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Employing a Convolutional Neural Network to Classify Medical Images: A Case Study

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ABSTRACT— ***A convolutional neural network is one of the deep learning architectures that has been involved in a lot of the literature, and it's incredible at work. The convolutional neural network is distinguished in its use in computer vision and graphical analysis applications. It is characterised by the actuality of one or more hidden layers that extract features in images or videos, and there is also a layer to show the effects. In this regard, the authors decided to involve the convolutional neural network algorithm to classify a few chest X-ray images of COVID-19 patients and study the behaviour of this algorithm and the effects that will be obtained at the time of training. Finally, this study concluded that the performance and practices of this algorithm are very excellent and give satisfactory effects with a perfect training time.***

Keywords—Deep learning, Machine learning, Convolutional neural network, COVID-19, Chest X-ray.

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1. INTRODUCTION

Deep learning techniques provide fast and practically error-free solutions and have the ability to create the right decisions [1][2]. Deep learning is widely employed in making intelligent machines [3]. it is part of machine learning and is a part of artificial intelligence applications [4]. Machine learning techniques are used in many fields due to their ability to create probabilities and statistics [5]. Also, deep learning is considered one of the most advanced techniques, and it has proven successful in much of the literature and in many domains, including the medical domain [6]. In the fifties, scholarly circles dealing with artificial intelligence applications developed two computer vision methods utilising decision trees and artificial neural networks [7][8]. The idea of artificial neural networks is accepted from the concept of the work of the human brain in thinking and making decisions, where a multi-layer network structure is created by simulating the work of neurons in the brain [9][10]. The convolutional neural network has recently achieved many triumphs in image analysis, especially chest X-ray images of COVID-19 patients [11-15]. Figure 1 illustrates how to analyse chest X-rays utilising deep learning techniques and determine whether an individual has COVID-19 or not. Convolutional neural networks, which are the basis for deep learning, are characterized by the provision of classifiers that are better than the human brain by developing their work in training and testing data. In the 1980s, deep learning techniques were difficult to implement because hardware limitations did not allow for dense matrix operations. Instead, a convolutional neural network consists of neurons with different weights and biases that can be learned where each cell is associated with some input and produces a result in a non-linear manner. At the end of 2019, the world witnessed the spread of a deadly virus called COVID-19, which infects the lung in humans and may lead to death [16][17]. Researchers and healthcare workers have rushed to conduct many studies utilising artificial intelligence techniques to analyse chest X-ray images and determine the location of the virus's spread in the lung and the infection rate [18][19]. Artificial intelligence techniques have demonstrated a high ability in predicting and diagnosing COVID-19 disease in many analyses, giving excellent effects and helping in decision-making [20][21]. In this article, we will briefly and quickly address the importance of applying a convolutional neural network in image analysis and what effects will be obtained. Figure 2 illustrates a set of images of medical units checking for citizens to check whether they have COVID-19 or not in 2019.

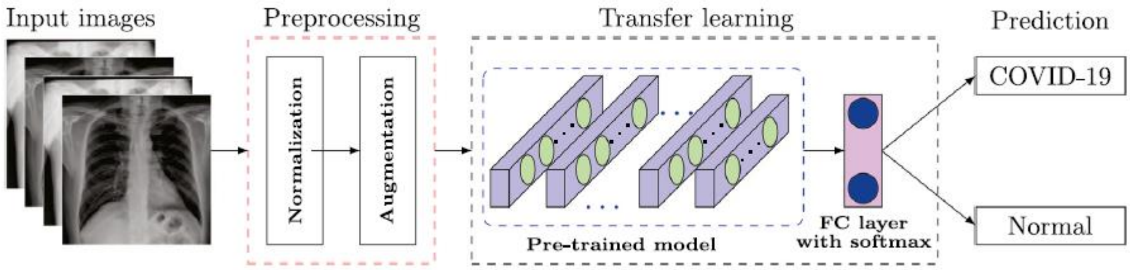

Figure 1: Analyse chest x-rays utilising deep learning techniques [22].

Figure 2: A set of images of medical units checking for citizens to check whether they have COVID-19 or not in 2019 [downloded from Google].

