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Quarantine Order Violators System using Face Recognition (FACID)

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ABSTRACT

Face recognition technology is commonly utilized for user authentication and verification by analysing a digital image of a person's face and matching it against a database of faces for identification purposes. The COVID-19 pandemic has led to mandatory quarantines and the use of quarantine bracelets for some individuals, which can be time-consuming and require a lot of effort. Face recognition technology can help raise awareness about the current situation and alleviate some of the burden associated with quarantine measures. The aim of this research is to concentrate on the face recognition of individuals with a history of quarantine, as a measure to prevent the spread of COVID-19 in educational institutions like universities, colleges, and schools. This research study concentrates on individuals with a history of quarantine orders. The system will employ the Histograms of Oriented Gradients (HOG) algorithm for face detection. Additionally, the system will utilize the Face Landmark Algorithm to compare the 128-d vector with images stored locally. The system will make use of the Helen face collection dataset for its data requirements. The aim of this study is to explore and identify techniques for detecting individuals who violate quarantine measures and issuing notifications through the proposed system. By implementing this system, it could contribute to creating a more secure environment within the educational institution and potentially reduce the spread of the virus.

1. INTRODUCTION

Face recognition is a widely discussed topic in the field of computer vision (Qian & Wang, 2022; Schnell et al., 2023; Yu & Pei, 2021) and facial recognition (Sajjad et al., 2023; Zhang et al., 2023), as it is a biometric technology that aims to identify human faces in digital images. This technology utilizes biometrics to map facial features from a photograph or video. The primary goal of face recognition is to search for a series of data of the same face in a set of training images in a database, from the incoming image. In recent years, face recognition technology has become a popular topic of discussion due to its

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ability to accurately identify and verify individuals. Its applications are widespread, including security systems, social media platforms, and mobile devices. With the COVID-19 pandemic since 2019, the use of face recognition technology (Yang et al., 2020; Ramos, 2020; Mundial et al., 2020) has become even more significant as it can help prevent the spread of the disease. In educational institutions, face recognition technology can be an effective tool in identifying individuals who have previously undergone quarantine and to ensure that they follow quarantine protocols. This will ultimately promote a safer and healthier environment for everyone in the education system.

In most of the higher educational institutions such as universities and colleges, the quarantine bracelet has been used to track the community who have quarantine records and to monitor them from roaming outside or inside of the campus. Even with the modern security sensor, there must be somebody that is assigned to track people. When an alert happens, so there is going to be a very strict process which requires a lot of work, energy and time. The shift from face-to-face learning to online education has been a constantly changing situation and poses numerous challenges (Kong, 2020; Uhomoibhi et al., 2022). This transition has required individuals to adapt to new learning and teaching methods, leading to many challenges that can be overwhelming and stressful (Fernández Cruz et al., 2020). Despite wearing a quarantine wristband, individuals may still struggle to comply with quarantine orders with the unpredictable and challenging situation. Thus, facial technology can help them to bring awareness to consciousness about the current situation. In addition, primary and secondary schools are also permitted to resume operations with certain guidelines and limitations in place. The school administration has the authority to prevent a student or staff member from returning to school based on their quarantine status. However, errors can occur because not all guardians or parents are knowledgeable or fully informed about social media notifications. To address this issue, it would be prudent for schools to establish a dedicated system for verifying the quarantine status of students or staff entering the school premises. This would enhance safety measures and reduce the risk of non-compliance with quarantine regulations. Therefore, if a student who has been barred from returning to school enters the school premises, it could serve as a warning to the school community.

The aim of this research is to investigate and recognize methods for identifying quarantine violators and generating alerts via the proposed system. Following, design and develop the proposed system by establishing a database communication link between Raspberry Pi and the web application. Furthermore, the Histograms of Oriented Gradients (HOG) algorithm will be integrated into Dlib packages, which include machine learning algorithms to transform the image into grayscale and extract face features from image data. The research scope encompasses individuals who have been issued quarantine orders and educational institutions, such as universities, colleges, and schools. The proposed system is in real-time and will be installed at the entrance of educational institutions. The user will receive an alert through an audible warning buzzer that produces a beeping sound. The proposed system uses Raspberry Pi Camera module to detect the images, processes in Raspberry Pi, alert using buzzer warning notification and the tool used is OpenCV with Python.

