

# Raspberry pi Based Osteoarthritis Disease classification

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## Abstract

Osteoarthritis (OA) is a disease that can be diagnosed by using x-ray images. The main technique that can be used to achieve this diagnosis is Convolutional Neural Network (CNN). With the fast development in recent years, deep learning techniques especially CNN in the medical field have become a popular solution to solve medical problems. Raspberry Pi is a small device the size of a palm and is considered a mini-computer. it used to perform many functions as computers do. In this research, Raspberry Pi has been used for the classification of degenerative arthritis disease through x-rays images. It is a joint disorder that affects the joints, especially the knee joint.

This paper was divided into two parts. First, the disease was classified by using Convolutional Neural Network (CNN) and pre-trained networks such as Efficient Net B7, and an accuracy of 89.69 % was obtained. Secondly, the saved model from the training process was uploaded to the Raspberry Pi and the Graphical User Interface (GUI) was designed for testing the model, so great results were obtained.

**Keywords:** Raspberry Pi, Convolutional Neural Network (CNN), Graphical User Interface (GUI)

## 1. Introduction

Osteoarthritis (OA) is the most frequent kind of joint condition. Knee OA can be painful, and it is the leading cause of loss of ability to conduct everyday tasks like walking and stair climbing. Knee OA is characterized by a decrease in articular cartilage thickness and is associated with aging[1].

The technique of developing visual representations of the interior structures covered by the skin and bones is known as medical imaging. It is a procedure that allows the inside portions of the body to be shown for clinical diagnosis and medical treatment. Medical imaging is a subset of biological imaging that includes X-rays, Computed Tomography (CT), Ultrasound, and Magnetic Resonance Imaging (MRI). OA is one of the most frequent types of arthritis, affecting mostly women, the overweight, and the elderly.

Pain and discomfort in joint mobility are the most major signs of OA, as are limited function and activity restrictions, and joint problems in the morning or after a lengthy period of rest. The current OA evaluation is based on clinical assessment, symptoms, and basic radiographic assessment techniques (X-ray, CT, and MRI). While alternative systems have been presented, the Kellgren-Lawrence (KL) method is a tried and true approach for grading specific joints into five categories. The table below shows the various stages of OA disease[2]. KL system has been approved by the World Health Organization in 1961[3].

Table 1 KL grades of OA

KL Grades	OA analysis
Grade 0	Normal - No Radiographic features of OA present
Grade 1	Doubtful - OA(narrowing of joint space)
Grade 2	Mild - OA(definite narrowing of joint space)
Grade 3	Moderate - OA (multiple osteophytes, sclerosis)
Grade 4	Severe - OA ( large osteophytes, severe sclerosis, bone deformity)

Figure 1 shows the OA X-rays in each KL grade. The KL scale may be shown graded based on the distance between the bones and whether or not the osteophyte develops[4].



Figure 1 Radiograph of OA in each grade

According to current technological advancements and recent development in medical imaging analysis, Deep learning (DL), is a type of Artificial Intelligence (AI), has been shown a good results in recognizing knee OA and even categorization of its illness based on the KL scaling system[5].

The Raspberry Pi Foundation in the United Kingdom created low-cost, hand-sized, single-board computers known as Raspberry Pi. The Raspberry Pi was created to encourage the teaching of fundamental computer skills in schools, and it succeeds wonderfully[6].

Raspberry Pi 4 specification:

- CPU Quad-core Cortex-A72 64-bit SoC @ 1.5GHz.
- SDRAM 2, 4, and 8GB LPDDR4-3200.
- It has a Gigabit Ethernet.
- It contains 4 USB ports (2 USB 3.0 ports and 2 USB 2.0 ports).
- It has a standard 40 pin GPIO.
- It has two micro-HDMI ports and it supports 4kp60.
- 2-lane MIPI DSI display and 2-lane MIPI CSI camera port.
- 4-pole stereo audio and composite video port[7].

In this paper raspberry pi 4 with 8G of RAM has been used. Figure 2 shows the raspberry pi 4.