2. DEEP LEARNING ARCHITECTURES

Deep learning techniques arise from artificial neural networks, where when the number of hidden layers exceeds five, the complexity of the network increases and the current state of the neural network cannot be enhanced. In addition, deep learning architectures are multi-layered and include many worthwhile parameters. The most notable deep science architectures are convolutional neural networks, long short-term memory/gated recurrent unit, recurrent neural networks, self-organizing map, autoencoders and restricted Boltzmann machines (see figure 3). In this section, some deep learning architectures will be mentioned, and then the convolutional neural network will be briefly and quickly mentioned.

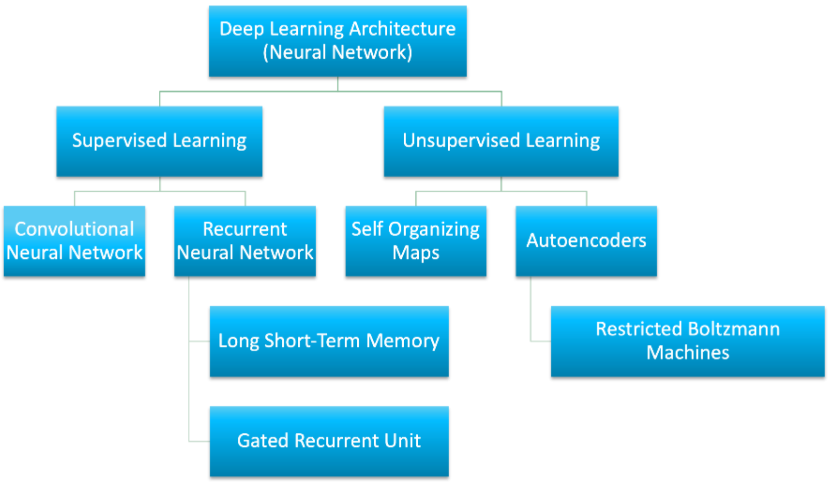

Figure 3: Types of deep learning architecture [23].

In general, nodes are the first structure of a neural network, and it consists of three main layers, where the balances can be changed in the first layer only and cannot be changed in the second and third layers. Figure 4 shows a simple sensor structure consisting of a set of inputs and weight values for the activation, summing and output function. Furthermore, weights constitute the memory of the network model. The main purpose of this model is to find the most appropriate weight for all inputs, and the resolution to the situation is obtained by finding the most suitable and proper weight for each input. Also, the inputs are multiplied by their weight values and then the values are summed to get only one value. The results are obtained by passing the effect through an activation function terminal, which is essential to any deep learning architecture. The weights in the first layer are selected randomly, and the second layer depends on them. In addition, the weights in the second layer are adjusted according to the first layer, and the weights in the third layer are adjusted according to the second layer. The second layer's weights are characterised by randomly changing their weights in the third layer.

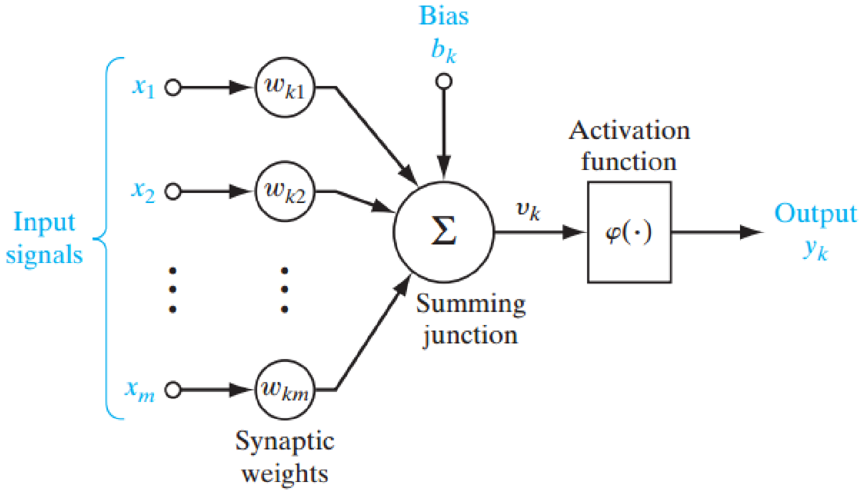

Figure 4: Simple structure [24].

2.1 Restricted Boltzmann Machine (RBM)

Constrained Boltzmann machines are a remarkable kind of Markov random field and are conditional binary graphs that consist of two layers, one observable and the other hidden. Boltzmann machines also consist of two layers; the units in the layer have connections within themselves, which adds to the confusion. The simplified configuration created by removing the bonds within the layer is the bound Boltzmann machines. As illustrated in Figure 5, the nodes in the layer are unconnected in the structure of constrained Boltzmann machines. That is, there is no communication between nodes in the visible layer, and there is no communication between units in the hidden layer. The visible nodes and the hidden nodes are connected in a bidirectional way to each other, each connection has a weight value. RBM can be qualified in supervised or unsupervised ways, depending on the type of situation.

