A Real-Time Analytic Face Thermal Recognition System Integrated with Email Notification

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ABSTRACT

COVID-19 is a contagious disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The disease has spread worldwide, leading to an ongoing pandemic. The most common symptom of COVID-19 is fever which can be detected using various manual screening techniques that have the risk of exposing the personnel. Since the virus has globally spread, a reliable system to detect COVID-19-infected people, especially before entering any premises and buildings, is in high demand. The most common symptom that can be detected is fever, even though people with fever might not have COVID-19. Thus, a real-time analytic face thermal recognition system integrated with email notification that has the capability to scan the person's temperature and simultaneously analyze the measured temperature with the recorded/stored information/data is presented in this paper. The proposed system is also able to send an email notification to the relevant authorities during the real-time analytical process. Besides that, this information is also recorded in the system database for continuous monitoring of the respective person's health status. The development of the proposed system is integrated with a Thermal Module AMG8833, Pi camera, and Raspberry Pi Zero Wireless. The proposed system has been tested and the captured results successfully accomplished the development objectives.

Keywords-Covid-19; face recognition; temperature; real-time analysis; email notification

I. INTRODUCTION

There is a high demand in face thermal recognition systems due to the COVID-19 pandemic. There are many off-the-shelf face thermal recognition systems available in the market, everyone with its abilities and advantages. To enable effective monitoring which also complies with the Standard Operating Procedure (SOP), a real-time analytic face thermal recognition system integrated with email notification and having the capability to simultaneously analyze the measured person's temperature and update recorded/stored information/data is presented in this paper. Prior to the development of the proposed system, off-the-shelf systems related to detecting possible symptom of COVID-19 are studied. The studied

systems investigate the aspect of simplicity in terms of product development as well as quick and fast delivering the analyzed and processed information to the relevant authorities. Although the developed system is not able to prevent the COVID-19 pandemic, it can assist in controlling it more effectively and efficiently. Generally, infrared and wireless thermometers are deployed as general medical tools, especially at the entries and exits of buildings. The infrared and wireless thermometers generally use body temperature sensing [1]. Designing and developing systems able to assist the early detection of any fever-related illness so that it can be further examined it is CoVID-19 or something else is a scientific topic of major interest.

In [2], fever is mentioned as the most common symptom of patients with COVID-19. The off-the-shelf studied systems [3-5] use the Pi Camera to visualize the thermal data, where the temperature values are mapped into a color gradient, ranging from blue to red. The blue color is mapped to value 0 representing the lowest temperature, while red color is mapped to value 1023 representing the highest temperature. A real image of the respective person is blended with the saved image to produce the read thermal temperature value. The produced thermal temperature value is displayed in real-time and an email is sent to the person in charge at the monitoring station if any abnormality is detected. In [6], an IoT smart health monitoring system that analyzes the human body temperature, pulse and SpO2 has been developed and integrated into a mobile application for COVID-19 detection. With the integrated system, the patient can immediately seek medical attention if a physician is not available. In [7], a smart helmet is developed to innovatively detect and monitor COVID-19 using a thermal imaging system attached onto the smart helmet. The smart helmet detects high body temperature and sends the measured value into a mobile application, assisting the early detection of COVID-19. Thermal face recognition systems have been proven to be effective in detecting possible COVID-19 affected persons besides from been used to authorize the person's authentication [5]. Authors in [8] utilized the smart home concept to detect if a visiting person is infected with COVID-19. Infrared technology was used to detect the person's temperature and if it was high, an integrated thermal face camera was used to scan and monitor the person's condition at the door. Authors in [9] mentioned that CT-scans and X-ray images can also be used for COVID-19 early detection. The paper also explains that the use of deep learning models [10, 11] could give more precise COVID-19 early detection, but systems with deep learning models is more expensive. Thermal detection is a popular method to screen people during the outburst of the COVID-19 pandemic. The infrared thermal scanning method is also widely used at many places as an early precaution step. Such systems are often able to make buzzer sounds when a person with high temperature is detected during the scanning process.

