Convolutional Neural Network for Predicting COVID-19 from Chest x-ray Images

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ABSTRACT

The world has recently witnessed many deaths for all age groups due to the respiratory COVID-19 but detecting this disease in its early stages helps to recover, avoid negative effects, and reduce the outbreak of the disease quickly. Many symptoms of this disease were found, most notably chest infections and shortness of breath resulting from infection with this disease. The goal of this project is to use chest x-rays images to predict whether a person has the COVID-19 or not.

In this study, we tested the solution performances for our problem on different versions of the CNN. Such as Mobile Net, CNN with Adam optimizer, CNN with Data Augmentation, CNN with Batch Normalization, CNN with Leaky Relu, CNN with Dropout, CNN with Early Stopping, CNN with Hyper-parameter Tuning, RESNET-50, VGG-16, and VGG-19. The results showed that the VGG-19 model outperformed all the models in detecting infection with MERS-Cove quickly and with high accuracy instead of regular examinations that take a long time and thus limit the spread of the disease.

Keywords: COVID-19, deep learning, VGG-19, conventional neural network, chest x-rays.

ÖZ

Dünya son zamanlarda solunum yolu kaynaklı COVID-19 nedeniyle tüm yaş grupları için birçok ölüme tanık oldu, ancak bu hastalığın erken evrelerinde tespit edilmesi iyileşmeye, olumsuz etkilerden kaçınmaya ve hastalığın salgınının hızla azalmasına yardımcı oluyor. Bu hastalığın birçok semptomu bulundu, özellikle de göğüs enfeksiyonları ve bu hastalığa bağlı enfeksiyondan kaynaklanan nefes darlığı. Bu projenin amacı, bir kişinin COVID-19'a sahip olup olmadığını tahmin etmek için göğüs röntgeni görüntülerini kullanmaktır.

Bu çalışmada, problemimizin çözüm performanslarını CNN'nin farklı versiyonları üzerinde test ettik. MobileNet, Adam optimizer ile CNN, Veri Artırma ile CNN, Toplu Normalleştirme ile CNN, LeakyRelu ile CNN, Bırakma ile CNN, Early Stopping ile CNN, Hiperparametre Ayarlama ile CNN, RESNET-50, VGG-16 ve VGG-19. Sonuçlar, VGG-19 modelinin, uzun zaman alan ve böylece hastalığın yayılmasını sınırlayan düzenli muayeneler yerine MERS-Cove ile enfeksiyonu hızlı ve yüksek doğrulukla tespit etmede tüm modellerden daha iyi performans gösterdiğini gösterdi.

Anahtar Kelimeler: COVID-19, derin öğrenme, VGG-19, bağlı sinir ağı, göğüs röntgeni, doğruluk.

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INTRODUCTION

1.1 Introduction

One of the respiratory diseases that spread recently at the end of 2019 is the COVID-19 shown in Figure 1.1. These viruses spread quickly, and the infection is transmitted between people through the respiratory system, in addition to their ability to develop. COVID-19 is one of the types of COVID-19, whose abbreviation refers to COVID-19, which began to appear in Wuhan, China, during the period between 2019-2020 [1], and then spread to the rest of the world quickly. On February 28, 2020, the statistics showed that the number of infections due to this disease had reached 4,600 patients, the number of deaths reaching 106, and the number of infections with the COVID-19 was rising and growing rapidly, as the number of COVID-19 infections reached 49,053 cases in less than a month (February 15), in addition to recording a large number of deaths, reaching 1,381 [2].

Many of the procedures and controls that have been applied in all countries of the world, such as quarantine, preventing movement between cities, wearing a muzzle other restriction, in an attempt to overcome the spread of the disease and reduce cases of injuries. On the other hand, a lot of medical efforts have been made in discovering this disease and its symptoms, as medical reports have shown that the COVID-19 virus is clinically similar to SARS, the emergence of severe chest infections that may cause death. The disease also has symptoms similar to the flu such as high temperature, coughing, and difficulty breathing, and in some cases symptoms of loss of smell and taste and joint pain have appeared. Clinical cases also showed that these symptoms are severe and expand to other diseases (such as acute kidney failure) in people who have other diseases, and most of the deaths were in this category of people [3].

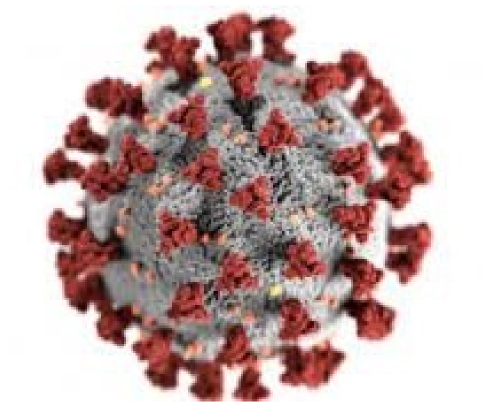

Figure 1. 1: COVID-19 [13]

Medical reports showed that there are a large number of people infected with the COVID-19 without any symptoms and they need to conduct a nasopharyngeal swab and analyze biological material to discover the disease [4], but at the same time they were able to transmit the disease, which increased the risk. Many medical diagnoses of the disease through the analysis of biological materials and swabs of people infected with the COVID-19, in addition to the x-ray images of the chest can show that a person is infected with the COVID-19 through abnormalities and signs of inflammation that appear in x-rays as shown in Figure 1.2 [5].

X-ray image of a normal person X-ray image of covid affected person

Figure 1. 2: X-ray images [5]

1.2 Research Motivation

Many previous research dealt with the problems of chest diseases and attempt to discover the disease based on medical image analysis, such as detecting chest cancer using artificial intelligence techniques. On the other hand, medical diagnoses related to COVID-19 have shown that chest radiography helps in better detection of the disease, so many research efforts have begun to try to build a predictive model to detect infection with the COVID-19 based on the analysis of medical images of the chest. Where the good results came, but it takes a lot of development to improve the accuracy of the prediction, especially since most of this research relied on the use of data sets with little data.

We suggest making use of deep learning techniques in analyzing chest images to detect whether there is an infection with COVID-19. The aim of this research is to train different versions of CNN model based on a data set related to chest x-ray images in order to build predictive models for detecting a person's infection with COVID-19 disease.

1.3 Problem Definition

The COVID-19 pandemic began to spread among people significantly, causing a significant increase in the number of injuries and deaths at an exponential rate, as the disease reached an epidemic. Many of the measures that were recommended to be taken in an attempt to prevent infection and reduce the spread of the disease, such as washing hands, achieving social distancing, not touching surfaces, and other measures, but they did not work, and the positive cases of people infected with the disease continued to increase daily.

Medical research has tended to use several tests for early detection of COVID-19 disease, such as computerized tomography (CT), nasopharyngeal swab, RT-PCR, and antigen tests. The results showed that the chest of the infected people is greatly affected by this disease, and the effects appear twelve days after contracting the disease. It is known that RT-PCR tests take a long time to detect the disease, so the analysis of chest radiographs has a major role in the rapid and early detection of the disease.

1.4 Research Contribution

In light of the increasing and accelerating spread of the contagious COVID-19 disease, and with the absence of any immunization factor that helps reduce its spread and infection, it is necessary to intensify research efforts in the early identification and detection of the disease using tests that include x-rays of the chest.

In this research, we present several solutions to the problems in the field of predicting the COVID-19 that faced researchers previously, as researchers relied on machine learning techniques that gave results with an inaccurate prediction. Therefore, the primary goal is to use deep learning in this research, as it is known that convolutional neural networks (CNNs) from deep learning technologies have the ability to detect respiratory disorders from chest X-ray images. Therefore, this research contributes to the use of medical images of chest x-rays for early detection of people's infection with the COVID-19 by adopting deep learning techniques.

1.5 Thesis Structure

This report is organized as follows. Chapter 2, we talk about the previous work in the academic literature and further background material. Chapter 3 is dedicated to the following methodology. Finally In chapter 4, we describe our work, presented with conclusion of this research and discussion of future investigations.

Chapter 2

LITERATURE REVIEW AND BACKGROUND

2.1 Introduction

In this chapter, we will discuss the works that fall within the scope of our research, as there are many previous works that discussed the analysis of medical images of the chest and the detection of infection with the COVID-19 according to multiple techniques, mostly in the field of machine learning and data mining. These studies had several drawbacks that helped us suggest a solution. This chapter also includes an explanation of several concepts related to deep learning to help understand the methodology to be implemented. First, in Section 2.2, we will give Literature review on COVID-19 detection and chest image analysis. Then, Section 2.3 we show more background materials.

2.2 Literature Review

In this section, we present some of the early studies that addressed the prediction of COVID-19 from chest X-rays.

Haritha et all.[5] have suggested using deep learning to build a predictive model of COVID-19 infection based on the use of a type of CNN is Google net. The study relied on the use of chest x-ray images in order to classify them if they indicate the presence of COVID-19 or not, as the results showed the ability of the model to give correct predictions of the disease, with a test accuracy of 98.5% and a training accuracy of

99% as show in Figure 2.1. This study suffers from the need to improve specificity and sensitivity through the use of large data sets of chest radiographs.

