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CovidX*plus*-A New Mobile Application for Image-Guided Diagnosis of COVID-19 Patients

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Abstract

Patients with unexplained pneumonia were discovered in Wuhan City, China, at the end of 2019, according to the World Health Organization (WHO). Chinese authorities announced on January 2020 that they discovered a new virus that causes these infections. That's why the virus was assigned the name of novel Coronavirus Disease 2019 (COVID-19). It is a new disease that affects the lungs and airways and can cause mild to severe illness, as well as pneumonia. Coronaviruses are a wide family of viruses that can infect both animals and humans. Extreme Acute Respiratory Syndrome 2 is the most recent Coronavirus to be discovered (SARS-CoV-2). According to the results, the virus spreads from person to person in close contact over a distance of about 2 meters. When someone coughs or sneezes, respiratory droplets are released, which spread the virus. As a result, we need to build an application that allows use of computer-aided diagnosis (CAD) systems for detection of the COVID-19 based on radiological techniques. This paper proposes a novel mobile application based on fine-tuned transfer learning models to boost the efficiency of CAD systems in the detection of the highly suspected COVID-19 patients using medical X-ray images. Three fine-tuned deep learning models, namely ResNet50, ResNet101, and ResNet152 are exploited in this study.

Keywords-COVID-19, computer-aided diagnosis, internet of medical things, transfer learning

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1. Introduction

The World Health Organization (WHO) has described Corona virus disease (COVID-19) as a novel infectious disease in 2019 [1,2]. It can cause Severe Acute Respiratory Syndrome (SARS-CoV), a critical care respiratory condition that can lead to breathing failure and death. According to the WHO's Position Report No. 74 [4,5], COVID-19's risk evaluation is globally high level. Furthermore, the cumulative number of confirmed COVID-19 patients was increased. COVID-19 is classified by the WHO as a pandemic, (an epidemic occurring worldwide, or over a very wide area, crossing international boundaries and usually affecting a large number of people). It has affected a large number of people which leads to crowding to take tests to diagnose COVID-19. This is where the developed project (CovidXplus) is used to solve many of the current medical problems facing patients. Also, the developed application saves diagnostic time and costs for analyzing PCR samples to support obtaining a fast, accurate and effective diagnosis for physicians to know the condition of patients and take all medical measures. Hence, appropriate treatments for the positive COVID-19 patients, using automatic X-ray image analysis by means of artificial intelligence and advanced Deep learning.

COVID-19 is a pandemic virus which means it has spread all over the world, cause of that the COVID-19 virus is a global interest among all countries and specially in Saudi Arabia. Classifying the recent COVID-19 viral virus quickly and easily on the spot using a smartphone application is a step and a significant improvement towards the healthcare system and technology in the medical field, it will also help reduce pressure on hospitals and medical facilities which will lead to a healthy community.

The remainder of this paper is divided into the following sections: Section 2 reviews previous studies. Sections 3 describes the design and development of our mobile application (CovidXplus). Experiments and performance evaluation are presented and discussed in Section 4. Finally, conclusion and prospects of this research study are given in Section 5.

2. Related Works

Automatic detection of COVID-19 and lung disorders was studied using different medical imaging techniques, such as X-ray, CT and Ultrasound imaging scans. Latest research [3,6] has shown that CT scans with deep neural networks are crucial for correctly detecting and segmenting COVID-19 infections. The focus of this study, however, is exclusively on the use of chest X-ray images. It is considered the first step in identifying COVID-19 infections, and/or other pneumonia diseases, as demonstrated by the following previous studies. For tuberculosis patients, automatic identification of chest diseases in medical X-ray screening has been proposed, including classification of consolidation in cases of elevated lung density [7, 8], and essential respiratory diseases [9]. In addition, recognizing the infectious health status of Corona virus in X-ray images, on the other hand, is still a recent emerging research subject that has only been listed in a

few peer-reviewed published reports. Fine-tuned transfer learning classifiers [10,11] have been used to validate COVID-19 infections. The DarkCovidNet model has been developed based on real-time You Only Look Once (YOLO) algorithm by Ozturk et al. [12]. This study achieved binary and multi-class image classification procedures of COVID-19 and pneumonia diseases. The developed model showed a binary classification accuracy of 98.08% and multi-class accuracy of 87.02%. Using the COVID-19 dataset as an example, a threefold deep learning approach with 97.0 percent precision has been proposed for conducting top-down binary classification to decide whether a patient is stable or has a pulmonary disease [13]. This suggested solution would also visualize infected areas in lung X-rays by using the VGG16 (Visual Geometry Group) classifier. Other medical image modalities have been also used to detect Corona virus infections like Computed Tomography (CT) [14] and chest Ultrasound imaging scans using advanced deep learning models [15, 16].