After reviewing some of the developed systems that use facial thermal measuring for early COVID-19 detection, and to the best of our knowledge, features such as real-time identification/authentication and email notification are not applicable. Hence, the current research project implements real-time facial identification/authentication, then analyzes the temperature reading and compares it with the preset temperature value before sending an email notification if the temperature is above the preset value. The email notification notifies the relevant authorities about the person's condition, or records the person absence from work. Phyton programming language was used to develop the proposed research project. Thonny application was selected as Python IDE because it is free and open-source and it provides significant features such as code inspection and debugging. The standard libraries used in this project are OpenCV and DLIB. The algorithm development begins with facial detection and face recognition. Then, the AMG8833 Thermal Camera Sensor for facial temperature measuring, recording, and comparing is activated.

The proposed project continuously processes the recorded/stored information/data and automatically updates the stored data into the developed system. Also, the developed and deployed system tends to reduce the risk of infection of manual screening.

II. RESEARCH METHODOLOGY

The proposed development methodology is divided into two phases. Phase one focuses on the hardware development which consists of 1) the integration of the Pi Camera to perform the facial detection and recognition and 2) the integration of the thermal camera sensor to measure facial temperature. The integration of the Pi Camera is conducted to perform the face detection and recognition via existing images that have been preloaded into the Raspberry Pi Zero Wireless SD-Card storage. Upon the success of the face detection and recognition, the thermal camera sensor is activated to measure the human facial temperature. Then, the recognized person and its measured temperature details are stored into the Raspberry Pi Zero Wireless SD-Card. The second phase focuses on the embedded software development for 1) facial detection and recognition, 2) measurement of the facial temperature, and 3) configuration of the email notification. The facial detection and recognition perform real-time face recognition based on the preloaded images. Upon detection of a human face, the thermal camera sensor measures the respective human facial's temperature and stores it into the SD-Card. While the recognized face and human body temperature information is recorded, the process of comparing the measured temperature with the preset temperature value is performed to detect normal and high temperature. If the measured temperature is above the preset temperature value, an email notification is delivered to the relevant authorities (security, managers, internal clinic, COVID-19 screening team, etc.).

A. IoT Face Thermal Recognition System Integration

- Pi Camera Integration

In the first phase, the Pi Camera performs facial detection and recognition. The integration is shown in Figure 1. The Pi Camera is connected to the Raspberry Pi Zero Wireless via the Camera Serial Interface (CSI) connector. The integrated Pi Camera has the capability to capture an 8 Megapixel real-time image which will be used to perform the facial detection and recognition with the images stored in the Raspberry Pi Zero Wireless SD-Card Storage.

- Integration of the AMG8833 Thermal Camera Sensor

This section describes the AMG8833 Thermal Camera Sensor connectivity with the Raspberry Pi Zero Wireless as shown in Figure 2. The General-Purpose Input/Output (GPIO) port 2 and port 3 are respectively connected to the Serial Information (SDA) and Serial Clock Line (SCL). The power source (VCC) is connected to 3.3V at port 1 and the ground is connected to port 9. The AMG8833 Thermal Camera Sensor is activated when the facial detection and recognition is completed.

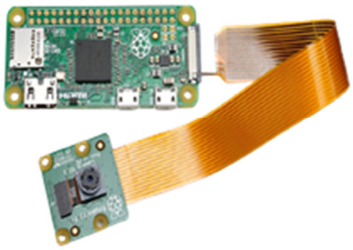

Fig. 1. Pi Camera and Raspberry Pi Zero Wireless connection.

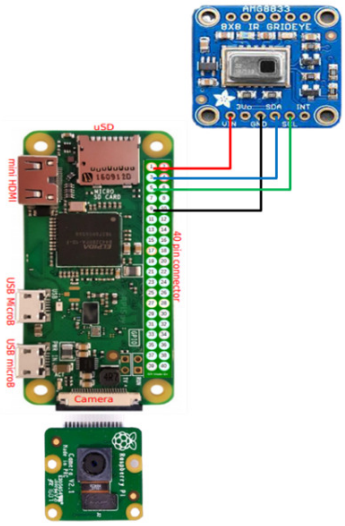

Fig. 2. AMG8833 Thermal Camera Sensor connection with the Raspberry Pi Zero Wireless.