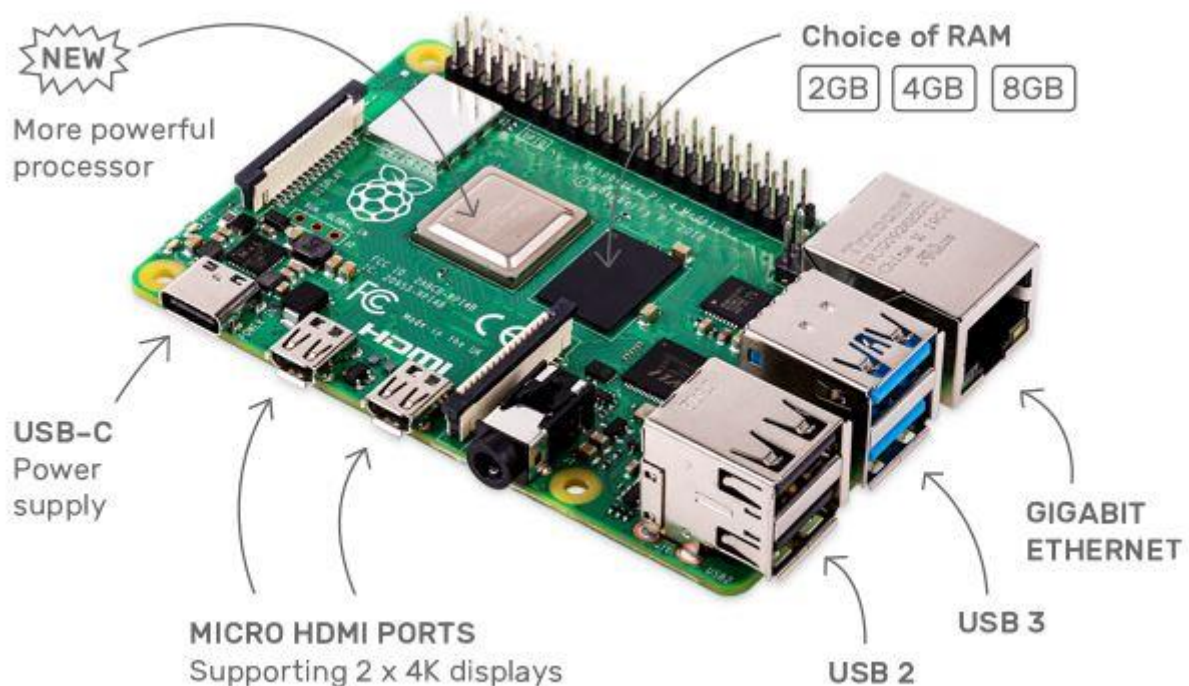


Figure 2 Raspberry pi 4 [8]

An end-user wants an application to be appealing for it to be useful. An application's quality and productivity are determined by its interface. The current tendency is to include a Graphical User Interface (GUI) in every program to increase user interaction. A cross-platform framework, such as Python's standard library's 'Tkinter,' makes it easier for programmers to create graphical user interfaces for a variety of applications[9].