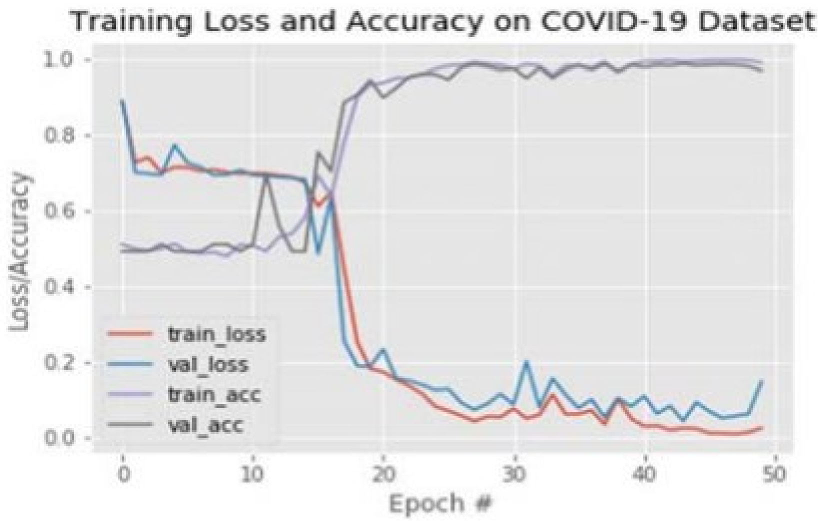

Figure 2. 1: Training and Validation Accuracy and loss [5]

Chen et all. [6] have suggested using deep learning to detect people with COVID-19 disease. Where the UNet++ model achieved a high accuracy of 98.85% based on the detection of disease from medical images of patients of Renmin Hospital of Wuhan University and the discovery of 51 people with COVID-19 disease. This study suffers from the data set's lack of images of healthy patients and thus the inability to obtain true predictions. Xu et all. [7] discovered the COVID-19 using a deep learning approach, in which two 3D CNNs were applied to a data set of 618 medical images. The results showed that the two user networks, RESNET-23, and the other modified in terms of the number of layers have a significant role in predicting a person's infection with the COVID-19, with an accuracy of 86.7%.

Ophir et all. [8] relied on the use of deep learning in image analysis and they used the RESNET-50 model to train a set of 6150 CT images of the chest region for the detection of COVID-19 as shown in the Figure 2.2 below. The results showed that the proposed model achieved classification results for the disease with a sensitivity of 98.2%, and a specificity of 92.2%. In our work after several experiments, we used CNN models by added three layers, then four layers, then five layers, but no results were obtained with high accuracy.

When adding one layer after the RESNET-50 model, a number of neurons were tested, since two classes are needed, so two neurons are placed in this layer using the Activation Soft Max function. Thus, we note that the presence of only one layer after the RESNET-50 model, gave results with higher accuracy than repeating several layers. The same working mechanism was adopted for the VGG-19 model, where after several experiments; the ideal solution was to place a layer with 100 neurons in addition to the output layer with two neurons. The results showed that these two layers gave high accuracy after training the VGG-19 model.

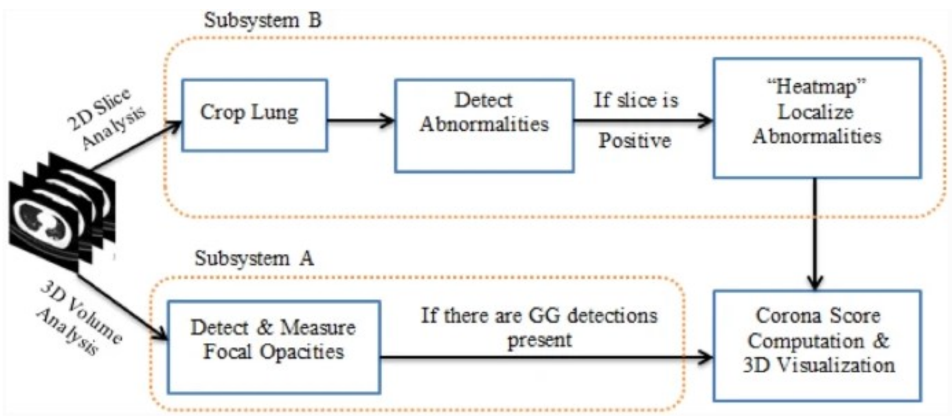

Figure 2. 2: The block diagram of the system [8]

Irmak [23]. has proposed the design of an automated model to classify the severity of COVID-19 disease. With the spread of the Corona virus, many people began to turn to chest x-ray examinations in order to diagnose and discover the presence of the disease or not and to determine the severity of the disease, and this led to crowding of clinical facilities. The proposed model relied on the use of the Convolutional Neural Network (CNN) in order to classify the severity of the disease into four categories that include mild, moderate, severe and critical. The results showed that the model achieves an accuracy of 95.52% and is of great importance in accelerating the diagnosis and treatment of patients.

Polsinelli et al. [24] have proposed designing a system to help classify images of the chest from computer tomography (CT). The convolutional neural network was used to distinguish between different computed tomography images and images containing COVID-19 infection. The results showed that the proposed model achieved an effective performance for distinguishing COVID-19 images and a high accuracy of 85.03%. Ibrahim et al. [25] designed a model that aims to distinguish between chest images if they have COVID-19 or pneumonia and lung cancer. It was based on the use of four types of architectures, including VGG19 + CNN, ResNet152V2, ResNet152V2 + GRU, and ResNet152V2 + Bi-GRU, where the model was applied to a sample of images taken from chest X-ray and computerized tomography (CT). The results showed that the VGG19 + CNN model helps in early detection of the disease, and it achieved the highest accuracy among the four models with a percentage of 98.05%.

Jia et al. [26] have proposed a model for diagnosing COVID-19 based on modification of convolutional neural networks. The proposed model is based on the use of a modified MobileNet to detect COVID-19 CXR images of five classes (COVID-19, tuberculosis, viral pneumonia, bacterial pneumonia and normal controls using CXR images), as well as the use of ResNet to classify the tomograms. The results showed that the proposed model is able to diagnose the disease with a high accuracy of up to

99.6% in COVID-19 CXR, and with an accuracy of up to 99.3% in the classification of CT images. Singh et al. [27] have designed a Covid-19 detection model based on the use of deep learning and concepts of convolutional neural networks. The proposed model was applied to a chest x-ray data set consisting of three categories including Covid-19, pneumonia and Normal. The results showed that the proposed model provides an effective method for disease detection with a classification accuracy of 87%.

Panwar et al. [28] proposed using deep learning techniques to detect Covid 19 disease. AlexNet and a convolutional neural network were applied to a data set of 300 chest X-ray images. The results showed that the small number of images used does not help to rely heavily on the proposed model in medical institution. Rawat et al. [29] have designed a model for the diagnosis and detection of Covid-19 based on the use of deep learning techniques. Four convolutional neural network structures (DenseNet, Incetption, Xception, and MobileNet) were applied to the ImageNet dataset containing chest X-ray images. The results showed that all the structures used have high performance, but the MobileNet model has outperformed all models in diagnosing Covid-19.

2.3 Background

This section contains further background material about the structure of deep learning and description of CNN and their types to understand the solution developed in our project. In section 2.3.1, we provide a description about the deep learning then in the section 2.3.2, we talk about the CNN models

2.3.1 Deep Learning

Deep learning is one of the machine learning algorithms that have been used to deal with big data, which is constantly increasing and growing. Deep learning is used in many studies that include speech and sound processing, natural language processing (NLP) and many others. Deep learning is based on the use of neural networks, which is a multi-layered architecture that analyzes data and extracts features. Deep learning differs from machine learning in the feature extraction stage, as shown in the Figure 2.3 below [9]. The figure shows that deep learning takes place entirely without human intervention at any of its stages. As for machine learning, humans must intervene at its beginning in the stage of extracting characteristics. They both fall under the same use of classification, but the algorithms used are different.

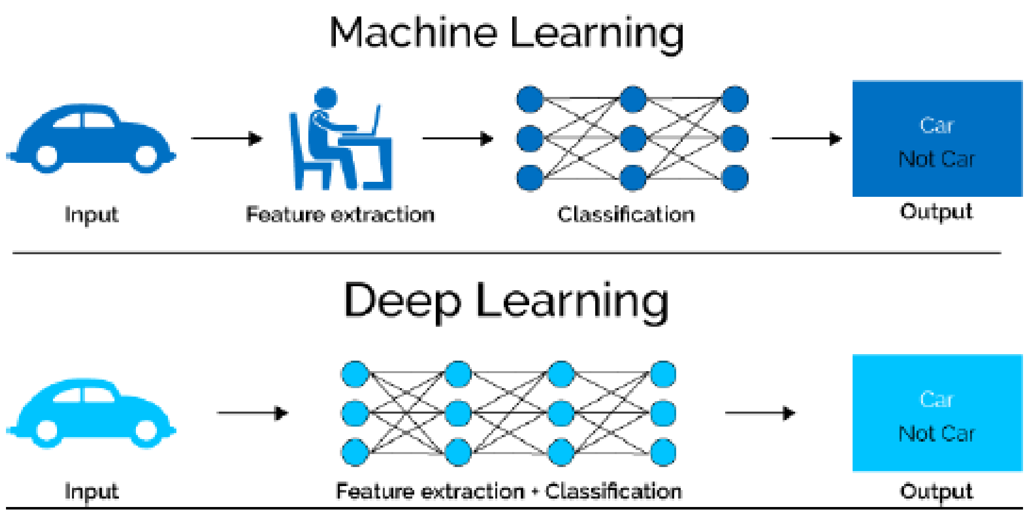

Figure 2. 3: The difference between machine learning and deep learning [9]

The structure of neural network consists of several layers, as shown in the Figure 2.4 below, where the first layer is called the input layer, which performs data entry x to be learned, and the number of neurons in this layer is the same as the number of input elements. The last layer is called the output layer, which gives the result of classifying the data y, in addition to the presence of several internal hidden layers that extract the features according to certain arithmetic operations [9].