B. Software Design and Development

- Embedded facial detection and recognition algorithm

To perform the facial detection and recognition tasks, a suitable algorithm has been implemented (Figure 3). When the integrated Pi Camera is active, it will acquire a real-time image which will be compared with a preloaded image. Upon confirming the acquired real-time image, the embedded software algorithm will perform facial recognition to confirm the person's identity and will provide the recognized person's name. Once the name has been confirmed, it will be recorded into the attendance list.

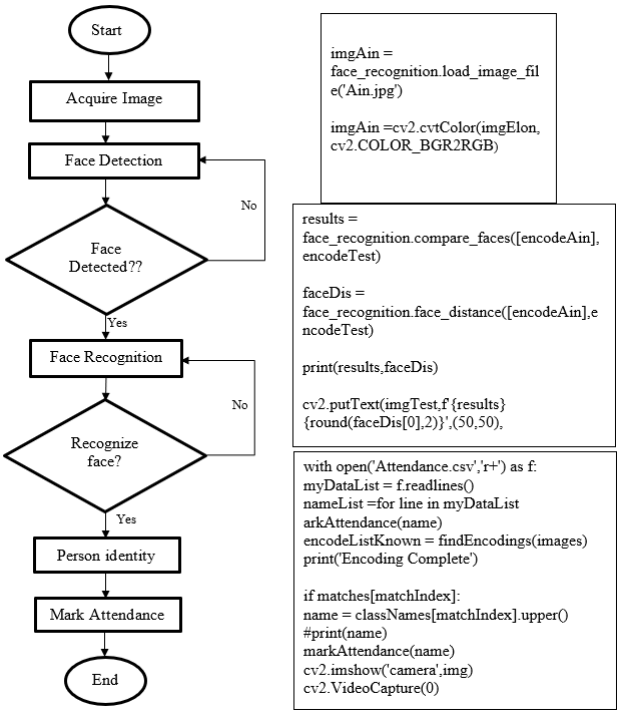

Fig. 3. Embedded face detection and recognition algorithm.

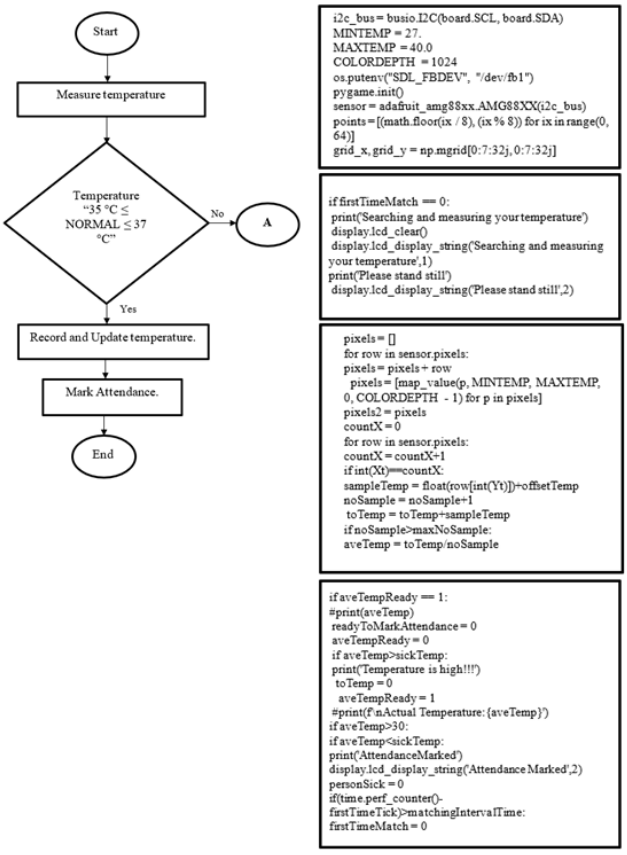

Fig. 4. Embedded AMG8833 thermal sensor algorithm.

