = \frac{e^{xj}}{\sum_{k=1}^{k} e^{x}{}_{k}}$$
(3)

For j = 1, 2, 3,…k , Where k is the number of classes, and Xj (for each value of j) are the inputs added to each node of the Softmax layer from the previous fully connected layer.

7. **Cost function**: The cost function of a neural network measures the error of the network's processing. In deep neural network learning, a cross-entropy feature is used. The object of the algorithm for optimization is to minimize or maximize) the error function. There are numerous algorithms for cost optimization, such as Adagrad, Adadelta, and Adam. Adam optimizer with a learning rate of 0.001 is sued in the proposed work and a gradient descent-based optimizer is used to reduce the cost function as in Eq. (4):

$$c = \frac{1}{m}\sum[\, y\, ln\, a + (\,1 - y)ln(1 - a)$$
(4)

Where m is the training data size, y is the predicted value, and a is the real output layer value.

Algorithm 1: Convolutional Neural Network algorithm

1. Initialize parameter: Convolutional layer, Polling layer and Softmax layer
   - Initialize convolution Layer: Initialize the values of (filter number, stride, filter size, padding, activation function).
   - Initialize Polling layer: Initialize the values of (window size, poling function, FC layer, the activation function, and weight matrix).
   - Initialize Softmax layer: Initialize output node, weight matrix. Number of CNN blocks.

2. For I =1 to number of dataset matrix samples do

    Input dataset samples.

    For J =1 to number of CNN blocks do

        Apply CNN layer

        Joint the feature map for all filters in CNN layer.

        Apply Relu activation function on feature maps.

        Apply pooling layer according to the pooling window size and the pooling function.

    End

End

3. Apply the flat layer to convert the produced tensor to a 1-D vector.

4. Apply the Fully Connected layer.

5. Apply the softmax layer.

End

4. EXPERMINTAL RESULT

The automated system is designed based on CNN deep learning model to recognized COVID-19 patients or healthy via chest X-ray images with resolution 256 x 256 using two different architectures of CNN model, LeNet-5 and VGG-11. Where LeNet-5 used in proposed work has architecture with seven layers. The design also has pooling and convolutional layers accompanied by a flattening convolutional layer and two fully connected layers. At the end of its architecture, there is a softmax classifier, also VGG-11 used in proposed work consisted of 8 convolutional layers and 3 fully connected layers accompanied by a single layer of Softmax.The parameter settings for each LeNet-5 and VGG-11 models during the training process are reported in Table 2.

Table 2. The parameter settings for each LeNet-5 and VGG-11 models

Pre-trained model	Learning rate	Mini-Batch (MB) -Size	Learning rate-decay	Weight decay
LeNet-5	0.001	32	0.9 every 3 epochs	0.001
VGG-11	0.001	32	0.9 every 2 epochs	0.0001

After experiment the automated healthcare system on Kaggle dataset with total number of 1000 chest X-ray images 80% for training the model and 20% for evaluation of the classification performance, the training and validation accuracies are (99.36%) and (98.16%) for VGG-11 and LeNet-5 of CNN respectively, see Figures 5 and 6. The train number in proposed work up to 6 epochs (number of iterations per epoch = 58). And we found the VGG-11 of CNN is more efficient then LeNet-5, and it gives the maximum accuracy (99.17%), where the LeNet-5 of CNN provides the maximum accuracy (98.01%). See table 3 and figure 7.

Table 3. Maximum accuracy on the Kaggale dataset for VGG-11 and LeNet-5 models at 256 x 256 resolutions

Dataset	Model	Resolution	Accuracy (%)
Kaggle dataset	LeNet-5	256 x 256	98.01%
Kaggle dataset	VGG-11	256 x 256	99.17%