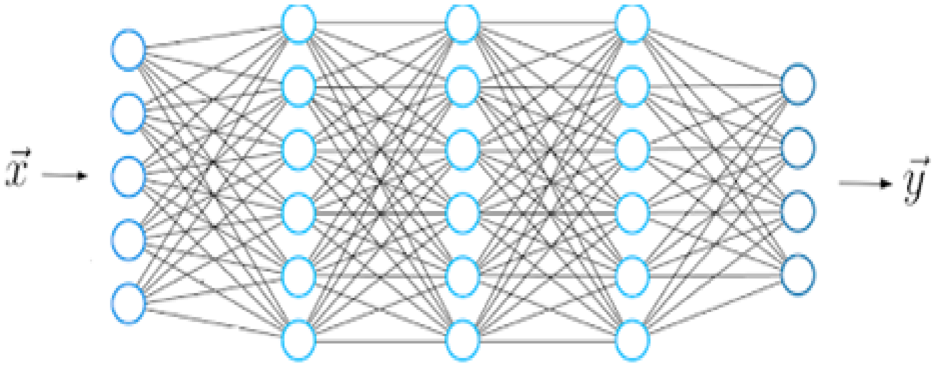

Figure 2. 4: The structure of neural network [9]

2.3.2 Convolutional Neural Network

A convolutional neural network (CNN) is a deep learning network that efficiently and accurately processes images through feature extraction. CNN is a three-layer mathematical model as shown in Figure 2.5 below, where the features are extracted using the first and second layers (convolution, pooling), while the features extracted by the third layer (completely conventional layer) are classified and mapped [10].

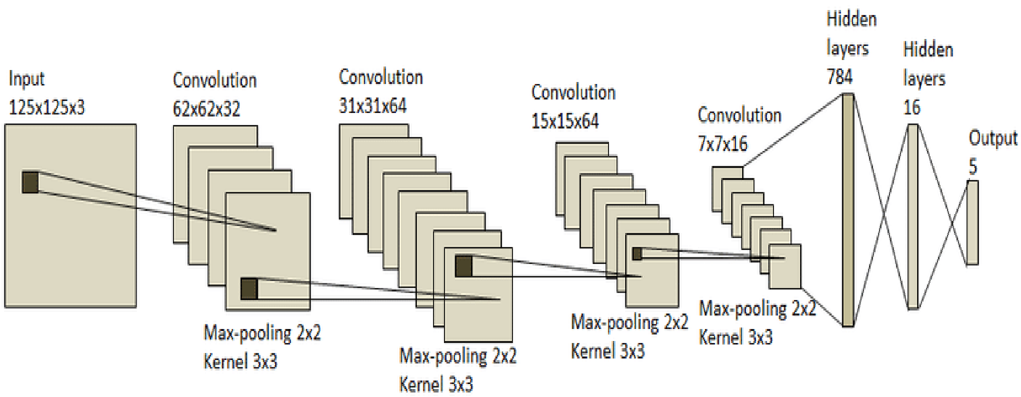

Figure 2. 5: The structure of CNN [10]

CNN provides an end-to-end output so, there is no need to do any feature engineering. But to train a CNN model we need a large amount of data, unlike the Machine learning algorithm. Filters (kernels) are used to extract the features of an image. Kernels are the learned matrices whose weights are updated during training so. The initial few layers of the CNN model learn the basic representation like edges, boundaries, etc. whereas the later layers learn fine-grained knowledge like a different section of the chest, etc. SO, here features of images are extracted by a convolutional operation, and then it’s converted to a vector which is then passed to a CNN, whose task is to classify whether the class is normal or abnormal.

2.4 Summary

In the second chapter, a review of the literature is presented. The scope of this research falls within the scope of COVID-19, we explain the most important main techniques used to predict this disease, which included deep learning and machine learning algorithms. Finally, a basic background was provided on the deep learning techniques.

Chapter 3

METHODOLOGY

3.1 Introduction

This chapter talks about the models that we used based on deep learning. Initially, it was necessary to study, understand and analyze the data set to discover the relationship between all the information. Also, we train different models based on deep learning and explain in detail all the steps to be followed in trainee process. In section 3.2, analyzing the dataset and user requirements for training models are mentioned. In section 3.3, the different steps of our following approach that should be done in order to detect the presence of COVID-19.

3.2 Dataset Description

The dataset is available on the Kaggle website. The dataset is images of chest x-rays. The data set consists of 6432 images and is divided into three classes are x-rays of the chest infected with the COVID-19 as shown in the Figure 3.1 below, x-rays of the chest infected with pneumonia as shown in the Figure 3.2 below, and finally, x-rays of the normal chest without infection with any disease as shown in the Figure 3.2 below. The data set is divided into two parts, a special section for the training data set consisting of 5144 images belonging to three classes, in addition to a special section for the verification data set consisting of 1288 images belonging to three classes.

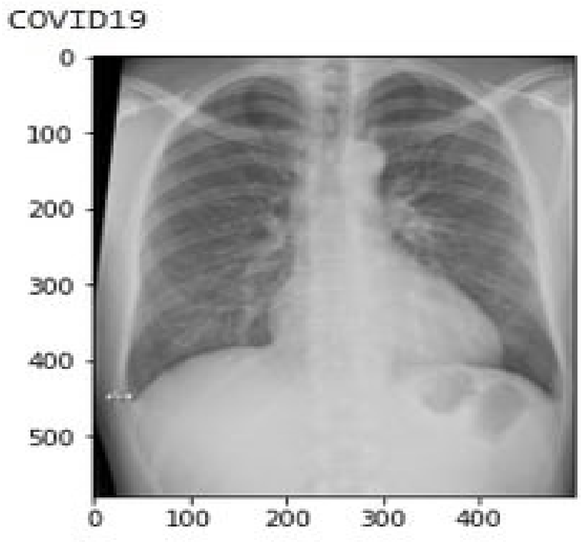

Figure 3. 1: X-rays image of COVID-19 [15]

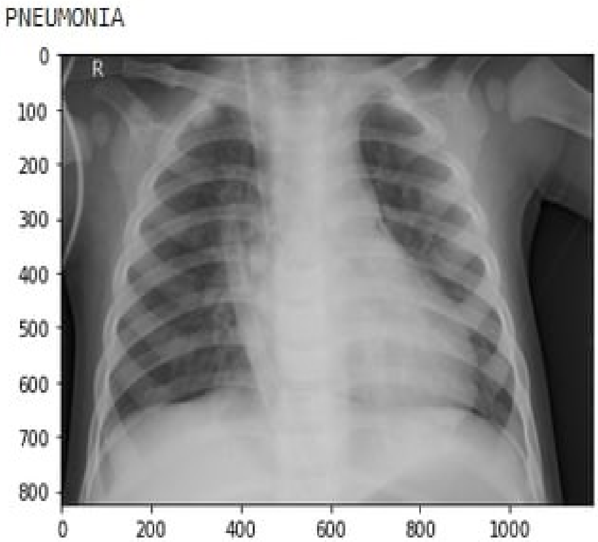

Figure 3. 2: X-rays image of pneumonia [15]

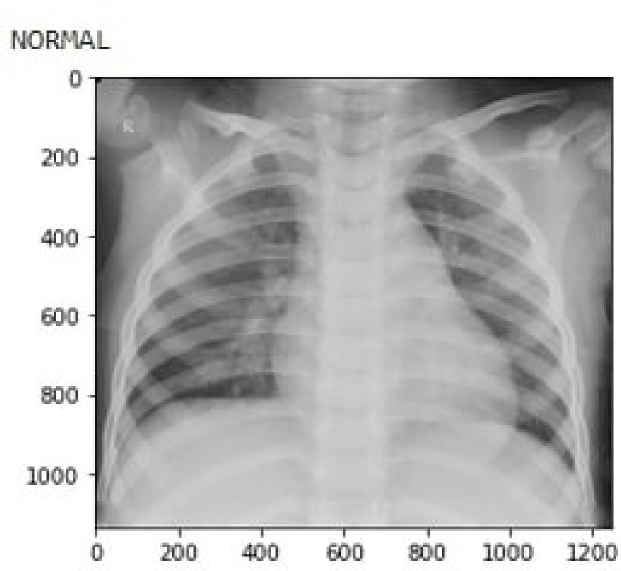

Figure 3. 3: X-rays image of normal [15]

3.3 The General Stages in the Solution Methods

Our methodology consists of several stages, including;

- Fetching the data set from a KAGGLE site, and it was pulled through a tool for fetching the dataset from this site, in this stage we will deal with 3 datasets, the first one for training, the second for testing and the third dataset for validation all of these datasets are in drive as zip files.
- Read data automatically in code, we mean the x-rays images, we want to read the data first in order to analysis it then apply the different techniques of the filtering process.
- Implementation of an operation for augmentation to increase the images and make adjustments to the single image to take into account all cases related to the image Like rotate and increase the accuracy, plus Converting all images into size (224*224).
- Building a CNN based on the KERAS library to form its layers, for building CNN model, first we define the model as Sequential to be a NN model, then

we start adding our layers of CNN such as (Adam, dropout, early stopping etc.…) and get the results.

- Classification and verification of the model using a library to form layers and methods of training and testing.

3.3.1 Used Models

There are many CNN models that can be used to predict whether or not COVID-19 is exist in our chest x-rays images such as;

1. Convolutional Neural Network

A convolutional neural network (CNN) is a deep learning network that efficiently and accurately processes images through feature extraction. CNN is a three-layer mathematical model as shown in Figure 2.5 below, where the features are extracted using the first and second layers (convolution, pooling), while the features extracted by the third layer (completely connected layer) are classified and mapped [10].