- Embedded algorithm for the AMG8833 thermal camera sensor and email notification

The AMG8833 thermal camera sensor is integrated to measure the real-time human temperature. The AMG8833 sensor reads a real-time temperature value when a person's face approaches the camera and the sensor. Hence, when the face is recognized, the AMG8833 thermal camera sensor is activated to measure the person's facial temperature and match the measured temperature with the person's name that is stored in the attendance list. If the person's name is matched, the name and measured temperature will be displayed at the integrated Liquid Crystal Display (LCD). Otherwise, the embedded software continues to perform the person's name search to record the measured temperature value. Also, during the temperature measuring, the embedded software algorithm for the AMG8833 thermal camera sensor categorizes the measured temperature into two classes, i.e. "35°C ≤ NORMAL ≤ 37°C" or "37°C < HIGH ≤ 40°C". If the measured temperature is Normal, its value is displayed on the LCD, otherwise an email notification will be sent to the authorities to inform about the person's condition as depicted in Figures 4 and 5.

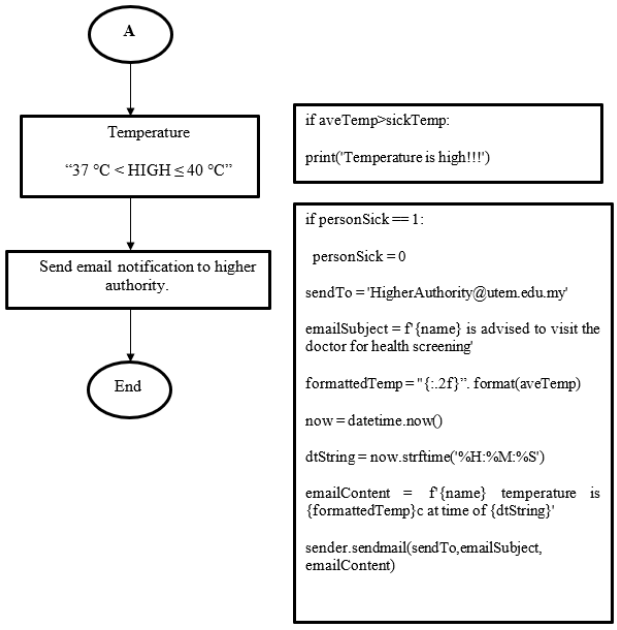

Fig. 5. Embedded real-time email processing and notification algorithm.

III. RESULTS AND DISCUSSION

A. Hardware System Design and Development

Figure 6 shows the arrangement of AMG8833 thermal camera sensor, Pi Camera, and LCD for the hardware system design and development. The AMG8833 and the Pi Camera are placed side by side to allow simultaneous facial detection and recognition and facial temperature measurement upon authentication. Details such as name and temperature of the scanned face are displayed on the integrated LCD.

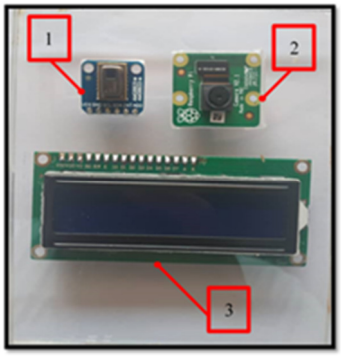

Fig. 6. Placement of integrated Pi Camera, AMG8833 Thermal Camera Sensor, and LCD - IoT face thermal recognition system.

Fig. 7. Illustration of face recognition in a rectangular box.

Another reason of placing the AMG8833 sensor and the Pi Camera side by side is because this way the AMG8833 thermal camera sensor picture size of 480×480 pixels is centered at the Pi Camera picture size of 640×480 pixels as shown in Figure 7. This allows the AMG8833 Thermal Camera Sensor to effectively scan the center of the forehead for temperature measuring as can be seen in Figure 7. Figure 8 shows the complete integration of Pi Camera, AMG8833 thermal camera sensor, and LCD into the Raspberry Pi Zero Wireless.

