Workshop Proceedings of the 19th International Conference on Intelligent Environments (IE2023)
G. Bekaroo et al. (Eds.)

doi:10.3233/AISE230020

COVID-19 Prediction Infrastructure Using Deep Learning

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Abstract. Coronavirus can lead to respiratory illnesses ranging from mild to severe, and even death, which makes early detection critical. However, current COVID-19 (Coronavirus Disease 2019) detection methods are not only expensive but also time-consuming. This poses a challenge, especially with an increasing number of patients and demand for testing kits. Waiting for test results for a few days is not ideal, as the outbreak can spread quickly in the meantime. To address this issue, we propose a COVID-19 prediction infrastructure using deep learning. This innovative android-based application uses a Convolutional Neural Network model, trained on a custom dataset with an accuracy of 97 percent, to predict whether COVID-19 is present or not. With this fast and low-cost approach, users can quickly detect COVID-19 and take appropriate actions to reduce the risk of transmission.

Keywords. COVID-19, Deep Learning (DL), Machine Learning (ML), Convolutional Neural Networks (CNN), X-ray image, Android-based application

1. Introduction

COVID-19, also known to be a novel coronavirus, is a highly contagious disease that caused a global pandemic. The SARS-CoV-2 virus, which is responsible for the illness, was first discovered in Wuhan, China, in December 2019. Since then, this virus has spread rapidly, affecting millions of people in various countries. The deadly coronavirus has not just devastated the lives of millions but has put the entire healthcare system under tremendous pressure [27]. Chest X-ray images have become a vital component for the diagnosis of COVID-19 patients. As the pandemic has surged across the world, healthcare systems have struggled to keep up with the influx of patients presenting with COVID-19 symptoms. Chest X-rays have emerged as an essential diagnostic tool, providing doctors with non-invasive, fast, and reliable imaging to identify the presence and severity of COVID-19 pneumonia. The images can reveal patches or ”ground-glass opacities” in the lungs, which are the hallmark signs of COVID-19 pneumonia. Chest X-rays can also provide a clear view of the heart and lungs, allowing doctors to assess lung function and identify any additional complications.

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The early prediction of any disease is vital in mitigating the effect of disease [21]. As the COVID-19 pandemic continues to spread globally, healthcare professionals are increasingly relying on diagnostic tools to help identify and monitor COVID-19 patients. One such tool is chest X-ray imaging, which has proven to be particularly useful in identifying the severity of COVID-19 infections in patients. Given that the virus primarily affects the lungs, chest X-rays have become critical in detecting signs of pneumonia, a common complication of COVID-19, and monitoring the progression of the disease. This is especially important in severe cases that require hospitalization, as chest X-rays can provide doctors with vital information on a patient's condition. It is useful to take advantage of advanced technology to assist patients especially patients with some impairments at home [7,8]

Clinical laboratories have responded by developing, validating, and implementing a variety of molecular and serologic assays to test for SARS-CoV-2 infection [3]. Molecular testing, such as polymerase chain reaction (PCR), is a diagnostic test that detects the genetic material of the virus in respiratory samples. PCR tests are considered the gold standard for COVID-19 detection and have high sensitivity and specificity. Serological testing, also known as antibody testing, detects the presence of antibodies in blood samples. Serological tests are crucial as they can provide information on antibody production and concentration even months or years after infection, along with the abundance and diversity of antibodies [4].

While several testing methods have been developed to detect COVID-19, RT-PCR (Reverse Transcriptase Polymerase Chain Reaction), rapid antigen, and antibody tests are a few examples., there are still significant challenges in making testing widely available and accessible. The availability of testing supplies and equipment has been a major concern, with some areas experiencing shortages or delays in receiving supplies. Additionally, the cost of testing and the lack of testing infrastructure in certain regions can also make it difficult for people to access testing, which can hinder efforts to track the spread of the virus and identify outbreaks. Moreover, there have been instances of false negatives and false positives, which can result in incorrect diagnoses and potentially contribute to the spread of the virus. Despite the efforts to improve testing capacity and accuracy, ensuring universal access to testing still remains one major obstacle in combating COVID-19.

With the advancement in machine learning algorithms [17] and neural network [16], the objective of Artificial Intelligence (AI) has become a step closer. AI has significant application in many areas including:healthcare [6,24], UAVs, 5G and autonomous control [19], risk management [22,25], communication [15,18].

This work also employs CNN and the contributions of this paper are given as:

- Developed a machine learning model using convolutional neural networks (CNN) to predict COVID-19 infection from chest X-ray images.
- Achieved a high level of accuracy in predicting COVID-19 infection using the CNN model.
- Developed an Android application that allows users to easily upload chest X-ray images and receive a prediction of COVID-19 infection status.