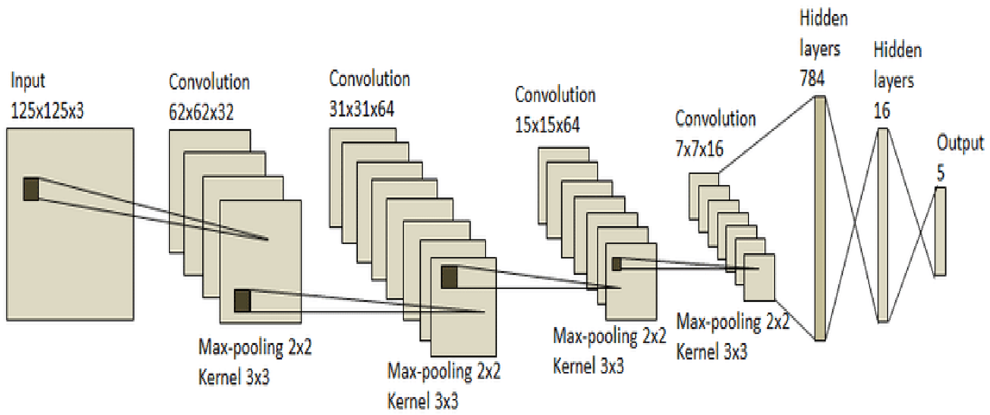

Figure 3. 4: The structure of CNN [10]

CNN provides an end-to-end output so, there is no need to do any feature engineering. But to train a CNN model we need a large amount of data, unlike the Machine learning algorithm. Filters (kernels) are used to extract the features of an image. Kernels are the learned matrices whose weights are updated during training so. The initial few layers of the CNN model learn the basic representation like edges, boundaries, etc. whereas the later layers learn fine-grained knowledge like a different section of the chest, etc. SO, here features of images are extracted by a convolutional operation, and then it's converted to a vector which is then passed to a CNN, whose task is to classify whether the class is normal or abnormal.

2. Mobile Net

Mobile Net is a CNN model used in mobile applications for image classification. This model consists of a simplified structure with low computational power, where Depth wise Separable Convolution is the base layer in this model that represents filters that are separable in depth as show in figure below [16].

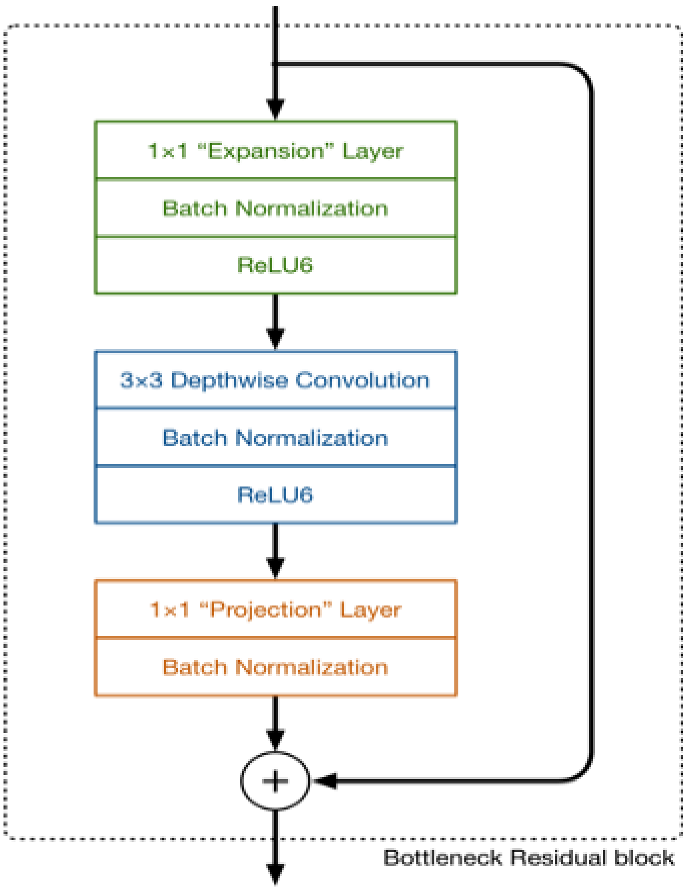

Figure 3. 5: The structure of the Mobile Net [16]

3. CNN with Adam optimizer

Adam optimizer is a technique for optimization for gradient descent, it is extremely efficient when we want to work with a problem that should deal with a huge data, such our case, Adam optimizer also give a fast result with less memory, it can be considered as hyper method because it involves a combination of two gradient descent methodologies which are;

- **Momentum**: This algorithm is used to increase the speed of the gradient descent algorithm by considering the Exponential Weighted Average of the gradients. Using averages results in the algorithm converging to lower bounds at a faster rate.
- **Root Mean Square Propagation (RMSP):** Root implies square prop or RMSprop is a versatile learning calculation that attempts to further develop AdaGrad. it uses the "exponential moving average" rather than the cumulative sum of squared gradients[30].

4. CNN with Data Augmentation

- It is possible to make simple adjustments to the data we have, and it is also possible to use machine learning models to create new data points whose purpose is to amplify the data set.
- **Synthetic data**: When data is generated artificially without using real-world images. Synthetic data are often produced by Generative Adversarial Networks.
- **Augmented data**: The derivation of the original images in addition to modifications or transformations that are considered geometric but simple, such as flipping, for example, or the rotation process, adding noise or

translation, are added in order to increase the diversity and difference of the training group used. When considering limitations such as inconsistencies with the original data, it is preferable to use augmented data over synthetic data. Because if we use data augmentation in deep learning models, we will be able to create new training data sets that have greater diversity, higher performance, and better performance [31].

5. CNN with Batch Normalization

Normalization is the method of processing is intended to unify the data, it can be considered as different sources of data within the same range, it is possible that problems occur in our network before training, so for whom we do the normalization process, and this thing may make training more difficult and reduce the speed of learning, the Batch Norm is used as a method An alternative normalization of the raw data, and it is performed between the layers of the neural network in small batches, not the entire data set at once, so its benefit lies in increasing the training speed, using high learning rates, and facilitating learning.

In convolution, there is a common filter that is run along the input feature map (The feature map for images typically consists of height and width). these filters are equal in all feature maps, then it makes sense to divide the output into feature maps and normalize it in the same way.

This indicates that each feature map as a whole is used to calculate the normalization parameters. Each characteristic has a unique mean and standard deviation for normal batch criteria. Here, a single mean and standard deviation are used for each feature in each feature map [32].

6. CNN with LeakyRelu

LeakyRelu, give zero as output for all the negative inputs. This makes it easier for neurons to die in CNN models. A diverse of LeakyRelu, transform the negative input into a negative signal output. According to the benefits of ReLU, we use the LeakyRelu function to fix some parameters and deal with gradient death. In order to build a new CNN framework, the PReLU parameters get joined with PReLU trained [33].

7. CNN with dropout

Another typical feature of CNNs is the dropout layer. A dropout layer is a mask that cancels the contribution of some neurons to the next layer, leaving all others alone. A dropout layer can be applied to the input vector. In this case, part of that function is overridden. But you can also apply it to hidden layers. If so, kill some hidden neurons. A dropout layer is important when training a CNN as it prevents overfitting of the training data. If they are absent, the first batch of training patterns will disproportionately affect learning [34].

8. CNN with Early stopping

Early stopping monitors the model's performance in each epoch of the persistent validation set during training and stops training depending on the validation performance. Early stopping is a very different way of regularizing machine learning models. This means that training will stop once the validation error is at its lowest point Early stopping is a technique that allows you to specify any number of training epochs and stop training when the model no longer performs better on the validation dataset. This requires providing the fit() function with a validation split and an Early

Stopping callback to specify the performance metric that the validation split's performance is being monitored for[35].

9. CNN with Hyper-parameter Tuning

They are the variables that work on determining the structure of the used network and responsible for determining how to train the network .Before training process , set the hyperparameters before the process of optimizing the weights and biases, and several methods are used to discover the hyperparameters, including Bayesian Optimization Manual Search, Random Search and Grid Search.

10. RESNET-50

RESNET-50 is a 50-layer CNN. It’s a huge model with less number of parameters, it scales the feature map from the original size to the smallest scale, and it has the identity mapping from the block before it to the block after it, which assists the model to be trained, without any gradient issue. The Figure 2.6 below shows the structure of this model, where the result of each convolutional layer, the frequency of every layer, in addition to the size of the filters, in addition to 1000 conventional layers [11].

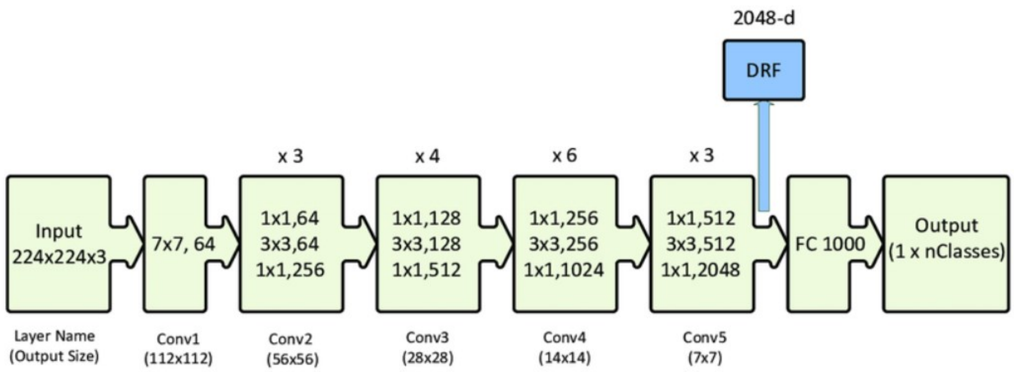

Figure 3. 6: The structure of the RESNET-50 [11]

11. VGG-16

It is a convolutional neural network model helps classify and recognize images. This model has proven its ability to predict disease based on the classification of medical images from X-rays or MRI scans. It’s a bit older model compared to that of RESNET-50, and it scales the size of the feature map by (1 /2) after each subsequent layer. The Figure 5.1 below shows the structure of this module consisting of a layer for inserting images at a constant size which is equal to 224 x 224 containing three color channels. The input is passed to the convolution layer with ReLU activations, since these two layers contain 64 filters.