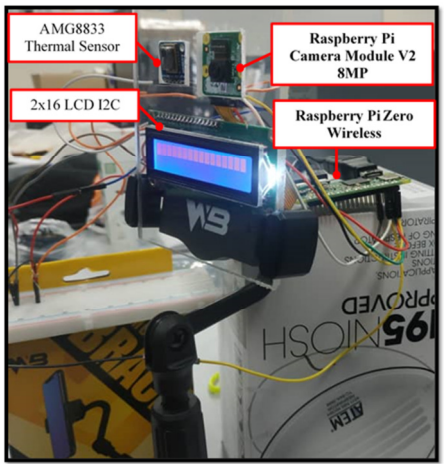

Fig. 8. Integration of the Pi Camera, AMG8833 Thermal Camera Sensor, and LCD in the Raspberry Pi Zero Wireless.

B. Validation of the Developed Software

This section validates the developed software algorithm which integrates the Pi Camera and AMG8833 Thermal Camera Sensor in Raspberry Pi Zero Wireless for face

detection, face recognition, and face temperature reading and measurement. To perform face detection and recognition a suitable algorithm (Figure 4) was implemented. The system starts with the embedded algorithm for face detection and recognition. When the integrated Pi Camera is activated it will acquire a real-time image, which will be compared with the stored image in the SD-Card. Upon confirming the acquired real-time image, the embedded software algorithm will perform face recognition to confirm the person's identity. Once the person's face is recognized, the AMG8833 thermal camera sensor will be activated to measure the person's facial temperature which will be evaluated based on the two conditions shown in Figures 4 and 5. These conditions will be matched while real-time facial temperature is measured and the information is stored into the Raspberry Pi Zero Wireless SD-Card. The person attendance status is also updated upon completing the temperature measuring process.

Figure 9 shows the captured result from the Python shell in the Raspberry Pi Zero Wireless when the program starts to operate. After the system successfully acquires the preloaded image, the person's face detection and recognition are executed. During the execution, the person's name is validated and the proposed system continues to measure the facial temperature by using the AMG8833 sensor and stores the measured temperature value into the SD-card. Figure 9 shows the name and temperature of the person after scanning, using the Pi Camera and the AMG8833 thermal camera sensor.

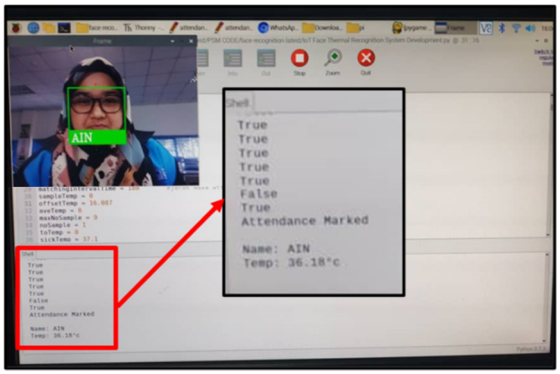

Fig. 9. Name and captured temperature– Phyton shell - Raspberry Pi Zero Wireless.

Fig. 10. Person's name and measured temperature are displayed at the integrated LCD screen.

The AMG8833 thermal camera sensor displays a real-time temperature value when a person's face approaches the Pi Camera. Hence, once the face is recognized, the AMG8833 thermal camera sensor is activated to measure the person's facial temperature and match the measured temperature with the person's name before storing the information into the SD-card and records the person's attendance. Figure 9 also shows the Phyton shell output which validates the information that has been stored into the SD-card. The output of the Phyton shell is also shown on the LCD as shown in Figure 10.

C. Conditions of the Face Thermal Recognition System

When the face detection and recognition are successfully validated, the program reads the temperature of the person. As mentioned above, fever is the most common symptom of COVID-19. This stage is important to validate the system's operation. If the system is unable to distinguish between a low-risk and a high-risk individual, this system failure will cause possible spread of the COVID-19 disease. According to the World Health Organization (WHO), normal human body temperature ranges from 35.0°C to 37.1°C as shown in Figure 4 and people with this range of facial or body temperature are considered healthy and fit to work. A person with a fever is defined as someone who has a body temperature greater than 37.1°C (Figure 5) [12-14]. So, the temperature scanned values are classified as Normal and High for the respective temperatures as shown in Table I.