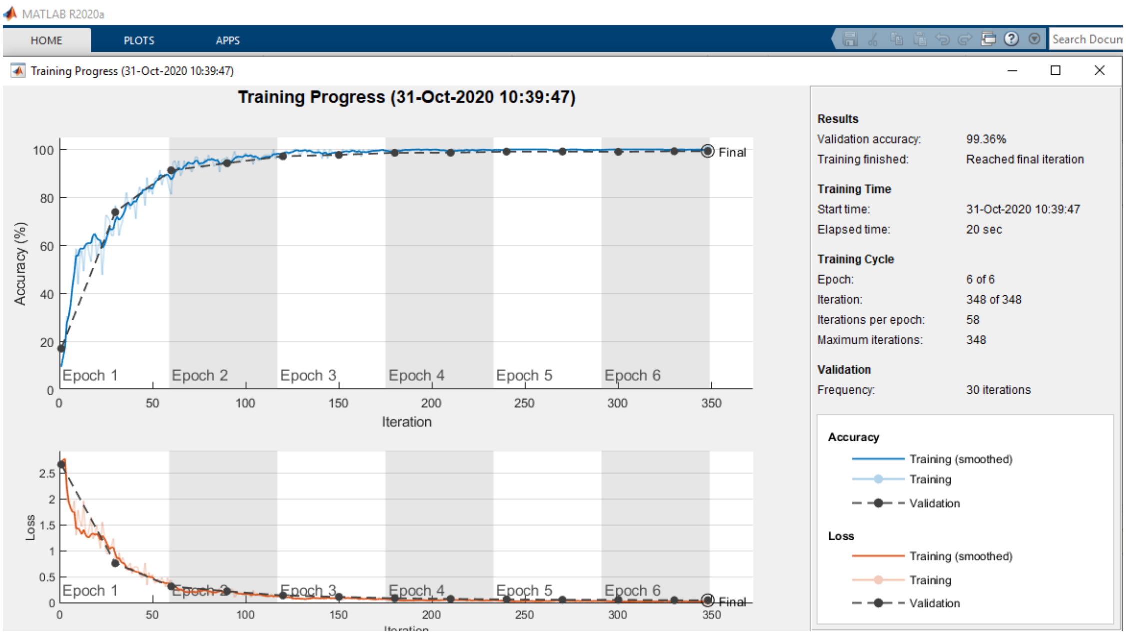


Figure 5. The VGG-11 of CNN validation accuracy (99.36%)

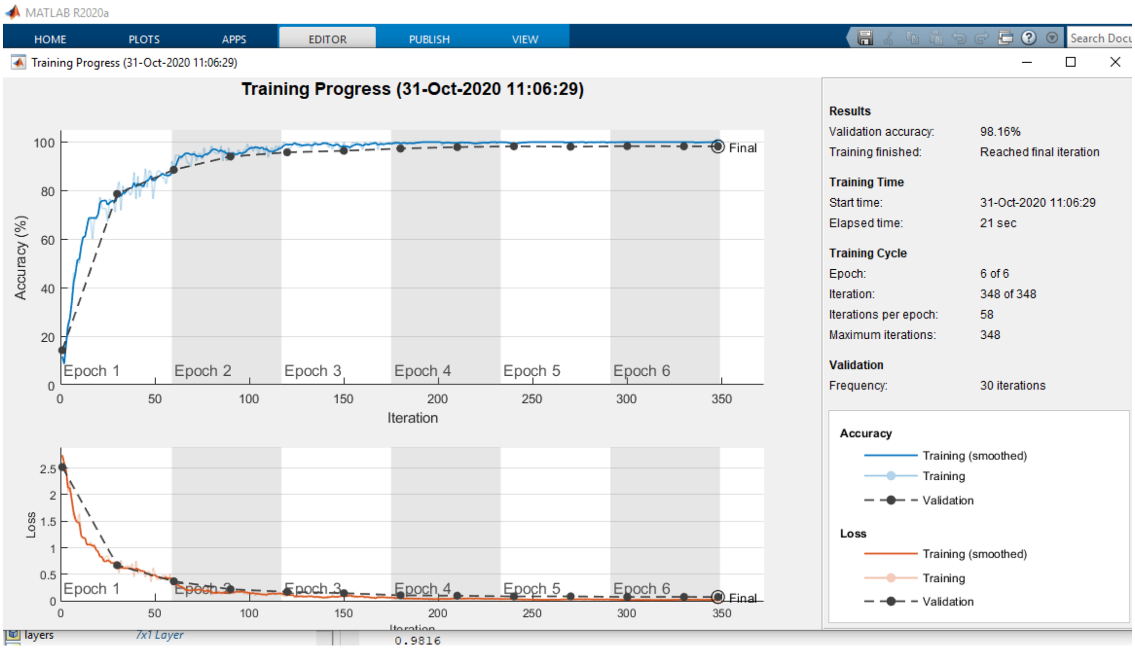


Figure 6. LeNet-5 of CNN provides the validation accuracy (98.16%)