Then, there are max pool layers and finally, there are fully conventional and SoftMax layers [12]. Pooling layers has its own way to minimize sampling of the maps feature , through summarize the existence of each feature in all the patches of the feature map. we have two methods of pooling which are (max pooling: the most activated existence of a feature respectively),(average pooing: the average of the existence of feature)[19]. The SoftMax is a function able to convert a vector of real values into a sum of that value of number 1 , input could be any kind of values either one ,more than one ,zero, less than zero ,positive for sure ,and also negative values , the purpose of using soft max is converted these values into value between (1and 0) so we can explain them as probabilities it will convert the small and big input probability to a value between 0 and 1while retaining its minimum or maximum value. [20].

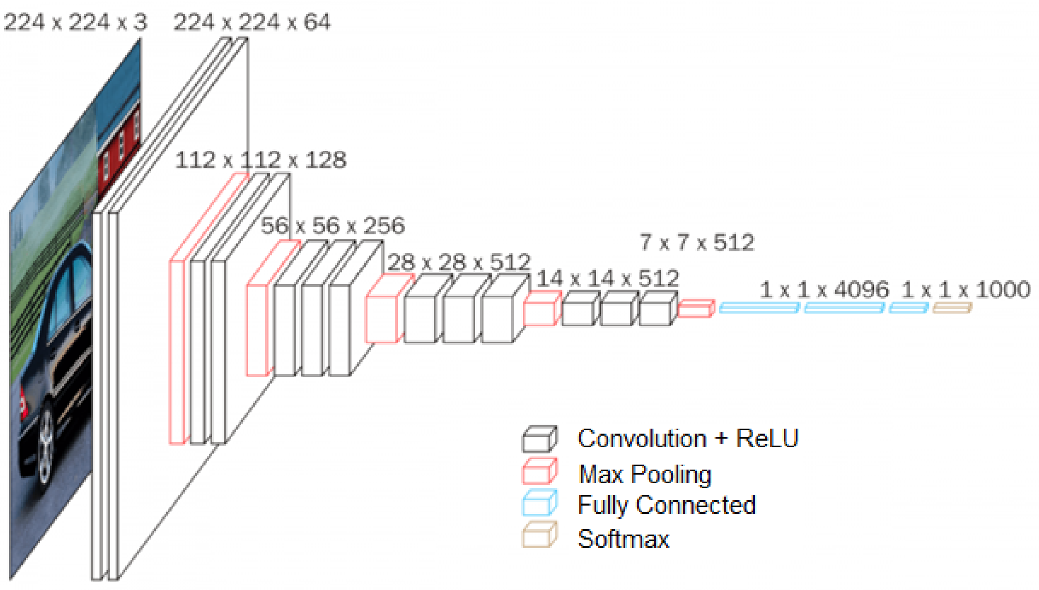

Figure 3. 7: The structure of the VGG-16 [12]

12. VGG-19

It is a convolutional neural network architecture that is deep with 19 layers. The goal of design VGG was to win the ILSVRC imagenet competition, it takes size in an image input which is 224×224, It’s known about the convolutional neural network that it makes use of a minimal field of reception , the smallest size that still includes all the four directions left, right, up, down. Additionally, to ReLU activation function. ReLU is a piecewise linear function that will output the input if it is positive or give an output as a zero. It is a rectified linear unit activation function. In order to preserve the spatial resolution after convolution, the stride is fixed at one pixel. It has three layers that are all connected. The image net dataset's total number of classes is represented by the first two layers, each containing 4096 nodes, and the third layer, which includes 1000 nodes.

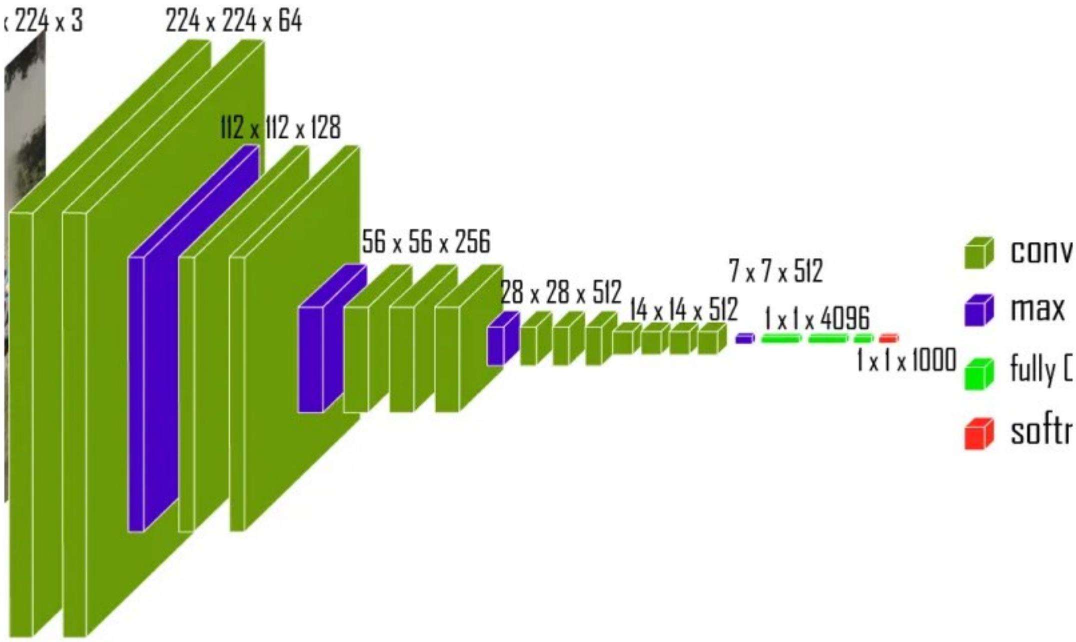

Figure 3. 8: The structure of the VGG-19 [21]

After defining each CNN model now, we will give an explanation for all the used model includes number of used blocks, optimizer name, number of neurons, learning rate, etc.

- **CNN Model 1**
  - This model is 3 blocks of CNN and 10 neurons in dense layer, we choose these 3 blocks to get better result , if we use 3>|<3 the result show up with low efficiency.
- **CNN Model 2**
  - This model is 3 blocks of CNN and 10 neurons in dense layer additionally to MobileNet model which is designed to be used in mobile applications.
- **CNN Model 3**
  - This model is 3 blocks of CNN and 10 neurons in dense layer and is using optimizer SGD (stochastic gradient descent) with learning rate = 0.001. The

SGD algorithm uses examples from the training set of error condition estimation, and then relies on the Backpropagation algorithm to update the model weights.

- **CNN Model 4**
  - This model is 3 blocks of CNN and 10 neurons in dense layer and is using Adam optimizer with learning rate= 0.001. Adam optimizer helps improve training of a deep learning model, addressing Optima problem and sporadic random gradients.
- **CNN Model 5**
  - This model is 3 blocks of CNN and 10 neurons in dense layer and is using Adam optimizer with learning rate= 0.001 and data augmentation. This model relies on data augmentation, such as rotation, unlike the previous model, in order to deal with large amounts of image and the ability to create synthetic data during training.
- **CNN Model 6**
  - This model is 3 blocks of CNN and 10 neurons in dense layer and is using Adam optimizer with learning rate= 0.001, data augmentation and batch normalization. The model is based on batch normalization, which leads to high-speed training of the data by normalizing the pixels of the feature map, so that the data is distributed over 0 mean and 1 standard deviation.
- **CNN Model 7**
  - This model is 3 blocks of CNN and 10 neurons in dense layer and is using Adam optimizer with learning rate= 0.001, data augmentation, batch normalization, and LeakyRelu. This model was based on the use of LeakyRelu with an alpha value = 0.1, where the LeakyRelu type of activation function

works to update the weight even if it is negative because the color gamut is not zero at that stage, thus enhancing accuracy and eliminating the problem of negative weight.

- **CNN Model 8**
  - This model is 3 blocks of CNN and 10 neurons in dense layer and is using Adam optimizer with learning rate= 0.001, data augmentation, batch normalization, LeakyRelu and dropout. This model is based on adding a dropout layer with a value of 0.2, where this layer drops neurons randomly during training and shuts them down during testing. Better accuracy can be obtained by solving the overfitting problem, which bypasses the Bayer error and selects the optimal parameters for the model.
- **CNN Model 9**
  - This model is 3 blocks of CNN and 10 neurons in dense layer and is using Adam optimizer with learning rate= 0.001, data augmentation, batch normalization, LeakyRelu, dropout and early stopping. This model has all the properties of the previous model, but it uses the optimal parameters for training instead of static.
- **CNN Model 10**
  - This model is 3 blocks of CNN and 10 neurons in dense layer and is using Adam optimizer with learning rate= 0.001, data augmentation, batch normalization, LeakyRelu and dropout. This model is based on shrunk down the feature map to the smallest scale from its original size that’s why we used RESNET-50.