TABLE I. CONDITIONS AND TEMPERATURES

Conditions	**Temperature (˚C)**
Normal	35.0 – 37.0
High	37.1 – 40.0

- Condition 1

If the measured temperature is between 35°C and 37°C (Normal), the temperature value will be displayed on the LCD when the person's name is matched (Figure 11). Once the person's name has been confirmed and the AMG8833 thermal camera sensor has successfully read the normal temperature of the user, the name and the temperature will be recorded into the attendance list accordingly. Similarly, the person's data are also recorded into the system's database to provide real-time health monitoring update of the person. This attendance record can also be sent to relevant authorities as shown in Figure 11.

- Condition 2

If the measured temperature is between 37^{o}C and 40^{o}C, then the person is not allowed to enter the premise or building. The person's information/data are sent through an email notification to the competent authorities. Also, during the temperature scanning, the status "Temperature High" is displayed on the LCD and at the Python shell as shown in Figure 13. Figure 14 shows an email notification containing information about the scanned person's temperature.

D. Summary

The presented results successfully validated the proposed real-time analytic face thermal recognition system integrated with email notification. The system did successfully perform the face detection and recognition tasks, measured the facial

temperature of the scanned person, and sent an email notification when required. Therefore, the proposed system's design and integration method can be implemented into premises or buildings to assist the early detection of any fever-related illness.

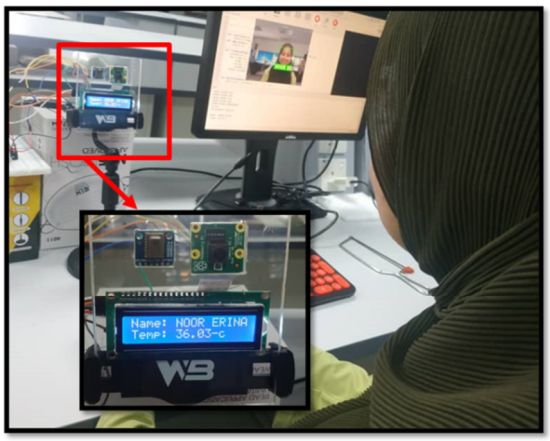

Fig. 11. Normal temperature condition.

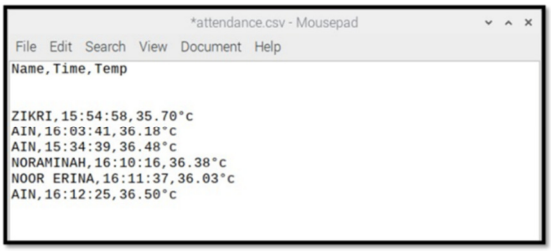

Fig. 12. File CSV- individual name and temperature - attendance list.

Fig. 13. High temperature condition.

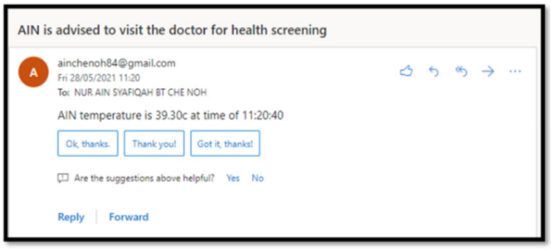

Fig. 14. Email notification.

IV. CONCLUSION

A real-time analytic face thermal recognition system integrated with email notification was developed and deployed in order to assist the early detection of any fever-related illness, especially COVID-19. Due to the severity of the COVID-19 disease, the proposed system has integrated some features that may assist the authorities and keep the premises or buildings safe. Also, the integrated hardware and software successfully validated the objectives of the real-time analytic face thermal recognition system integrated with email notification. In terms of system deployment, the system can be placed in any open space, where the respective person is needed to perform temperature scanning before entering a building or premise.

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