## 2. Methodology

Figure 3 below shows a block diagram of the whole system design

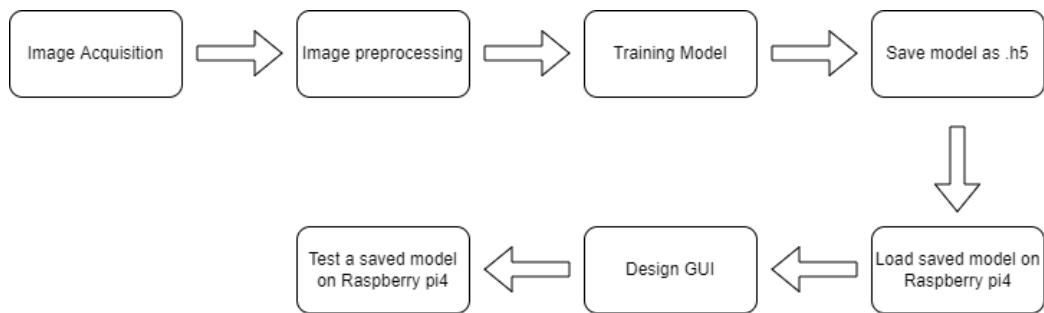


Figure 3 block diagram of whole system design

The first 4 blocks were done by the computer. After that, the Raspbian 64-bit system was installed on the Raspberry Pi 4. The saved model(.h5 file) was placed on the Raspberry Pi. A graphical interface to facilitate user interaction and also test the system has been implemented.

### 2.1 Image Acquisition

The dataset that has been used in this project consists of 1650 images (x-ray) these images are divided into five classes unequally as shown in table 2[10].

Table 2 Number of x-rays in each grade

Grade	Number of x-rays
Normal (G0)	514
Doubtful (G1)	477
Mild (G2)	232
Moderate (G3)	221
Severe (G4)	206
Total	1650

### 2.2 Image preprocessing

Two types of preprocessing have been used in our model

- Image resize: all x-ray images have been resized to 300 widths and 224 heights.
- Data Augmentation: Data augmentation has been used to reduce overfitting during CNN training and generate more images from the original image [11]. In our model data augmentation was used such as zooming 0.1, height shifting 0.1, width shifting 0.1, Rotation 5°, vertical flipping, and horizontal flipping equal True as shown in figure 4.

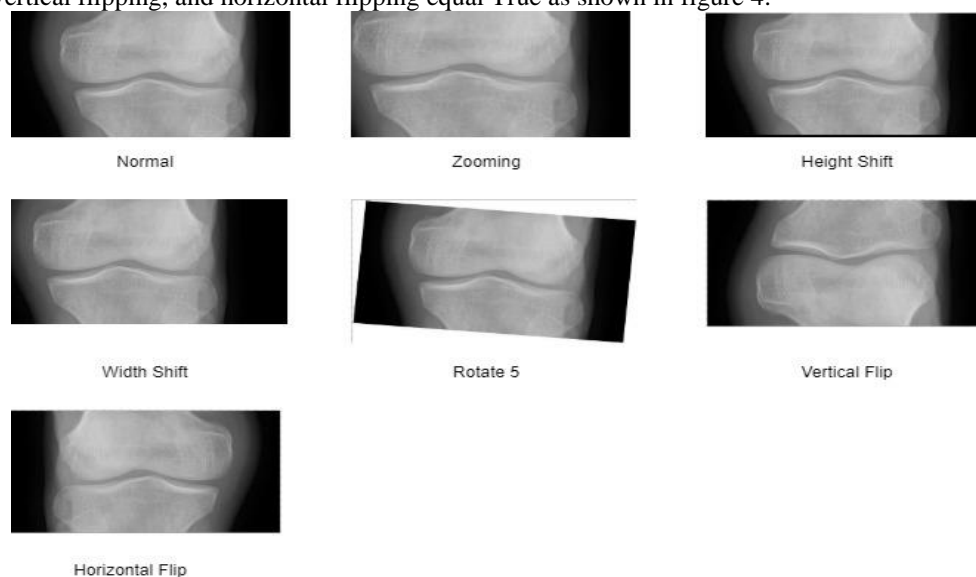


Figure 4 data augmentation in our model.

## 2.3 Training model

### 2.3.1 Convolutional Neural Network (CNN)

Deep CNN is now one of the most popular models, with excellent results on a variety of image categorization challenges. By uncovering robust characteristics (features) in images and reducing the vanishing gradient problem, the notion of sharing weights in DCNN allows for successful image categorization. CNN has three layers: a convolution layer, a pooling layer, and a fully linked layer. The major goal of the convolutional layer, which functions like filters, is to extract characteristics (features) from input images. The pooling layer follows the convolutional layer, doing downsampling and retaining the most significant information in the input images. This layer minimizes the model's spatial dimension and even the number of parameters and avoids overfitting, resulting in a more efficient model. The fully linked layers (last layer), utilize a soft-max activation function to extract high-level information from input images to categorize them into multiple categories with labels[12].