2. RELATED WORKS

With the continuous demands for applications such as in information security, surveillance and smart cards, face recognition gained great popularity nowadays. It is also a relevant subject in pattern recognition (Kumar et al., 2006) and object retrieval (Passalis et al., 2007; Bakar et al., 2019). Basically, for any face recognition algorithm, there are two main phases which are the training phase and testing phase. During the training stage, facial features from all the faces in the gallery are identified and recorded within the database. The features could be either the Eigen features or the HOG features. HOG features are employed in this research for face recognition.

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2.1 Histogram of Oriented Gradient (HOG)

The Histogram of Oriented Gradients (HOG) is a feature-based descriptor mostly used in image processing to purposely detect the objects. Usually, in the HOG feature descriptor the input facial images are split into small grids known as cells, generally 8x8 pixels. In the OpenCV tutorial, the researcher (Mallick, 2023) guides the process and concept of RGB patches and gradients. An arrow is placed to visually the RGB patch and gradients as seen in the center of the Fig. 1. Moreover, on the right side of the figure, it also provides a numeric representation of the gradients within the same patch.

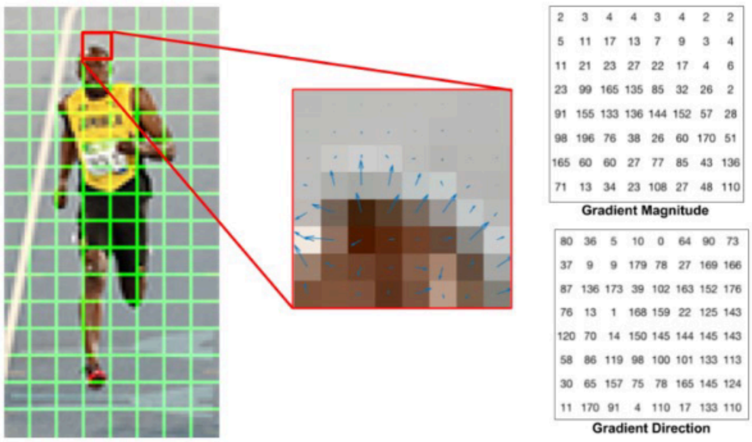

Fig. 1. The example of HOG using OpenCV

Source: Mallick (2023)

Normally, normalized HOG descriptors provide excellent performance to other existing features including SIFT descriptors and wavelets. Researchers (Lowe, 2004) introduce the SIFT descriptors approach which provides the underlying image patch descriptor for matching scale-invariant keypoints. SIFT descriptor has also been implemented in several studies including object recognition (Zhao & Ngo, 2013); (Azad et al., 2009) and detection of corners (Bakar et al., 2020). The experimental results conducted by Zhao & Ngo (2013) focusing on three applications; video copy detection, object recognition and image classification. The finding indicates that the computation of dominant curl and explicit flipping of local regions causes the extraction of F-SIFT to be slower compared to SIFT. The experiments (Azad et al., 2009) have proven that the scale-invariance is achieved efficiently and effectively, without the need for the time-consuming process of analyzing scale space by combining the Harris corner detector with the SIFT descriptor. The proposed method by Bakar et al. (2020) successfully finds a significant number of corner points, outperforming the original approach in terms of additional corner point detection. The performance of the proposed method was evaluated by comparing it with six established shape detectors and descriptors: Harris, SUSAN, Harris-Laplace, CSS, SIFT, and global and local curvature properties (GLCP).

2.2 Quarantine Order Violators

Ever since the outbreak of the COVID-19 pandemic, numerous techniques have been integrated into various systems and applications. Several systems have been implemented to detect quarantine order

