Convolutional Neural Network based X-Ray Image Classification for COVID-19 Diagnosis

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***Abstract*—Machine learning has become a vast area of interest to researchers and data scientist in the last few years. Convolutional Neural Network (CNN) is a deep learning method used to solve complex problems. Medical image segmentation plays a vital role in clinical treatment and teaching tasks. The CNN dominates with the optimum results on varying image classification tasks. However, medical image datasets collection is arduous because it needs lots of professional expertise to label them. Therefore, this project explores how to apply the CNN on chest X-ray datasets to classify COVID-19 as positive or negative. The neural network consists of three convolutional layers, followed by max-pooling layers and one fully-connected layer with a final one-way softmax. A Kaggle chest X-ray images dataset is used in the experiments. To reduce overfitting, I employ a method called "dropout" that proved to be very effective.**

***Index Terms*—Convolution Neural Network, Transfer learning, Image classification, Pattern recognition, Artificial Neural Networks, Machine Learning, Image Analysis**

I. Introduction

The novel Corona Virus (nCOV) or Corona Virus Disease 2019 (COVID-19) first originated from Wuhan city of China to the rest of the world in December 2019. Globally as of 07th August 2021, there have been around 202,978,883 cases is affected by this disease and 4,299,649 is dead that is confirmed by World Health Organization (WHO); the statistics show that the United States has the maximum number of cases followed by India, Brazil, France, Turkey, Russia, and many others.

Corona Virus Disease 2019 (COVID-19) has become a global epidemic with an exponential growth rate and a partially understood transmission process. The virus is sheltered most commonly with little or no symptoms, but can also conduct to a quickly growing and often lethal pneumonia in 2–8% of those infected.

The most extensively used method to test Covid-19 disease is the real-time reverse transcription-polymerase chain reaction (RT-PCR) test. This method is usually costly and time-consuming as the process of taking the test along with transporting samples takes more than half a day. The average turnaround of the test is 3-6 days. On the other side, X-rays and CT scans also help in the diagnosis of the disease in a short time. The main benefit of using X-Ray image classification over CT Scans is cost-effective, especially for under-developed and developing countries, where resources are scarce.

Nowadays, a medical degree is not mandatory to develop artificial intelligence based model can contribute to healthcare in massive ways, including automated disease diagnosis. Effectively classifying medical images play a vital role in helping clinical care and treatment. Artificial Neural Networks (ANN), especially the convolutional neural networks (CNNs), are immensely used in changing image classification tasks and have achieved significant performance since 2012.

In this project, I use a CNN algorithm that is trained by an X-ray dataset to detect whether a person is suspected of being infected with the COVID-19 virus or not. The Chest X-ray images dataset collected from the Kaggle website and the CNN model run on a Google virtual machine (Google Colab) with a Python 3 Google Compute Engine backend (GPU).

The next section II represents a review of the related works on medical image classification. Section III describes the system model with the problem statement. Section IV outlines the result of the experiments, and discussion. Finally, the conclusion section V is concluded and followed by references.

II. Related Work

Pneumonia Chest X-ray dataset availability and the recent advances in machine learning models have led to the possession of multi-view ensemble deep learning model, which represents of inflammatory patterns from bacteria and viruses.The human lung area can be affected by bacteria and viruses, leading to pneumonia.Recent research has developed a variety of automatic pneumonia detection systems based on chest X-rays. Machine learning technique is applied for the training AI algorithms to detect pneumonia by learning chest X-ray images.

Rakibul et al. introduce the LeNet-5 CNN architecture based COVID-19 prediction model based on COVID-19 lung CT images that reached the highest accuracy of 82.91%.

Features extraction from medical images can help in detecting diseases in the early stages. Researchers worked on medical data using a CNN algorithm. Musleh at al. consider CheXNet algorithm was developed for detecting Pneumonia from large datasets of X-ray images by Stanford University same algorithm has been applied to detect the COVID-19 Virus with acceptable prediction accuracy of 89.7% that is similar to the CheXNet algorithm.

The standard Reverse Transcription Polymerase Chain Reaction (RT-PCR) testing mechanism is costly and time-consuming. The three pre-trained DCNN networks - NASNet, MobileNet and DenseNet used for testing COVID-19 large population size with less time-consuming. Deb et al. proposed ensemble architecture for extracting features from Chest X-Ray images that lead to a better generalization performance than single classifier as counterparts.

Singh et al. consider a CNN model of maximizing convolution layers of the DarkCovidNet model consists of 19 convolution layers (7 are single-layered convolution structures and 4 are triple-layered convolution structures) along with 6 max-pooling layers which can determine the detection of Covid-19 disease and segregate it from pneumonia, using X-ray images. Their project revolves around binary as well as multi-class classification with acceptable prediction accuracy of 87%.