### 2.3.2 Transfer Learning (TL)

TL techniques attempt to transfer knowledge from previous old tasks to target new tasks[13].

TL is a deep learning technique in which a model created for one job is reused as the starting point for a model on a different task. Because our dataset contains a small number of images of an OA knee joint, our method creates a new model using weights from a model that has been pre-trained on a bigger dataset, such as ImageNet[14].

To speed the convergence rate of neural networks and increase the performance of models with small training datasets, TL techniques are used[15]. These well-known models can be used to tackle challenges in TL. VGGNet, ResNet, AlexNet, DenseNet, MobileNet, GoogLeNet, and EfficientNet are some of the well-known models that have been suggested so far[4].

### 2.3.3 proposed model

The proposed CNN models using a pre-trained network (Efficient Net B7) with fine-tuning with data Augmentation to classify osteoarthritis severity. After image preprocessing, a dataset has been divided into 90% for training and 10% for validation.

In transfer learning, the convolution and pooling layers have been stopped and replaced the fully connected layers of the Efficient Net B7 with the 2 FC layers. The 2 FC layers contain 512 neurons and 256 neurons respectively and train the network with 200 epochs.

The proposed network uses a 32 Batch size and is trained to utilize Adam optimizer with a  $1e-4$  learning rate. Loss function (categorical\_crossentropy) has been used to determine a loss function. A callback from Keras called Early Stopping has been used. This callback allows to provide the performance measure that can be monitored, in addition, to preventing overfitting. checkpoint function from callbacks is also used to save the best weight during training. To reduce overfitting a 0.25 drop out has been utilized. The dropout reduces computation in the training process. The final layer is the output layer with a soft-max activation function, this layer consists of 5 neurons according to the KL grading system.

## 2.4 Loading .h5 file on Raspberry pi 4

After Raspbian (Raspberry pi OS) has been installed on the micro sd card. The saved model (.h5 file) has been uploaded to raspberry pi 4 and uses Thonny python IDE to write a GUI code for testing knee x-ray images to classify x-ray according to the KL grading system into 5 classes. A five-inch HDMI display (800 x 480 pixel) has been used.

Figure 5 shows all hardware components that have been used to design the classification system.

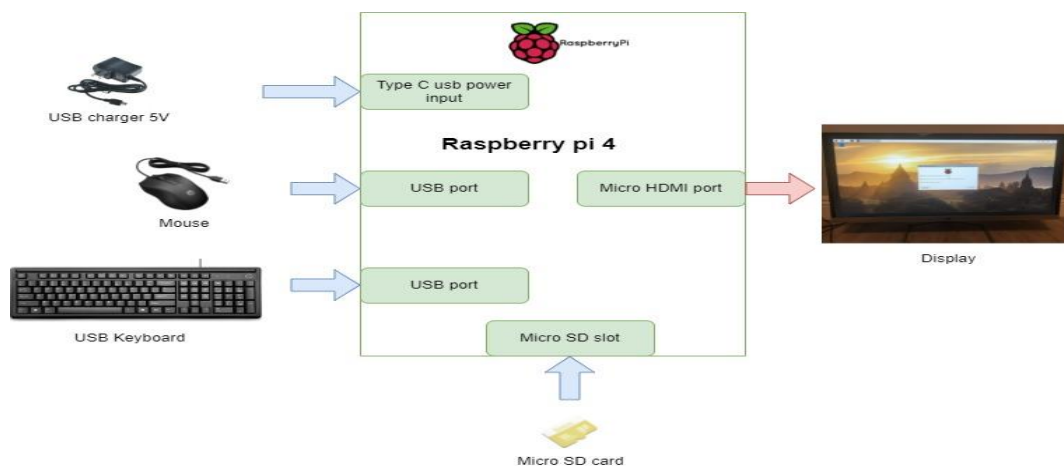


Figure 5 hardware components

## 2.5 GUI Design

In the development of computer science and software design, the GUI is a huge step forward. The use of a graphical user interface (GUI) makes human and computer interaction easier and more enjoyable. Python's popularity as a programming language has grown in recent years, but it has yet to be fulfilled in GUI design. Tkinter has the benefit of native Python support[16].