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violators, including the Digital Quarantine System (Fan, 2021), IoT-based namely StayHomeSafe App (Tan et al., 2020), technologies that incorporate geofencing systems (Monir et al., 2021; Arif et al., 2020; Alqrnawi & Myderrizi, 2021) and Wi-Fi fingerprinting (Bahl & Padmanabhan, 2000; He & Chan, 2016). In Taiwan, the Digital Quarantine System is utilized by institutional communities (Fan, 2021). The system includes a mobile application and quarantine wristband that monitor quarantine patients using their mobile information and wristband without utilizing GPS tracking. The application interface is created using Android Studio, and its data is stored in a cloud-based database. It gathers information from telecommunications companies, existing government databases, and third-party applications. The app offers several advantages, such as its user-friendly interface that requires filling out an online health form only once. Another advantage is that the system utilizes real information from telecommunication companies, making it simpler to locate individuals compared to GPS tracking. Apart from that, there are certain drawbacks of the Digital Quarantine System. Firstly, the tracking of cellular location ceases once the 14-day quarantine period is over, however, it is uncertain whether it stops immediately or if there is a delay. Secondly, the app necessitates the constant use of Bluetooth which can lead to a rapid drain of the user's phone battery. The approach proposed by Tan et al. (2020) utilized an IoT-based geofencing algorithm, which was automated and designed to monitor the confines in a cost-effective manner. This StayHomeSafe App which is being used in Hong Kong, combines artificial intelligence technology with electronic wristbands to make sure that people who are quarantined stay in the right place throughout their quarantine period as shown in Fig. 2. This helps to ensure the safety of individuals and the wider community by preventing the spread of diseases. This application has two main advantages which it does not gather or share any personal data, nor does it track the user's location. Instead, it only logs close interactions with other individuals. Secondly, the application is secure and requires a unique PIN number to access where information and instructions can be accessed through a Quick Response (QR) code.

Fig. 2. An example of home quarantine monitoring system StayHomeSafe deployed in Hong Kong

Source: Tan et al. (2020)

The researchers (Monir et al., 2021; Arif et al., 2020; Alqrnawi & Myderrizi, 2021) proposed a system for home quarantine that involves the use of geofencing technology. A geofencing system for home quarantine was proposed by Monir et al. (2021), which utilizes a wristband to verify that the individual under home quarantine remains in proximity to their mobile phone. Another researcher (Arif et al., 2020)

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proposed a geofencing framework with the aim of monitoring the movements of individuals during lockdown periods, in accordance with the Movement Control Order. This work also included a density detection procedure that enables authorities to monitor gatherings in a specific area. The proposed system by Alqrnawi & Myderrizi (2021) is designed as a bracelet that can be worn by a quarantined individual, and consists of a microcontroller, GPS, and GSM module. The microcontroller is linked to a web server and a database whereas the individual's location is updated through GPS coordinates, besides the quarantine boundary is set by administrators using geofencing. One commonly used method involves utilizing Wi-Fi fingerprinting (Bahl & Padmanabhan, 2000; He & Chan, 2016) to approximate the location of a person under confinement, followed by verifying whether their position falls within the predefined restricted zone. Even though this method is accurate, it requires a significant amount of effort to calibrate signal patterns in advance, both inside and outside the quarantine zone. This can be quite costly and not practical for quarantine locations that are spread out over a large area. Thus, this paper identifies an appropriate method for detecting quarantine violators, and the proposed system is capable of issuing notifications to alert relevant parties.

3. PROPOSED SYSTEM

In this work, the proposed system for quarantine order violators by using face recognition is named as FACID. The FACID administrator has the ability to access the list of administrators and institutions, while the administrator can view the list of quarantine records.

3.1 System Architecture

Fig. 3 illustrates both the function and the architecture of the proposed system. To utilize the Raspberry Pi as a web server and enable the proposed system or FACID, it is essential to install a range of libraries such as MySQL, Apache, PHPmyadmin, cmake, opencv, dlib, and face_recognition earlier. Firstly, the Raspberry Pi must be powered on. Following, the administrator of the FACID application incorporates other administrators into the system who will then add community data of individuals who have a quarantine record. This information is stored in the database by the system. The FACID admin has the ability to access the list of administrators and institutions, while the administrator can view the list of quarantine records. After that, the system initiates the face recognition process by reading the image data. In order to do this, the system accesses MySQL to retrieve the relevant attributes such as the image and the name from a specific table.