I apply and assess a CNN model that would build on a dataset of chest X-ray images collected from the Kaggle website so that it can precisely detect COVID-19.

III. System Model and the Problem Statement

This section describes the proposed CNN model that includes the steps used for COVID-19 detection. The steps are shown in Fig.-1 and discussed hereafter.

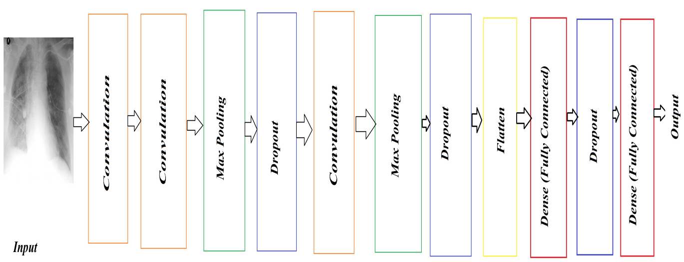

Fig. 1. The Proposed CNN Model for COVID-19 Detection

A. Dataset

The collected X-Ray images dataset is divided into 70% for training and 30% for testing. The dataset was collected from the Kaggle website and importing the Keras libraries.

B. Initialization

1. Add the first layer(Convolution 2D): I use 32 output filters in the convolution 3x3 filter matrix that will multiply to input RGB size image 224x224 and use activation “relu”.

2. Second layer(Convolution 2D): specifies 64 filters in the convolution 3x3 filter matrix and use activation “relu”.

3. Add a Max pooling: 2x2, which specified the size of the pooling window.

4. Add Dropout 0.25: This means that the model will not overfit, as 25% neurons randomly will not be selected for activation.

5. Add third convolution layer(Convolution 2D): specifies 128 filters in the convolution 3x3 filter matrix and use activation “relu”.

6. Steps 3 and 4 are repeated.

7. Add Flatten layer: This means converting the matrix into a 1D array.

8. Add a fully connected (Dense) network: 64 layers of outputs with activation “relu”.

9. Add Dropout 0.50: This means that the model will not overfit, as 50% neurons randomly will not be selected for activation.

10. Add a fully connected (Dense) network: 1 final layer of outputs with activation “sigmoid”.

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 222, 222, 32)      896
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 220, 220, 64)      18496
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 110, 110, 64)      0
_________________________________________________________________
dropout (Dropout)            (None, 110, 110, 64)      0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 108, 108, 128)     73856
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 54, 54, 128)       0
_________________________________________________________________
dropout_1 (Dropout)          (None, 54, 54, 128)       0
_________________________________________________________________
flatten (Flatten)            (None, 373248)            0
_________________________________________________________________
dense (Dense)                (None, 64)                23887936
_________________________________________________________________
dropout_2 (Dropout)          (None, 64)                0
_________________________________________________________________
dense_1 (Dense)              (None, 1)                 65
=================================================================
Total params: 23,981,249
Trainable params: 23,981,249
Non-trainable params: 0
```

Fig. 2. The Proposed CNN Model Summary

C. Fit the CNN Model

The optimizer ”adam’ is used because it delivers good results quickly. It is an optimization algorithm for updating iterative network weights based on training data. It is also an efficient variant of gradient descent that does not generally require a manual learning rate.

D. Evaluating and Testing the Model

Binary cross-entropy is the default loss function to use for binary classification problems. It is aimed for use with binary classification where the target values are in the set $\{0, 1\}$. Binary cross-entropy will measure a score that summarizes the average difference between the actual and predicted probability distributions for predicting class 1.

For a binary classification, the typical loss function is the binary cross-entropy / log loss.

$$H_p(q) = -\frac{1}{N}\sum_{j=1}^{N} y_i log(p(y_i)) + (1 - y_i) log(1 - p(y_i)) \quad (1)$$

Where, y is the target or label and p(y) is the predicted probability.

IV. Results and Discussion

The performance matrix of a CNN architecture refers to the experimental results is based on the test accuracy, test loss, f1 score and, so on. The accuracy and the f1 score can be defined by Equation (2) and Equation (5) respectively:

$$Accuracy = \frac{Tp + Tn}{Tp + Tn + Fp + Fn} \tag{2}$$

$$Precision, P = \frac{Tp}{Tp + Fp} \tag{3}$$

$$Recall, R = \frac{Tp}{Tp + Fn} \tag{4}$$

$$f1score = 2 * \frac{P * R}{P + R} \tag{5}$$