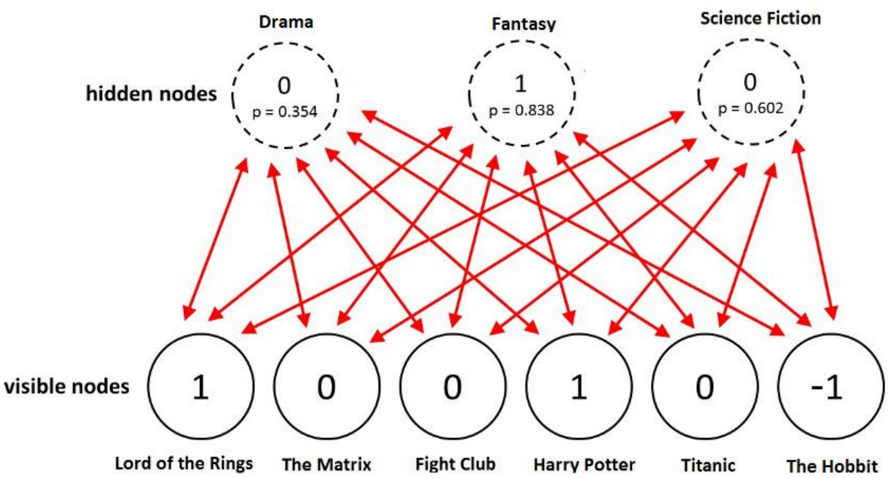

Figure 5: Simple example of RBM [25].

2.2 Autoencoders

An autoencoder is a neural network architecture that aims to output unlabelled data in the same way it entered the architecture, where hidden features are extracted by taking the input data and improving or reducing the number of units in the hidden layer. In Figure 6, there are 3 nodes in the hidden layer and 6 nodes in the input and output layers. There are cases in which the number of neurons in the hidden layer is very low, and there are other cases where it is more. The autoencoder update the parameters using improved mathematical methods in the neural network. In addition, the error is estimated by utilising the input layer data instead of the label employed in supervised learning to identify the mistakes in the output layer and identify ways to reduce these mistakes.

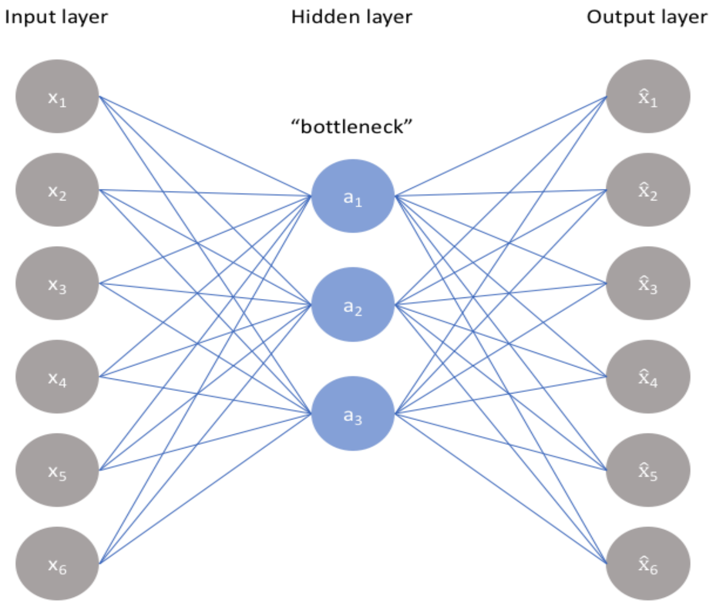

Figure 6: Simple example of autoencoder [26]

2.3 Convolutional Neural Network (CNN)

It is a deep neural network that is widely utilised and involved in many fields as it consists of many layers that can be trained on big [27-29]. Each layer contains three layers: a convolutional layer, a pooling layer, and a fully connected layer. In the convolutional layer, there are many cores for extracting different features from the data. In the pooling layer, each obtained feature map is treated separately. Each map provides a mean or maximum value of the neighbourhood value. Figure 7 illustrates a model of a convolutional network structure where the network has two convolutional layers, two subsampling layers that follow the convolutional layers, and a fully connected layer on top. In this structure, the image is divided into parts. Next, a filter is applied to each part. After the filtering process, the image becomes smaller. The pixels obtained as a result of this operation are interpreted, and an attempt is made to solve the problem.