The structure of the rest of this study is as follows. In section 2, the work relevant to this study is discussed. The materials and methods are examined in Section 3. Section 4 describes the results of the proposed system. At the conclusion, Section 5 presents the concluding remarks for this article along with suggestions for future work.

2. Related work

Following the emergence of COVID-19, scientists have divided their efforts into two main areas developing a vaccine on the one side [14], and PCR and imaging system-based COVID-19 detection on the other [1].

In this article, we examine research that focuses on the utilization of radiography images as a supplementary tool to PCR for the diagnosis of COVID-19 cases.

Early studies reported in paper [10] revealed that the patients had abnormalities in chest radiographs that were typical of people who had Covid-19 infections. The Covid-Net has discussed the development of a method for diagnosing COVID-19 cases from chest X-ray (CXR) images.

The study [9] discusses a novel method for separating patients with covid19 pneumonia from those with noncovid19 pneumonia using chest X-ray images and convolution neural networks. This kind of tool can speed up the diagnosis process and provide results that are nearly 95 percent accurate. In order to increase accuracy, a large number of datasets were collected. It was done through supervised learning. In addition to helping to solve the problem of a physician shortage in remote communities, modern AI techniques especially in combination with imaging techniques can help in the proper classification of this disease [20].

The paper [13] introduces the baseline approach for the 2nd Covid-19 Competition at the AIMIA Workshop in ECCV 2022. The COV19-CT-DB database, containing 7,700 annotated 3-D CT scans for COVID-19 detection, is presented along with annotations for severity conditions. The dataset is split into training, validation, and testing sets for machine learning model training and evaluation. The baseline approach uses a CNN-RNN network and its performance is compared to that of the Challenges organized in the Competition. Results are presented in the paper.

A large percentage of the initial tests concentrate on finding coronavirus genetic information, which has a limited detection rate because the process is tedious [28].

According to Shuai et al., [30], authors employed the Inception transfer-learning model to produce an accuracy of 89.5 percent, a specificity of 88.0 percent, and a sensitivity of 87.0 percent when predicting COVID-19 cases using CT images.

Xiaowei et al. [31] used pulmonary CT images to feed image patches focused on regions of interest into the Resnet18 model to create an early prediction model for categorizing COVID-19 pneumonia from Influenza-A viral pneumonia and healthy cases. CT image accuracy for the CNN model was at its highest at 86.7 percent.

To distinguish coronavirus cases from pneumonia and normal cases, a set of X-ray images was analyzed over a range of CNN architectures in [2]. Such CNN architectures have been utilized for a variety of classifications of medical images. CNN reported an overall accuracy of 97.82 using a dataset comprising 224 COVID-19 pictures, 700 non-COVID-19 pneumonia images, and 504 normal images.

Another study proposes the use of convolutional neural networks for efficient and accurate identification of COVID-19 disease, compared to traditional methods which rely on human interpretation. The study uses and fine-tunes seven convolutional neural networks and proposes a lightweight convolutional neural network, LightEfficientNetV2, which demonstrates promising performance on chest X-ray images, CT images and three different datasets. Results show high accuracy rates of up to 98.33 percent on chest X-ray images and 97.48 percent on CT images [11].

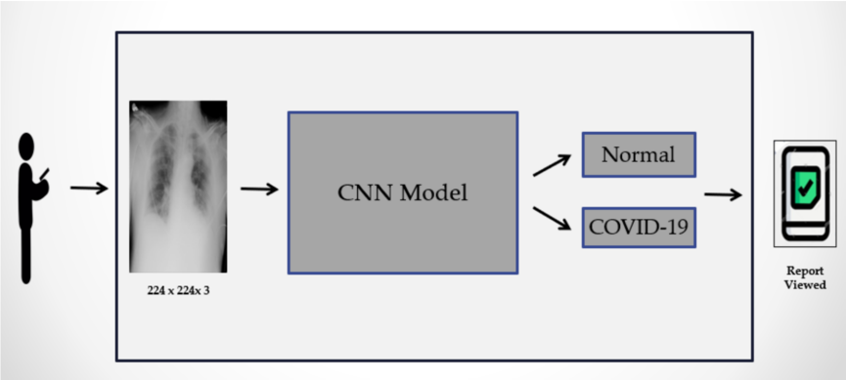

Figure 1. Workflow of the proposed system

In order to identify COVID-19 instances from open source chest X-ray radiography pictures, [29] studied a dataset they termed COVIDx and a neural network architecture they called COVID-Net. The dataset comprises of chest radiography pictures from four different groups, including Normal X-rays, which cover instances without any infections, Bacterial, Viral, which include pneumonia that is not COVID-19, and COVID-19 X-rays. Overall accuracy was reported to be 83.5 percent.

In the study [12], 192 severely and 4010 mildly infected patients hospitalized with COVID-19 between March and September 2021 were analyzed. The feature dataset consisted of 28 routine blood value parameters and age, and the highest performing supervised machine learning models was found to be local-weighted learning, K-star, Naive-Bayes, and k-nearest-neighbor.