- **CNN Model 11**
  - This model is 3 blocks of CNN and 10 neurons in dense layer and is using Adam optimizer with learning rate= 0.001, data augmentation, batch normalization, LeakyRelu and dropout. In this Model we use VGG-16 which is an object identification and classification method that has a high accuracy up to 92.7% when classifying huge number of images.
- **CNN Model 12**
  - This model is 3 blocks of CNN and 10 neurons in dense layer and is using Adam optimizer with learning rate= 0.001, data augmentation, batch normalization, LeakyRelu and dropout. In this Model we use VGG-19 which is able to do the following by using a specific layer such as,(Convolutional layer) creates a feature map by applying a filter that scans the image several pixels at a time.(Pooling layer) scales down the information generated by the convolutional layer to effectively store it. (Fully connected input layer) flattens the outputs into a single vector.(Fully connected layer) applies weights over the inputs generated by the feature analysis. (Fully connected output layer) generates final probabilities to determine the image class.

3.4 Summary

In the third chapter, we describe the adopted dataset in this research and clarify its sections, then we explain the following stages that we do to dedicate the COVID-19 disease, Finally, details about the selected model and the performance measures of each one is provide.

Chapter 4

EXPERIMENTAL RESULTS

4.1 Introduction

This chapter talks about carrying out several experiments with different models. It is necessary to implement the proposed approach according to different models, and then get the results. In Section 4.2, there are a comparison between all the CNN models, with different setting. In Section 4.3, compare the models. In the section in Section 4.4, the results we obtained.

4.2 Comparisons Between CNN Models

The table below show a comparison between the models to be applied in building the predictive model.

Table 4. 1: Comparison between the CNN models

No. CNN model	Number. blocks	Number. neurons	Name of Optimizer	Data augmentation	Batch normalization	LeakyRelu	dropout	Early stopping	Hyper-parameter
Model 1	3 blocks	10 neurons	(SGD)optimizer						
Model 2	3 blocks	10 neurons	ADAM optimizer						
Model 3	3 blocks	10 neurons	ADAM optimizer	✓					
Model 4	3 blocks	10 neurons	ADAM optimizer	✓	✓				
Model 5	3 blocks	10 neurons	ADAM optimizer	✓	✓	✓			
Model 6	3 blocks	10 neurons	ADAM optimizer	✓	✓	✓	✓		
Model 7	3 blocks	10 neurons	ADAM optimizer	✓	✓	✓	✓	✓	✓

4.3 Results

After several experiments, we added three layers, then four layers, then five layers, but no results were obtained with high accuracy. For depth wise separable convolutions we add MobileNet , if we want to talk about the optimizer we pick Adam and (SGD) ,also we use data augmentation and Batch Normalization, LeakyRelu , dropout, Early stopping , Hyper-Parameter tuning ,and we get their results ,When adding one layer after the RESNET-50 model, a number of neurons were tested, since two classes are needed, so two neurons are placed in this layer using the Activation Soft Max function. Thus, we note that the presence of only one layer after the RESNET-50 model, gave results with higher accuracy than repeating several layers. The same working mechanism was adopted for the VGG-16 model, where after several experiments; the ideal solution was to place a layer with 100 neurons in addition to the output layer with two neurons. The results showed that these two layers gave high accuracy after training the VGG-16 model, we also change the used model from VGG-16 to Vgg-19 and the difference between them is the number of layers, but this small change give the best accuracy that we can ever get it in all this research.

4.4 Model Accuracy

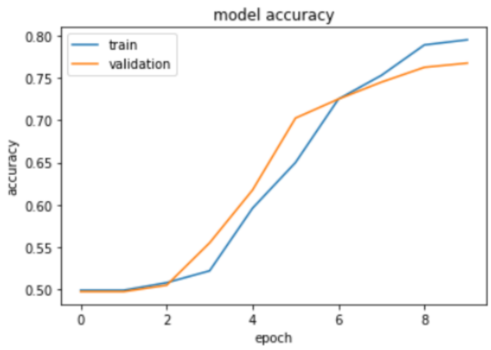

Figure 4. 1: Accuracy of CNN

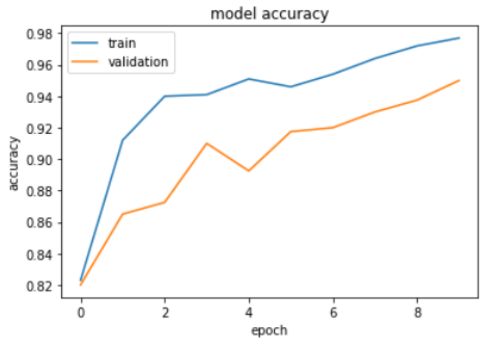

Figure 4. 2: Accuracy of CNN with Adam optimizer

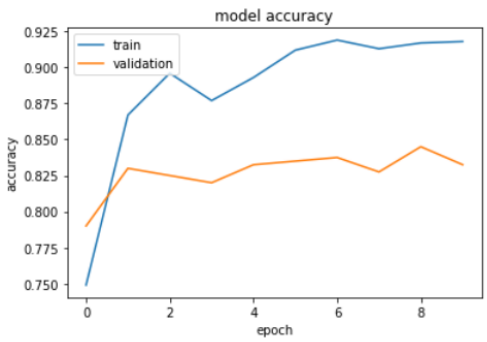

Figure 4. 3: Accuracy of CNN with Batch Normalization

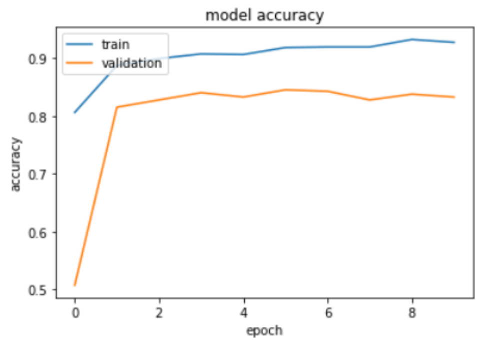

Figure 4. 4: Accuracy of CNN with Data Augmentation

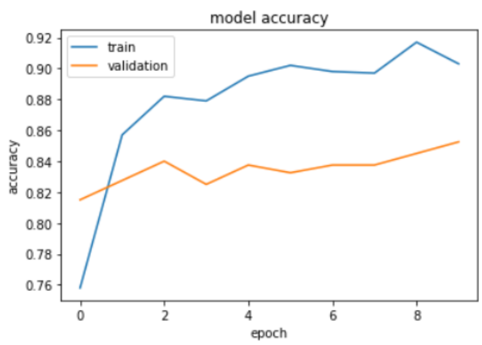

Figure 4. 5: Accuracy of CNN with Dropout

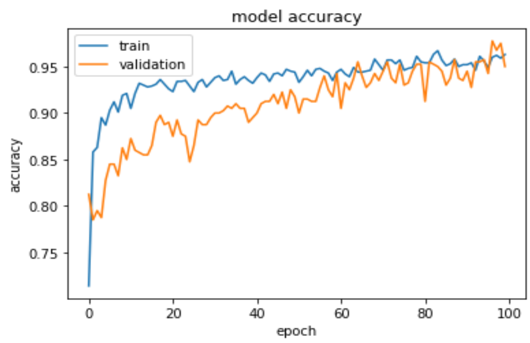

Figure 4. 6: Accuracy of CNN with LeakyRelu (Activation)