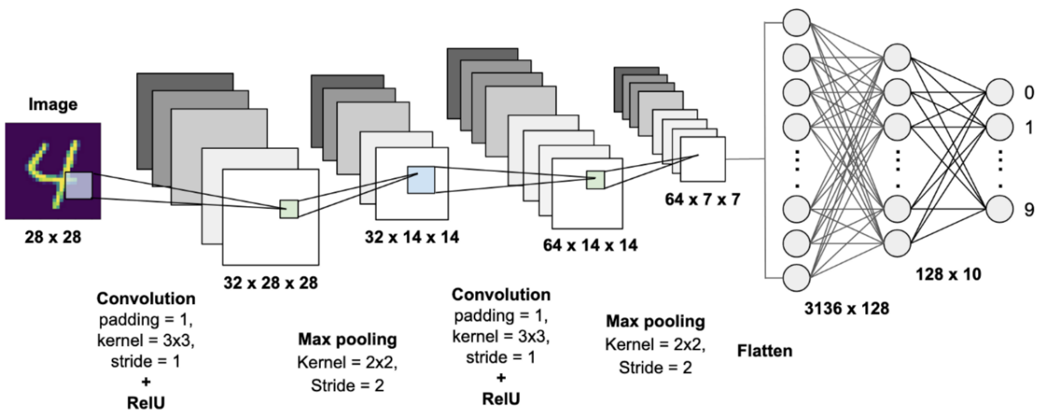

Figure 7: A simple structure of CNN [30].

3. CLASSIFICATION AND EFFECTS

In this work, the open-source Python software is utilised, which is considered one of the favourite programs in the application of deep learning techniques. This program contains offices that are used to classify images. Python offices are successful in giving excellent results in image analysis. Furthermore, the same network in Figure 8 and Figure 1 is employed. In the first phase, images are appointed, where ten black and white images are selected from the x-ray images of patients with COVID-19 (five images of infected people-positive and five images of non-infected people- negative) with dimension $299x299$. X-ray images have a lot of features that the neural network can detect. In addition, with the increase in the number of images used for training, the classifying rate for this work increases, but it negatively affects the time. In the second phase, the size of the images in the pre-processing was changed to $256x256$ to train the network better to perform the classification process and ensure its ability to classify whatever size. After that, two images are added to become 12 images in order to conduct more tests on the network's execution. Table 1 illustrates the network's execution in the tests conducted on it, the number of training hours and the final effects of the test. Figure 7 illustrates the mechanism of CNN in this study.

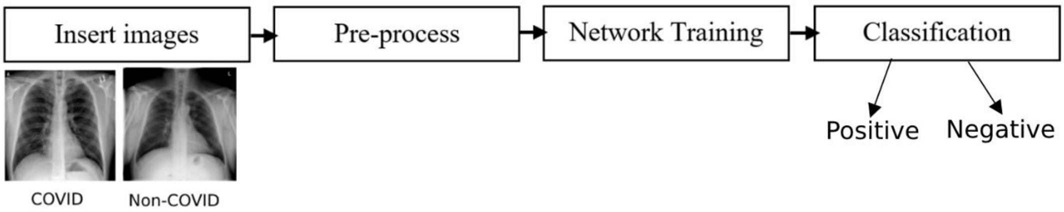

Figure 8: Classification of chest x-ray images using a convolutional neural network.

Table 1: The Effects

Images	Dimension	Training time	Effect
10	299x299	7 hours	Very well
	256x256	6 hours	
12	299x299	8 hours	More acceptable
	256x256	7 hours	

4. CONCLUSIONS AND FUTURE WORK

This study examined the significance of applying the convolutional neural network, one of the most important and most widely employed deep learning techniques based on the artificial neural network, in classifying images. Successful and satisfactory effects are received in classifying very few images. The process of training the algorithm on the chest X-ray images took about 7 hours in its original form, 6 hours when changing the dimensions of the images. In addition, the number of images is increased to 12, which increased the algorithm's performance and reached positive results. The training process took 8 hours. Increasing the number of images leads to an increase in the training time. In the future, more studies will be conducted on the practices of the convolutional neural network.

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