A method to improve the quality of chest X-ray images and extract robust features for classification using a random forest machine learning classifier is proposed [26]. The proposed method achieves an average accuracy, F1 score, recall, and precision of 97 percent, 96 percent, 96 percent, and 96 percent, respectively, and outperforms existing similar work. The proposed approach can be used to effectively screen COVID-19-infected patients.

3. Materials and Methods

The working of the proposed system is shown in Figure 5. Chest X-ray images from the COVID-19 Radiography Dataset were fed into a CNN model. The model was developed and then deployed as an Android application.

3.1. Dataset

The dataset to perform the experiments is chosen from Kaggle, named COVID-19 Radiography Database [5,23]. Collaborating with medical doctors, a team of researchers from Qatar University in Doha, Qatar, and the University of Dhaka in Bangladesh, together with their collaborators from Pakistan and Malaysia, have established a database of chest X-ray images that includes positive COVID-19 cases as well as images of normal and viral pneumonia cases.

For this particular experiment, we only make use of 2000 images from the original dataset. We use 100 images of COVID-19 patients and 1000 images of Normal patients. Figures 2 and 3 show an x-ray image sample of a COVID-19 patient and an x-ray image sample of a normal patient respectively.

Figure 2. An x-ray image sample of COVID-19 patient

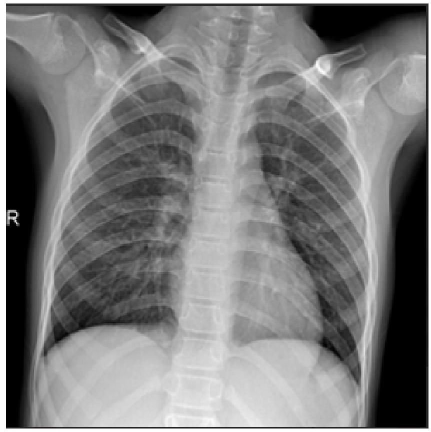

Figure 3. An x-ray image sample of Normal patient

3.2. Model development

The proposed study involved developing a CNN model, to identify COVID-19 through chest radiography images. The decision to use this model was based on the need for radiologists to distinguish between COVID-19 and normal chest X-rays to effectively diagnose and treat the patient. Consequently, the CNN model was designed to provide two possible predictions: either the X-ray is normal (indicating no infection) or it shows signs of COVID-19 (indicating infection). The proposed system was trained using the Python programming language. The experiments were conducted using Google Collaboratory (Colab), a cloud-based service. The experiments were performed using the Central Processing Unit (CPU) available on the online cloud service.
TensorFlow is a software library that is both free and open-source, designed for machine learning and artificial intelligence applications. While it has a wide range of uses, its primary emphasis is on the training and inference of deep neural networks. Since our dataset differs significantly from those utilized in pre-trained models, we employed the principle of transfer learning. We chose the TensorFlow framework to build our CNN model.

We have designed a custom model illustrated in Figure 4, which comprises of four convolution layers using 32, 64, 64, and 128 filters respectively, with each layer followed by a corresponding max-pooling layer. The ”relu” activation function is utilized in each convolution layer. A Flatten layer is added after the convolution layers, followed by two dense layers that use the relu and sigmoid activation functions, respectively. To prevent overfitting, a dropout of 0.5 is applied after the first dense layer. The first convolution layer's input size is defined as (224, 224, 3). Our dataset is partitioned into 70 percent for training data and 30 percent for testing data. We employed binary cross-entropy as the loss function and Adam optimizer for optimization, ensuring that the training process is effective. For the training phase, splitting is randomly done with the help of “split-folders” library in Python.

3.3. Android Application Development

To develop the Android application, the Flutter framework was used. The CNN model was developed using TensorFlow with extension “.h5”. To enable the model to run on the phone, the Tflite package dependencies were installed. This Flutter plugin facilitates image classification and object detection on iOS and Android platforms. Once the fundamental user interface (UI) screens were developed, the necessary gallery image picker was integrated. The model’s file path in the “.tflite” format was passed as a string to the Tensorflow service. The model classifies images into known labels as COVID-19 or Normal. These labels are stored in the .text file which is saved along with the assets in Android Studio.

4. Results

4.1. Training and testing results

The Convolutional Neural Network (CNN) model used in this study achieved a high level of accuracy, with a performance of 97 percent as shown in Fig 3. This result indicates that the model is effective in predicting whether COVID-19 is present or not. The high accuracy of the model is attributed to the use of a custom dataset, which allowed for the training of the model on relevant and specific data. The CNN model is a powerful tool for image recognition and classification tasks, and its success in this study highlights its potential for use in medical diagnosis and detection. The use of deep learning models like CNNs can greatly enhance the accuracy and speed of medical diagnosis, allowing for early detection and treatment of diseases like COVID-19.