After completing the training of the model and saving it in the h5 file, and to facilitate the testing and use of the model smoothly and comfortably by specialists, a GUI must be designed and built.

GUI design steps:

1. Import Tkinter library.
2. Add icon.
3. Add labels.
4. Add text entries to write email and password for Sender(Radiologist).
5. Add text entries to write email doctor (To) and patient name.
6. Add text entry to write results.
7. Add a button to upload an image from the computer for testing it.
8. Add a button to classify an image that will appear after image uploaded.
9. Add a three-button to send an email, Rest contains of all text entries, and attach an x-ray image (using Gmail server for sender email).

Figure 6 below shows a design of GUI for the classification of knee joint OA in Raspberry pi.

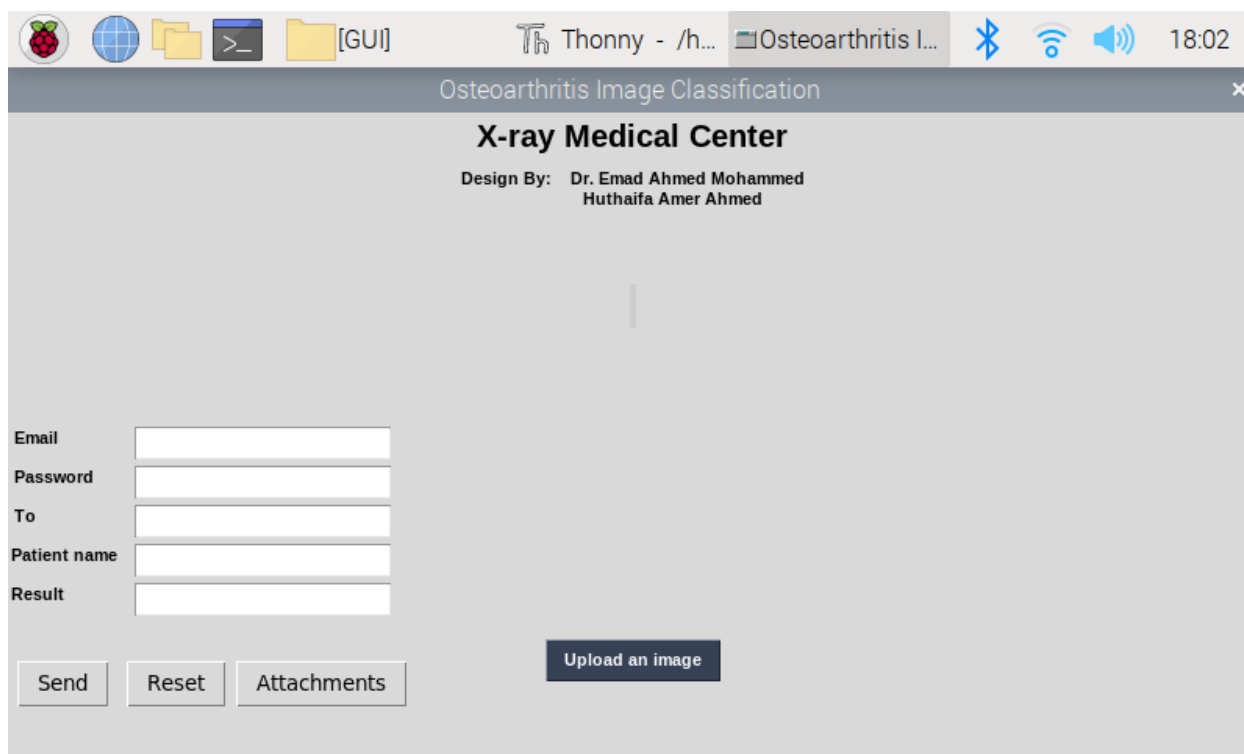


Figure 6 Design of GUI

### 3. Results

This research shows results of the pre-training network (Efficient Net B7) based on fine-tuning for detecting knee OA diseases. The Early stopping and Checkpoint have been used to get the best result from a network.