3. Mobile application Development and Design

CovidXplus is designed as a flexible, user-friendly tool for predicting Covid 19 infection in highly suspicious cases using radiographic images. This section describes the CovidXplus mobile application's technical design, the motivation for its selection, and the framework used to develop it. We chose hybrid app development, a cross-platform application where an app developed in a common language such as HTML/CSS and jQuery or Python can run on multiple mobile platforms Android, iOS, Blackberry, and Windows Phone. The primary usage of the CovidX app is documented, showing how it can be utilized to validate different scenarios of results. Additionally, some examples were given to show the generated output by our developed mobile application. The project of CovidXplus mobile app is divided into the server-side and the client-side. This division is important, because it is a hybrid app that connects the client to the server. In the following sub-sections, the description of our developed framework will be given from both the server-side and back-end user-side.

3.1 Backed Framework and Mobile UI

We used the Flash framework for the backend process to develop a web-based API that allows interaction with client interfaces and returns only JSON data[1]. Flask is a Python framework that provides a high-performance and customized client-server-based applications in a flexible way . Additionally, we choose Flask because of facilitating our TensorFlow model deployment as a web service. That allows clients to communicate with it and send radiological images for the prediction of CovidXplus infection. Furthermore, the capabilities of Flask simplify the implementation of server-client sides communications.

Fig. 1 depicts the schematic design of our developed CovidXplus app model. View of the main components of this application was simply represented as static blocks. The solid lines represent the relationships for

each component of the application. We used the Flask framework authentication system to create personal user-space to privately save customized configurations and launch jobs without connecting for the entire processing time.

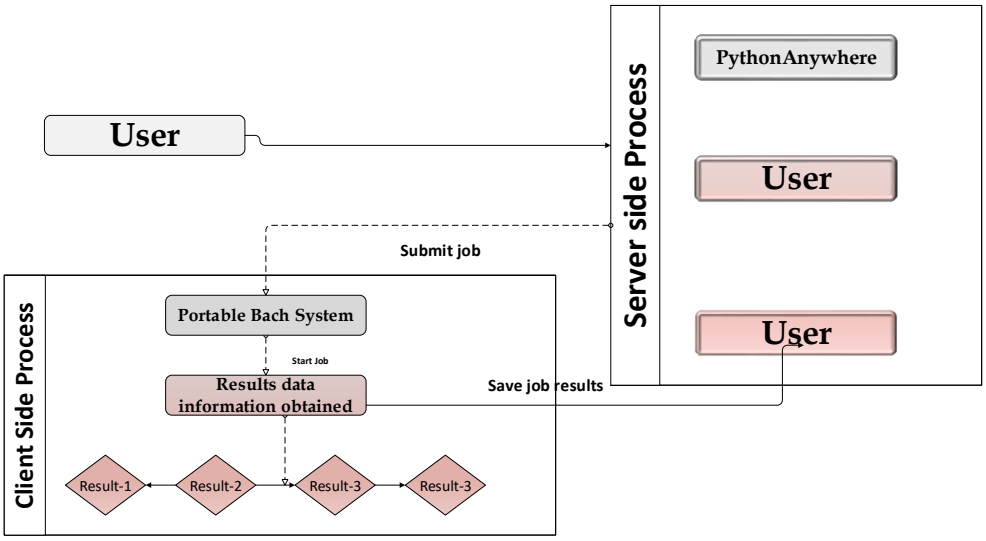

Fig. 1 Schematic diagram of the CovidXplus application model.

3.2 Computation Engine and Server Deployment

The app front-end (GUI) is developed using Apache Cordova technology, which uses Ajax requests to retrieve and send data to the server, and HTML, CSS, and JavaScript are used for layout design. This type of mobile application development is based on hybrid technologies and avoids mobile applications' parallel development in different mobile operating systems, such as Android or iOS. Moreover, the use of hybrid mobile development has been complemented with an MVC (Model - View - Controller) pattern that leads us to implement an extensible and modulable application.

In this code, the prediction model name is "CovidXmode.h5", which returns two results that are stored into the classes variable. Scheme of the application structure is depicted in Fig. 3. Users from mobile app send requests to a Flask server, which is implemented using an online web hosting service (Platform as a service) PythonAnywhere [3]. PythonAnywhere-server process the client's requests (mobile app) using the Flask, at this level CovidXplus model jobs accept input images and predict the results, which response to the mobile app interfaces. The development and compilation of mobile interfaces focused on performance. The clear separation between GUI and computational engine results in relevant improvements in computational speed compared to current mobile apps. Figure 3 shows the deployment layout of CovidXplus application.

```
from tensorflow.keras.models import load_model
from imutils import paths
import cv2
import numpy as np
import os

filename = 'CovidXmodel4.h5'
model = load_model(filename)
model.compile(loss='binary_crossentropy',optimizer='SGD', metrics=['accuracy'])

image = cv2.imread('.../normal24.png')

image = cv2.cvtColor(image, cv2.COLOR_BGR2RGB)
image = cv2.resize(image, (224, 224))

#img = cv2.resize(img,(224,224))
image = np.array(image) / 255.0
image2 = np.reshape(image,[1,224,224,3])

classes = model.predict(image2)

print(classes)

# All images should be converted to jpg or png first with training and then make the test.

# image = cv2.imread(imagePath)
# image = cv2.cvtColor(image, cv2.COLOR_BGR2RGB)
# image = cv2.resize(image, (224, 224))
```

Fig. 2 A sample of the Python code of our developed CovidXplus application.