4.2. Mobile Application Deployment results

An Android application is developed in Android Studio using Flutter for the prediction of COVID-19. The application is authorized with the aid of Firebase authentication through email and password. After the application has launched, the user can choose to log in or signup as an admin or a patient.

The application has a splash screen as in Fig 4. After authentication, the admin/ user can see the upload screen in Fig 5. After the submission of an image, the results are shown based on the trained images as COVID-19 or Normal, as shown in Fig 6.

5. Conclusion and Future Work

The COVID-19 pandemic has highlighted existing issues in disease management, expensive testing, delays, and high demand for testing kits, which pose significant challenges for healthcare systems worldwide. Immediate action is crucial to ensure every-

```
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, 64)      36928

 max_pooling2d_1 (MaxPooling  (None, 54, 54, 64)       0
 2D)

 dropout_1 (Dropout)         (None, 54, 54, 64)        0

 conv2d_3 (Conv2D)           (None, 52, 52, 128)       73856

 max_pooling2d_2 (MaxPooling  (None, 26, 26, 128)      0
 2D)

 dropout_2 (Dropout)         (None, 26, 26, 128)       0

 flatten (Flatten)           (None, 86528)             0

 dense (Dense)               (None, 64)                5537856

 dropout_3 (Dropout)         (None, 64)                0

 dense_1 (Dense)             (None, 1)                 65

=================================================================
Total params: 5,668,097
Trainable params: 5,668,097
Non-trainable params: 0
_________________________________________________________________
```

Figure 4. Summary of CNN model

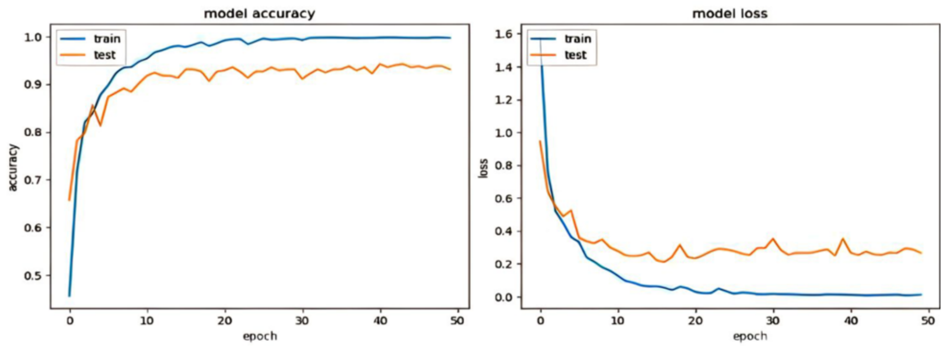

Figure 5. Graph for model accuracy and model loss

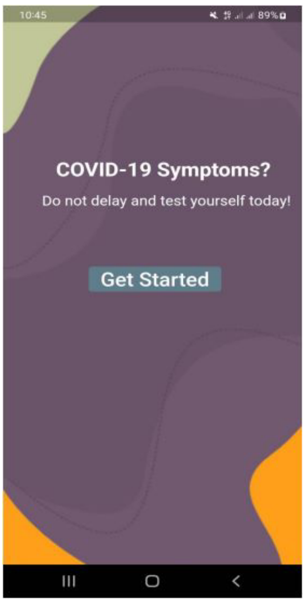

Figure 6. Splash Screen

Figure 7. Upload Image Screen

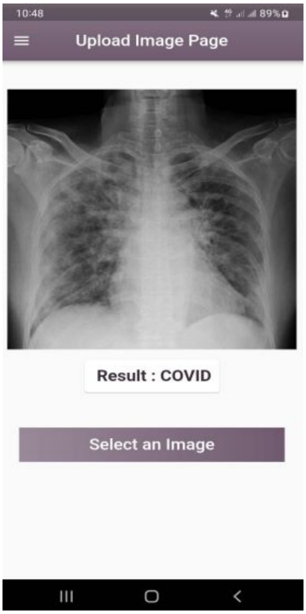

Figure 8. Result Screen

one has adequate access to healthcare and resources to combat this global health crisis. To address this, this study proposes a system that is both economical and efficient for predicting COVID-19. The Android application allows users to upload the X-ray images from their phone's gallery and obtain results based on a CNN model trained on an X-ray Image dataset. With its high accuracy, this system can assist individuals in coping with the pandemic.

In future work, further validation is needed to test the model's performance on larger and more diverse datasets. You may want to consider collaborating with medical institutions or organizations to obtain more data for testing and validation. This model can be integrated with other technologies to further improve the speed and accuracy of COVID-19 detection including creating a web-based application with image-processing features to display annotated images as results.

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