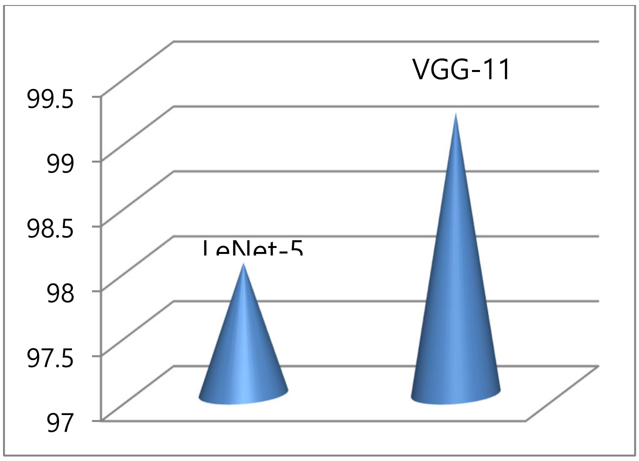


Figure 7. Maximum accuracy on the Kaggale dataset for VGG-11 and LeNet-5 models at 256 x 256 resolutions

To ensure and verify the efficiency effective of proposed work to diagnosis Covid-19 disease, the result of proposed work was compared with [11] and [28], where the detection rate in proposed workto detect covid-19 using VGG-11 has maximum accuracy rate (99.17%). That means the detection rate in proposed work is better to diagnosis covid-19 disease, see table 4 and figure 8.

Table 4. Maximum accuracy for proposed work, [11] and [28]

Research	Dataset	Model	Resolution	Accuracy (%)
[11]	Kaggle dataset [1000] images	VGG-19	256 x 256	99%
[28]	80 samples	AlexNet	4020 × 4892	93.84%
[28]	80 samples	VGG19	4020 × 4892	94.59%
[28]	80 samples	ResNet	4020 × 4892	92.5%
[28]	80 samples	GoogleNet	4020 × 4892	93.68%
Proposed work VGG-11	Kaggle dataset [1000] images	VGG-11	256 x 256	99.17%
Proposed work LeNet-5	Kaggle dataset [1000] images	LeNet-5	256 x 256	98.01%

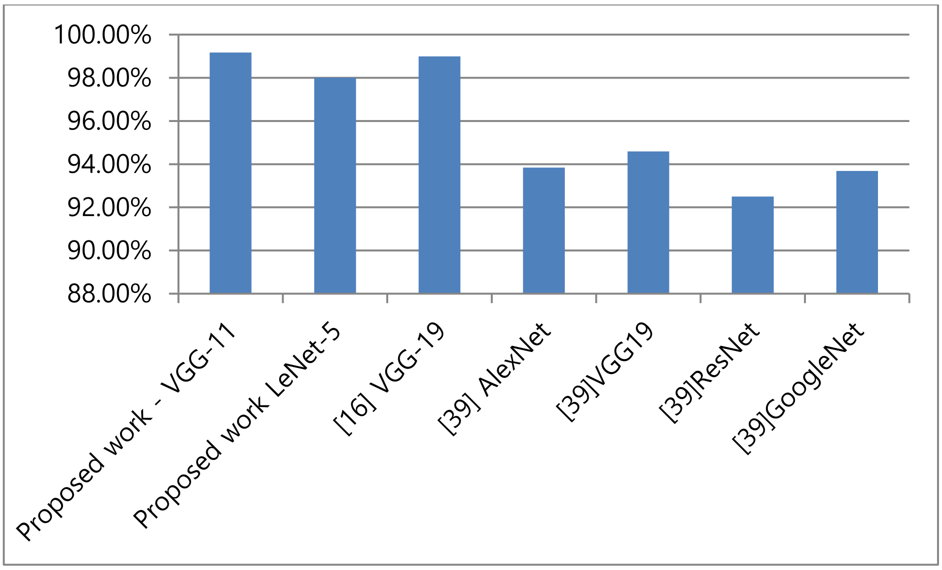


Figure 8. Maximum accuracy for proposed work, [11] and [34]

5. CONCLUSION

Due to the rapid spread of COVID-19 in all countries of the world and the significant increase in the number of deaths, it was imperative to take rapid action to diagnose COVID-19, as Covid-19 disease is synonymous with pneumonia symptoms observed by imaging scans, radiography chest x-ray is one of the most common procedures that play an important role in the diagnosis of Covid-19 disease. In so doing, testing can provide rapid detection of COVID-19 and thus contribute to controlling the spread of the disease.

In this research, an automated healthcare system is proposed based on CNN to diagnose COVID-19, to classify COVID-19 images depended on Kaggale dataset of chest X-ray images based on two architectural of CNN (LeNet-5 and VGG-11) in efficient and robust diagnostic solutions for COVID-19 cases and their ability to cope with data anomalies. The detection accuracy rate for in two architectural CNN models (LeNet-5 and VGG-11), have highest resolution 99.17 obtained by VGG-11.

In the future, we aim to use another CNN architecture to enhance the usability of the model.

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