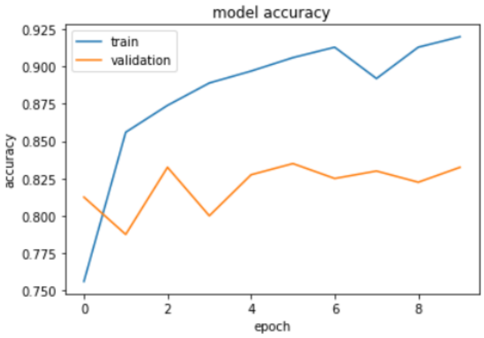

Figure 4. 7: Accuracy of CNN with Early Stopping

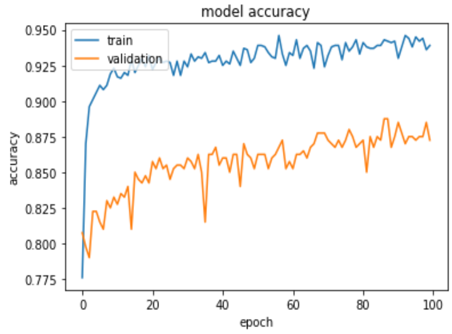

Figure 4. 10: Accuracy of CNN with Hyper-parameter Tuning

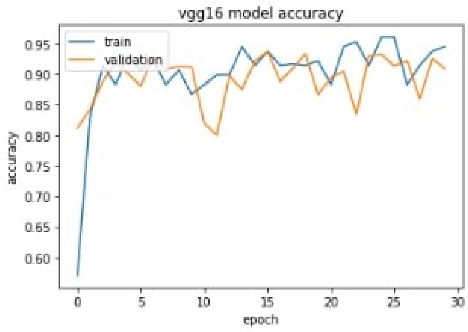

Figure 4. 8: Accuracy of VGG-16

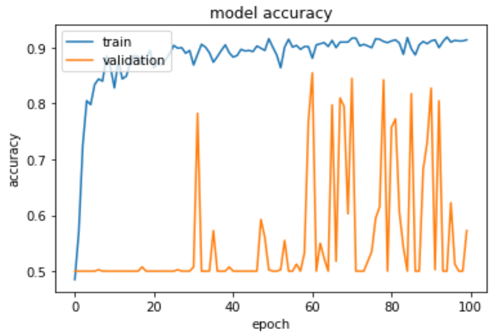

Figure 4. 11: Accuracy of RESNET-50

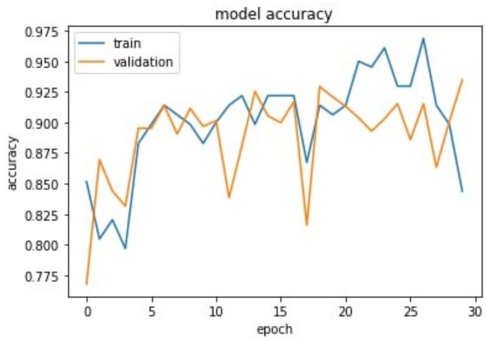

Figure 4. 9: Accuracy of VGG-19

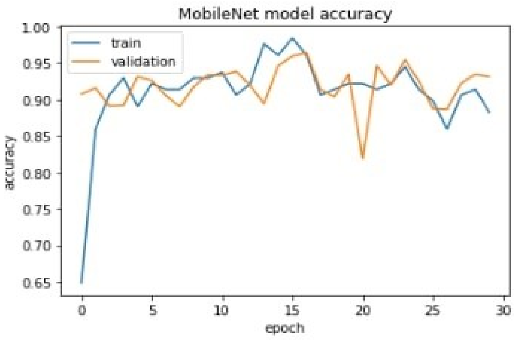

Figure 4. 12 : Accuracy of Mobile Net

In this point we will show Accuracies of all the models given below in details:

- **CNN:** It shows a flat curve on the train-dev-test set and reaches an accuracy up to 74%. So, in this case, the chances of predicting the output are 74%. The results of CNN model are as follows:
  - The Accuracy is 0.749400
  - The precision is 0.672677
  - The Recall is 0.727500
  - The F1 score is 0.699015
  - The ROC AUC is 0.822466.

- **Mobile Net:** In this model, we notice that the accuracy of the validation data increases until it reaches a constant rate, while the accuracy of the training data starts with a small value and then increases, until it reaches a constant rate accuracy in the last epoch. The results of Mobile Net model are as follows:
  - The Accuracy is 0.931677
  - The precision is 0.934848
  - The recall is 0.975
  - The F1 score is 0.2098
  - The ROC AUC is 0.339.

- **CNN with Adam optimizer:** Accuracy of the train-test set reaches up to 98% after 40 epochs, by using Adam optimizer model gets out of the local minima due to momentum. The results of CNN with Adam optimizer model are as follows:
  - The Accuracy is 0.825600

- The precision is 0.701141
- The Recall is 0.983000
- The F1 score is 0.818485
- The ROC AUC is 0.938152.

- **CNN with Data Augmentation:** The accuracy of the train-test set reaches up to 88% after 90 epochs. Using the Data Augmentation model gets more data during training and due to the diverse range of images, the model does not overfit the dataset, unlike the previous case. The results of CNN with Data Augmentation model are as follows:
    - The Accuracy is 0.695800
    - The precision is 0.570921
    - The Recall is 0.964000
    - The F1 score is 0.717129
    - The ROC AUC is 0.858465.

- **CNN with Batch Normalization**: Model achieves an accuracy of 66%, but till the 40th epoch model overfits the dataset but later on due to the difference between the train and validation set reduces to a minimum value because as we know Batch Normalization too randomly adds the regularization term to get rid of the overfitting and maintains the same distribution of the data across the training. The results of CNN with Batch Normalization model are as follows:
    - The Accuracy is 0.662800
    - The precision is 0.543085
    - The Recall is 0.989500

- The F1 score is 0.701276
- The ROC AUC is 0.925262.

- **CNN with LeakyRelu (Activation)**: Using this approach model achieves an accuracy close to 86% and in this case validation accuracy is more than that of training accuracy for a few epochs before the training ends. Because in this case, the derivative is non-linear when the weight is less than zero, i.e., the model weight is still updated when the weight is negative. The results of CNN with LeakyRelu model are as follows:
  - The Accuracy is 0.94684
  - The precision is 0.759474
  - The recall is 0.982
  - The F1 score is 0.85652
  - The ROC AUC is 0.967009.

- **CNN with Dropout**: Using this approach model achieves an accuracy close to 75%, dropout layer shuts off a few neurons randomly during training to ensure that all the neurons in a particular layer must learn something, instead of passing the identity output. The results of CNN with Dropout model are as follows:
  - The Accuracy is 0.758400
  - The precision is 0.636552
  - The Recall is 0.923000
  - The F1 score is 0.753469
  - The ROC AUC is 0.871210.

- **CNN with Early Stopping**: After 100 epochs model shows 93% accuracy on the train set and around 82.5% on the test set, which represents that the model overfits the train set. The results of CNN with Early Stopping model are as follows:
  - The Accuracy is 0.670200
  - The precision is 0.548709
  - The Recall is 0.988500
  - The F1 score is 0.705693
  - The ROC AUC is 0.850737.

- **CNN with Hyper-parameter Tuning**: In this case to model overfits the train set, this is due to a huge gap of around 13% between the train-validation set. However, parameter tuning helped to find the optimal parameters. The results of CNN with Hyper-parameter Tuning model are as follows:
  - The Accuracy is 0.772
  - The precision is 0.642478
  - The recall is 0.9695
  - The F1 score is 0.772818
  - The ROC AUC is 0.913535.

- **RESNET-50:** It's a huge model with less number of parameters, it scales the feature map from the original size to the smallest scale, and it has the identity mapping from the previous block to the next block, which helps the model to be trained, without any gradient issue. The results of RESNET-50 model are as follows:
  - The Accuracy is 0.9275

- The precision is 0.734848
- The recall is 0.744
- The F1 score is 0.306962
- The ROC AUC is 0.593125.

- **VGG-16:** In this model, we notice that the accuracy of the validation data increases until it reaches a constant rate, while the accuracy of the training data starts with a small value and then increases, until it reaches a constant rate accuracy in the last epoch. The results of VGG-16 model are as follows:
  - The Accuracy is 0.95838
  - The precision is 0.734848
  - The recall is 0.194
  - The F1 score is 0.306962
  - The ROC AUC is 0.593125.

- **VGG-19**: It is a bit older model compared to that of RESNET-50, and it scales the size of the feature map by (1 /2) after each subsequent layer. The results of VGG-19 model are as follows:
  - The Accuracy is 0.957
  - The precision is 0.9724
  - The recall is 0.808
  - The F1 score is 0.571429
  - The ROC AUC is 0.517.