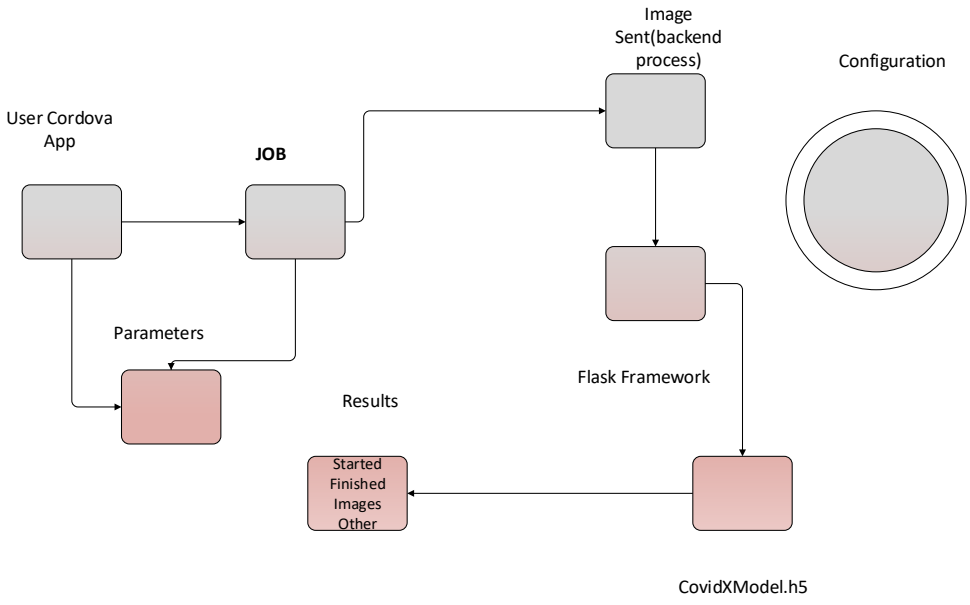

Fig. 3 Deployment layout of CovidXplus mobile application.

4. Experiments

This section demonstrates the use of the mobile app, showing results that a user can obtain through the CovidXplus application. The first step is to select an X-ray image on the user's mobile device. The explanation for the COVID-19 infection testing process are described as follows. First, install the mobile app and select an x-ray image from the mobile app's home activity, which should be in .well-known image formats such as .png, .jpg, and .jpeg. After selecting the image successfully, hit the result button to send the selected image to the prediction server. Second, the request sent by the mobile app is sent to the Python anywhere server via Rest APIs. After receiving the image on the server-side, the image is further transmitted to the fine-tuned CovidXplus. h5 model for infection prediction and the resulting JSON data is sent to the mobile interface as a response, and the result is displayed in the resulting activity of the mobile app. In this study, three different deep learning models, namely ResNet-50V2, ResNet-101V2 and ResNet-152V2 have been employed to classify the chest X-ray image of COVID-19 patients. The hyperparameters of these models are fixed [10], such that number of epochs = 50, batch size is 7, learning rate = 0.001, and Adam optimizer has been used. The performance of deep learning classifiers has been evaluated based on the cross-validation metrics, namely accuracy, precision, recall and F1-measure as given in equations (1-4) [16, 17]; where TP, TN, FP and FN are true positive, true negative, false positive, and false negative, respectively. Examples of outputs generated by the CovidXplus app are ordered from left to right, as shown in Fig. 4.

$$Accuracy(\%) = \frac{TP + TN}{TP + FP + FN + TN} 100\% \quad (1)$$

$$Precision = \frac{TP}{TP + FP} \quad (2)$$

$$Recall = sensitivity = \frac{TP}{TP + FN} \quad (3)$$

$$F1\text{-}measure = 2\left(\frac{precision \times recall}{precision + recall}\right) \quad (4)$$

Table 1 Evaluation of CovidXplus application using three deep learning models of residual networks.

Deep Learning Model	Health Status	Precision	Recall	F1-score	Accuracy (%)
ResNet50V2	Positive COVID-19	1.00	1.00	1.00	**99.0**
	Negative COVID-19	0.92	0.92	0.92	
ResNet101V2	Positive COVID-19	1.00	0.55	0.71	70.0
	Negative COVID-19	0.80	1.00	0.89	
ResNet152V2	Positive COVID-19	1.00	0.36	0.53	55.0
	Negative COVID-19	0.63	1.00	0.77	

Fig 4 Screenshots of the developed CovidXplus application.

5. Conclusion and Future Work

This article presented a novel mobile application regarding the classification and diagnoses of COVID-19 patients with the advantage of being able to classify COVID-19 infections on-line. The results are accepted using ResNet models, and can be further improved by upgrading CovidXplus application to include the following features:

- Adding other deep learning models as advanced classifiers to improve the infection diagnosis accuracy.
- Customized UI to adapt the needs of physicians, medical staff, and patients.
- Linking the developed application with the hospital management system to handle the queries of COVID-19 patients.
- Considering privacy and security aspects of patient data over local computer networks and internet.

Declaration

This paper presents purely research work and was not tested on real patients.

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Competing Interests

The authors have no conflict of interest to disclose.

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