```
Accuracy Score :  1.0

Classification Report :

              precision    recall  f1-score   support

           0       1.00      1.00      1.00        20
           1       1.00      1.00      1.00        20

    accuracy                           1.00        40
   macro avg       1.00      1.00      1.00        40
weighted avg       1.00      1.00      1.00        40
```

Fig. 3. The performance matrix of the CNN model

The accuracy for training and validation sample curves are presented in figure (4), and the loss for training and validation sample curves of our COVID-19 detection CNN model are also presented in figure (5).

Using equations (2) and (5), the CNN COVID-19 diagnosis model reached an accuracy of 96.24% and loss of 0.0993 after 20 epochs for COVID-19 disease identification.

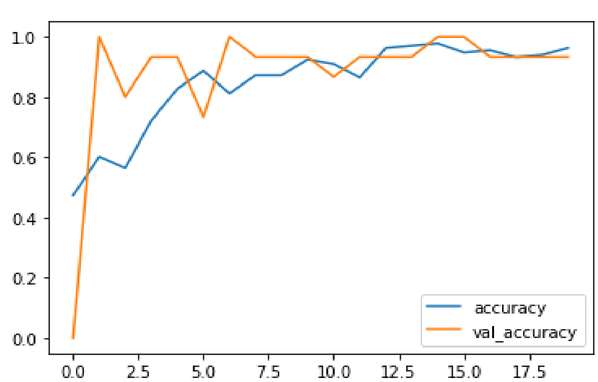

Fig. 4. The accuracy of COVID-19 diagnosis

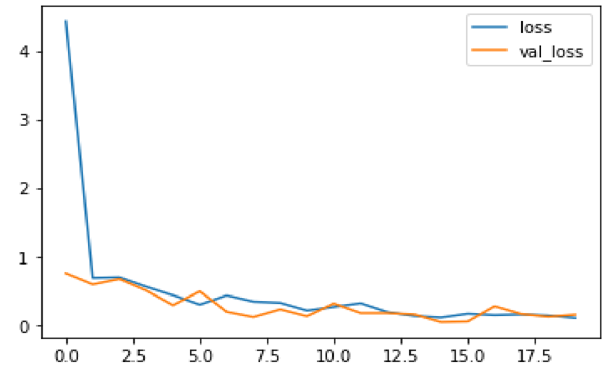

Fig. 5. The loss of COVID-19 diagnosis

```
Epoch 9/20
5/5 [==============================] - 40s 8s/step - loss: 0.3195 - accuracy: 0.8722 - val_loss: 0.2245 - val_accuracy: 0.9333
Epoch 10/20
5/5 [==============================] - 40s 8s/step - loss: 0.2076 - accuracy: 0.9248 - val_loss: 0.1242 - val_accuracy: 0.9333
Epoch 11/20
5/5 [==============================] - 40s 8s/step - loss: 0.2603 - accuracy: 0.9098 - val_loss: 0.3105 - val_accuracy: 0.8667
Epoch 12/20
5/5 [==============================] - 40s 8s/step - loss: 0.3143 - accuracy: 0.8647 - val_loss: 0.1707 - val_accuracy: 0.9333
Epoch 13/20
5/5 [==============================] - 40s 8s/step - loss: 0.1853 - accuracy: 0.9624 - val_loss: 0.1707 - val_accuracy: 0.9333
Epoch 14/20
5/5 [==============================] - 40s 8s/step - loss: 0.1285 - accuracy: 0.9699 - val_loss: 0.1508 - val_accuracy: 0.9333
Epoch 15/20
5/5 [==============================] - 40s 8s/step - loss: 0.1060 - accuracy: 0.9774 - val_loss: 0.0392 - val_accuracy: 1.0000
Epoch 16/20
5/5 [==============================] - 43s 8s/step - loss: 0.1604 - accuracy: 0.9474 - val_loss: 0.0475 - val_accuracy: 1.0000
Epoch 17/20
5/5 [==============================] - 40s 8s/step - loss: 0.1405 - accuracy: 0.9549 - val_loss: 0.2705 - val_accuracy: 0.9333
Epoch 18/20
5/5 [==============================] - 40s 8s/step - loss: 0.1503 - accuracy: 0.9323 - val_loss: 0.1571 - val_accuracy: 0.9333
Epoch 19/20
5/5 [==============================] - 40s 8s/step - loss: 0.1348 - accuracy: 0.9398 - val_loss: 0.1175 - val_accuracy: 0.9333
Epoch 20/20
5/5 [==============================] - 40s 8s/step - loss: 0.0993 - accuracy: 0.9624 - val_loss: 0.1466 - val_accuracy: 0.9333
```

Fig. 6. The result of CNN model training in 20 epochs

V. Conclusion

In conclusion, the results of the CNN model show a vital role to quickly identify patients, which would be effective and useful in fighting the present outbreak of COVID-19.

In this project, a novel and robust CNN architecture is designed and proposed for COVID-19 disease detection using publicly available (Kaggle) datasets. Diagnosis of COVID-19 (i.e. classification of chest X-ray images into COVID-19 (+) and COVID-19 (-) images) is achieved with high accuracy such as 96.24%. It is believed that the model proposed in this project can be used in practice to help physicians for diagnosing the COVID-19 disease.

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