GUI has been designed to reduce diagnosis time by making radiologists check the case of the patient before the doctor and who will send the result with the x-ray image by email to the doctor.

Two emails have been used in this paper one for the radiologist and the second for a doctor and it is possible to change these emails by a user.

#### 3.1 classification result

Figure 7 below shows the confusion matrix of OA classification by using Efficient Net B7 pre-trained network. The main diagonal represents the correct predicated samples. The accuracy has been determined by dividing the correct predicated sample by a number of all samples  $(44+44+21+25+14)/(165) = 89.69\%$

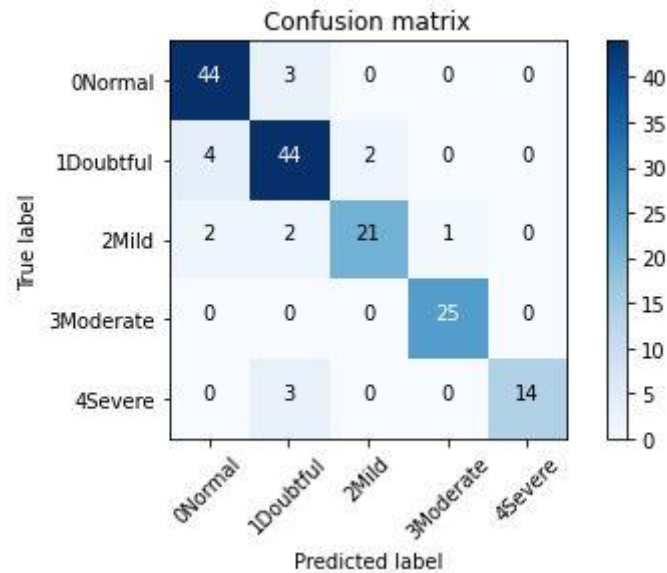


Figure 7 confusion matrix of OA classification

### 3.2 GUI result

First, upload an image from the computer, then automatically appear the second button to classify the image based on the KL grading system (G0:Normal, G1:Doubtful, G2:Mild, G3:Moderate, G4:Severe), after pressing on classify button get the result in the middle of the window as shown in figure 8.

Then we fill the email and password for sender (Radiologist), (TO) entry text fill with an email of the doctor, we write the patient name and result. After that, we add an x-ray image from the attachment button and click on the Send button to send (patient name, Result, and x-ray image) to a doctor.