4.5 Model Loss

The figures below show the loss results for all the

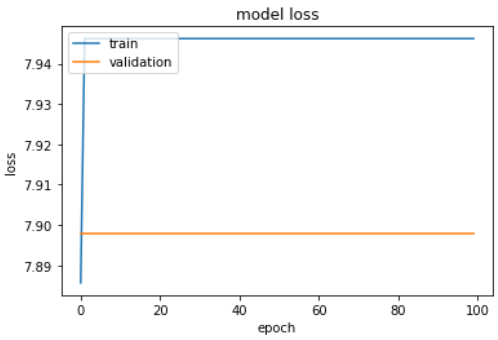

Figure 4. 13: Loss of CNN with Adam optimizer

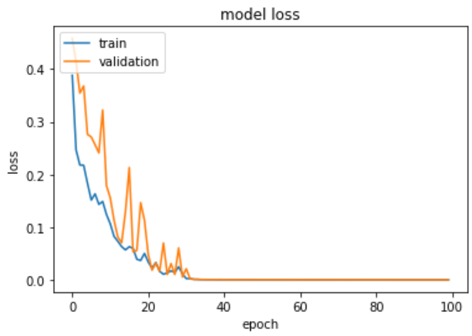

Figure 4. 14: Loss of CNN

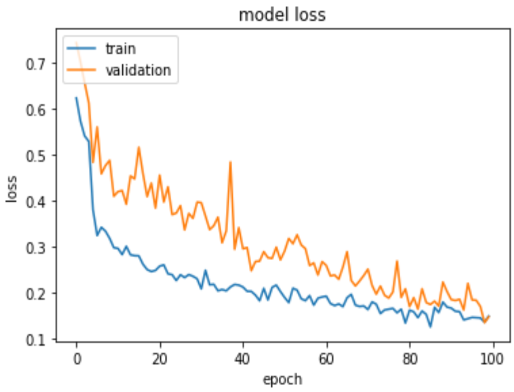

Figure 4. 15: Loss of CNN with Data Augmentation

Figure 4. 18: Loss of CNN with Batch Normalization

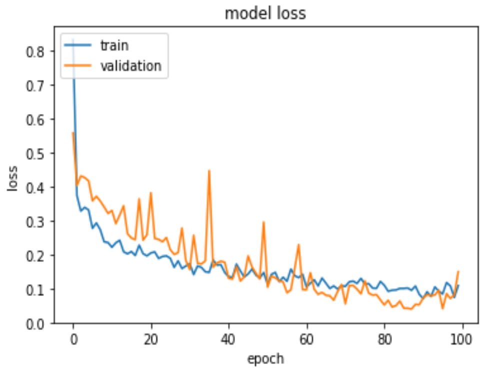

Figure 4. 16: Loss of CNN with Dropout

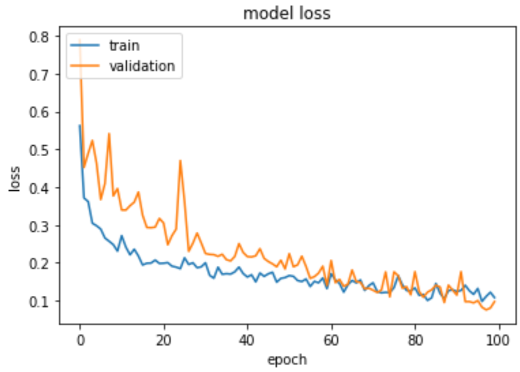

Figure 4. 20: Loss of CNN with LeakyRelu

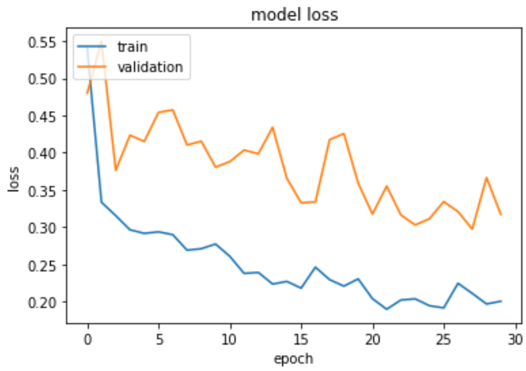

Figure 4. 17: Loss of CNN with Early Stopping

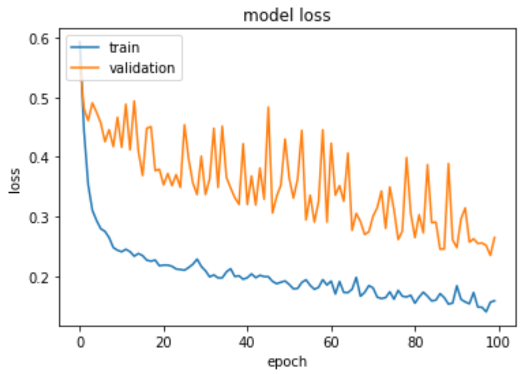

Figure 4. 19: Loss of CNN with Hyper-parameter Tuning

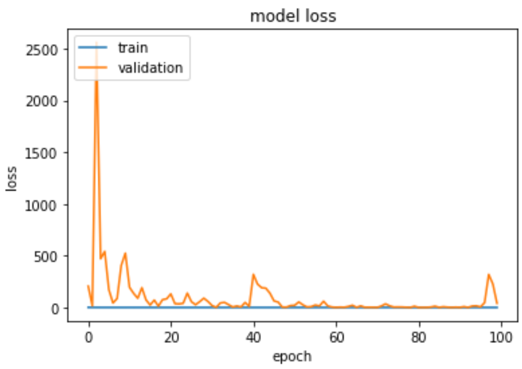

Figure 4. 20: Loss of RESNET-50

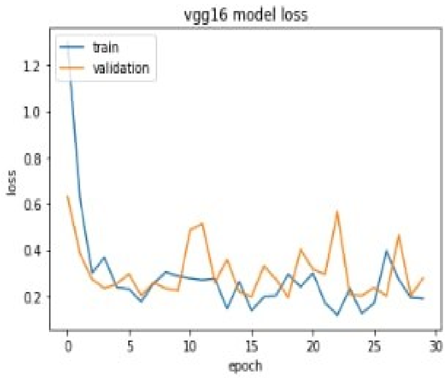

Figure 4. 21: Loss of VGG-16

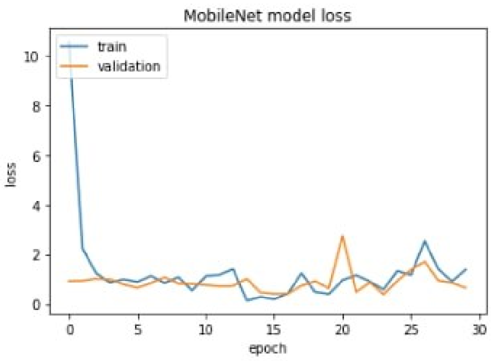

Figure 4. 22: Loss of Mobile Net

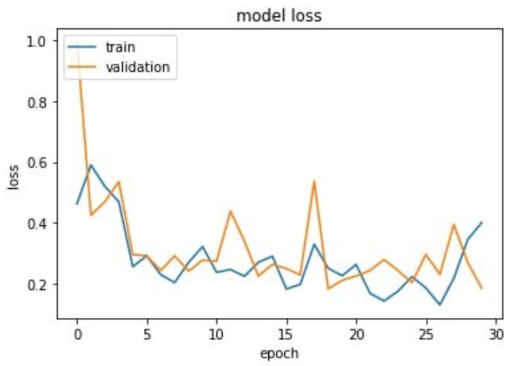

Figure 4. 23: Loss of VGG-19

4.6 Summary

In the five chapter, the details of the implementation of several experiments and the final results of the experiments are presented. This chapter explains the construction of the models, as well as the final results of the proposed models. The results showed that the VGG-19 model achieved high accuracy in predicting the presence of COVID-19 as show in table below.

Table 4. 2: Comparison of accuracy results for CNN models on test data set

Model	Accuracy
CNN	0.749400
Mobile Net	0.931677
CNN with Adam optimizer	0.825600
CNN with Data Augmentation	0.695800
CNN with Batch Normalization	0.662800
CNN with LeakyRelu	0.946840
CNN with Dropout	0.758400
CNN with Early Stopping	0.670200
CNN with Hyper-parameter Tuning	0.772800
RESNET-50	0.927500
VGG-16	0.957000
VGG-19	0.958380

Chapter 5

CONCLUSION AND FUTURE WORKS

5.1 Introduction

This chapter provides a comprehensive review of the following approach and the results obtained. In Section 5.2, a comprehensive review of the research is provided in detail. In Section 5.3, it describes a conclusion of the research. Finally, in Section 5.4, we describe the limits of the research and future work.

5.2 Research Review

COVID-19 is one of the respiratory diseases that have recently spread all over the world, which has caused a large number of deaths and millions of infections. Medical reports have shown that the COVID-19 virus causes chest infections that can be detected using X-ray images. Many research focused on reducing the spread of this disease by suggesting many methodologies for predicting the COVID-19, but the results were of low accuracy and needed more research effort. In addition, RT-PCR tests to detect COVID-19 take a long time to detect this disease.

During this research, we wanted to fill the gaps that accompanied previous research in predicting COVID-19 disease by building a methodology based on the use of deep learning, a method that helps analyze chest images to discover whether there is an infection with the COVID-19 virus or not.

The following methodology relies on training a CNN models based on chest x-ray dataset available on the Kaggle website in order to build predictive models for COVID-19 disease detection. The methodology consists of several steps, first fetching the dataset from the site, then reading the data consisting of 6432 images. The data set includes three types of images including X-rays images of COVID-19, X-rays images of pneumonia, and X-rays images of normal. After reading the data, the implementation stage of an operation for augmentation begins, then the image size is converted to 224 * 224, and finally the stage of building a CNN neural network, classification, and model validation.

In this research, we want to concentrate on twelve methods of data classification which are (CNN ,Mobile Net ,CNN with Adam optimizer, CNN with Data Augmentation, CNN with Batch Normalization, CNN with LeakyRelu, CNN with Dropout, CNN with Early Stopping, CNN with Hyper-parameter Tuning, RESNET-50, VGG-16, and VGG-19)which the output of the VGG-19 model is the input of conventional neural network layers. Also, several experiments have been conducted that include testing two models are VGG-16 and Mobile Net. The results showed the success of the VGG-19 model in increasing the accuracy of prediction of the COVID-19 in humans by making use of deep learning techniques as it increased the prediction rate and had a significant impact on the prediction accuracy compared to previous studies and other models. The importance of the research lies in reducing the spread of the COVID-19 by providing a predictive model with high accuracy that helps in detecting whether a person is infected with the COVID-19 or not at an early stage instead of tests that take a long time.

5.3 Conclusion

In this project, we wanted to predict whether or not people have COVID-19, especially for those with the disease who are asymptomatic. Based on the analysis of several chest images associated with this disease, we first processed the dataset containing three types of X-rays (pneumonia, normal, and COVID-19). This project was based on the application of one of the deep learning techniques, the VGG-19 model, where the classification process was implemented in way is the conventional neural network. The results showed obtaining high accuracy in predicting a person's infection with the COVID-19, as the accuracy value was 0.958 when classifying based on the conventional neural network.

Secondly, we implemented another deep learning model, the VGG-16 model, where the classification process was implemented in way is the conventional neural network. The results showed high accuracy in predicting a person's infection with the COVID-19, where the accuracy value was 0.957when classifying based on the conventional neural network. Thirdly, we implemented another deep learning model, the MobileNet model, where the classification process was implemented in way is the conventional neural network. The results showed obtaining high accuracy in predicting a person's infection with the COVID-19, where the accuracy value was 0.931 when classifying based on the conventional neural network.

By comparing between the most important models, we note that the VGG-19 model outperformed all models when it is applied to the data set. One of Our models could be a solution in identifying the COVID-19 in its early stages and being able to treat and reduce the number of deaths resulting from this disease.

5.4 Limitations and Future Work

The limitations of the research are limited to focusing only on disease prediction based on chest images associated with this disease, thus not addressing all the etiological factors. Among the future work that can be done in the continuation of this research is to work on studying other factors that are more related to the disease, as well as increasing the number of factors and then applying the proposed method to them. Also, other deep learning algorithms can be used to make decisions about disease occurrence.

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