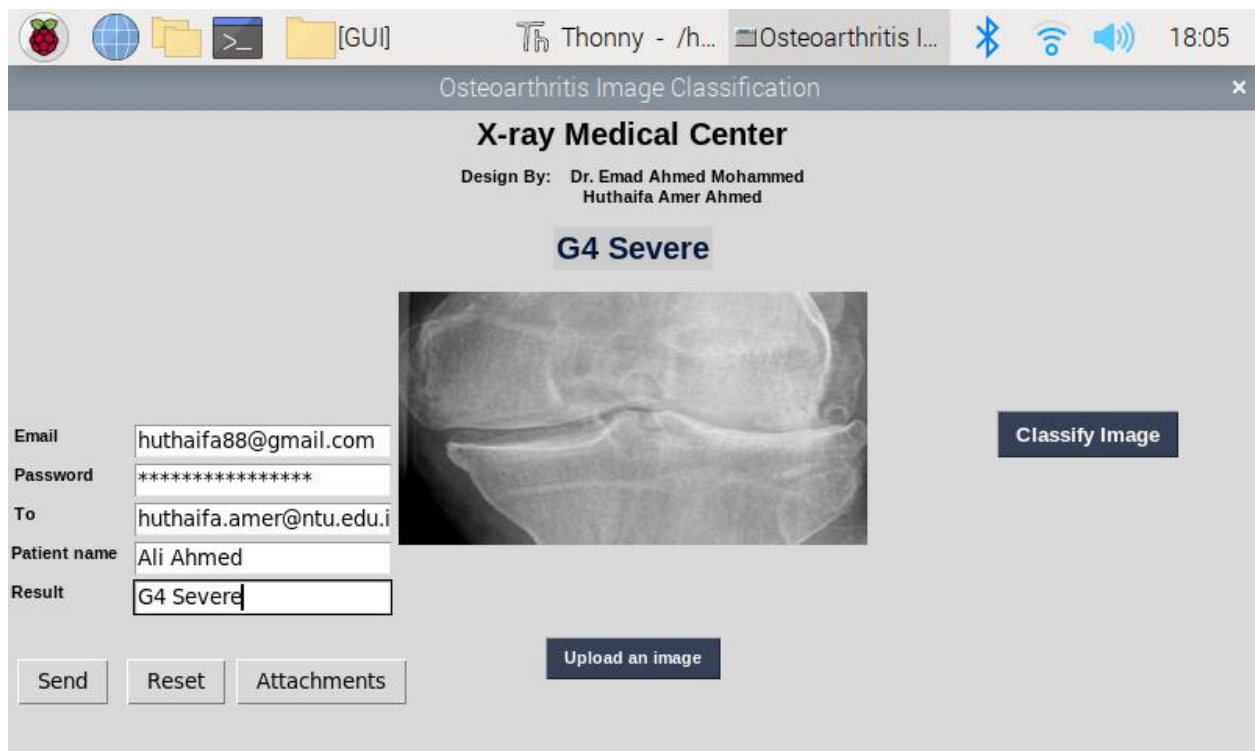


Figure 8 GUI Result

Figure 9 shows the received email by a doctor that contains the patient name, Result, and x-ray image

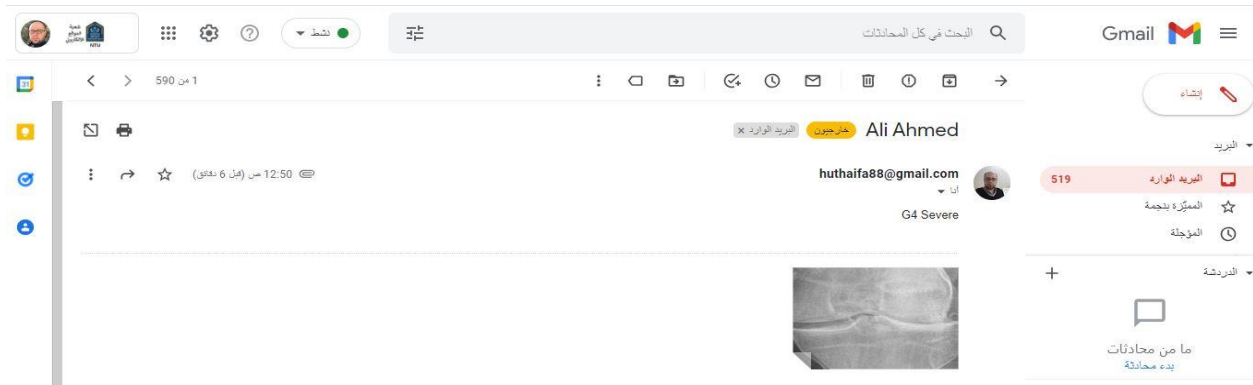


Figure 9 received an email by a doctor

## Conclusion

A method to classify the OA of the knee joint was successfully implemented by using deep learning techniques with transfer learning to reduce the training process. This work uses an Efficient Net B7 pre-trained network and achieved a good accuracy.

The design of the GUI greatly facilitates the diagnosis of this disease and reduces the time for diagnosis. Raspberry Pi was an alternative solution to the computer, as this small device was able to do computer work and give accurate results.

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