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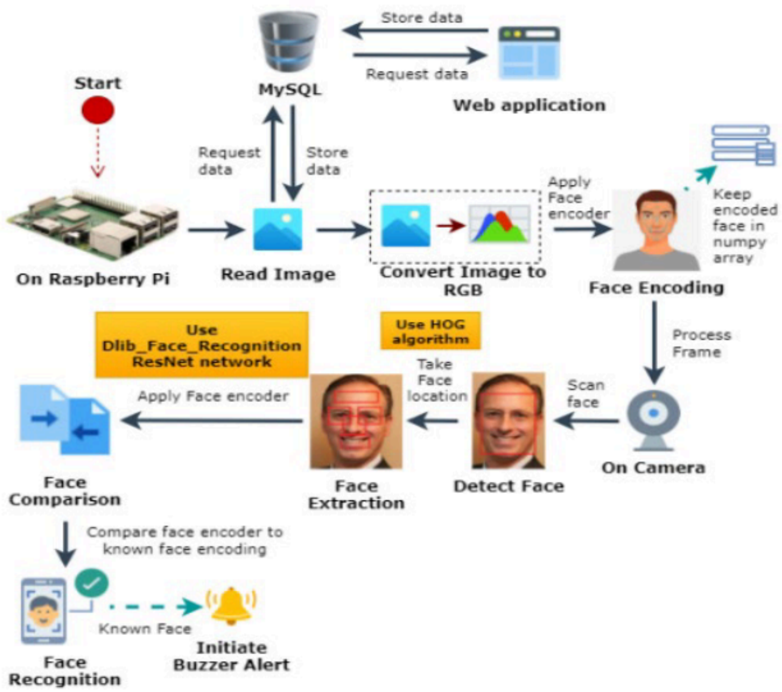

Fig. 3. The system architecture of the proposed system (FACID)

Following, the chosen images from the dataset is opened as a byte file using the PIL library and then converted into RGB format. The Helen Dataset utilizes this system to evaluate the accuracy of face recognition. The facial features of the image are encoded using a pretrained Res-Net neural network. The Res-Net network generates a 128-dimensional vector that encapsulates the essential facial characteristics of an image. After encoding the image with this vector, it is then stored in a NumPy array as shown on the right of Fig. 3 with highlighted in the green color. With the image data encoded, the system can now proceed to process the frame. The encoding process for the entire database only needs to be performed once, which helps to accelerate the scanning process. Afterwards, the system can activate the camera. Once the user scans their face using the camera, the system will detect their face and use the HOG algorithm to read its location within the scanned image. Prior to processing, the HOG algorithm will pre-process the image by resizing it. The system will convert the image back to RGB format and encode it by applying a 128-dimensional vector for feature extraction. It can now compare the face to known face encodings by comparing their respective 128-dimensional vectors. To generate the face embedding for the image, the system utilizes the same network as described above. It then compares this embedding with the existing embeddings within the system. If the generated embedding is similar or close to any of the other embeddings, which by default is set to a tolerance of 0.6, the system will recognize the face and send the data for face recognition. If the image is recognized as a known face, the system will activate an alarm alert.

3.2 Dataset

The Helen Dataset (Illinois.edu, 2023) consists of 2330 face images with dimensions of 400x400 pixels, which includes manually annotated contours for facial components such as eyes, eyebrows, nose, lips, and jawline. These images were sourced from Flickr and were selected based on queries that included

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the keyword "portrait" and other terms like "family", "outdoor", "studio", "boy", "wedding" and many more as illustrated in Fig. 4.

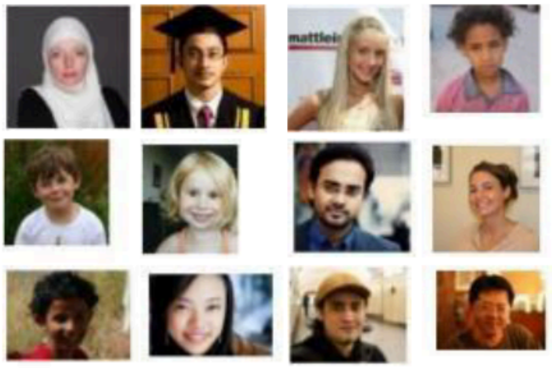

Fig. 4. Sample of Helen Dataset

Source: Illinois.edu (2023)

The FACID system employs the Helen dataset to analyze facial features within the image to utilize a pre-trained ResNet neural network for encoding. To perform face recognition, the system utilizes the Helen dataset, which includes 2000 training and 330 test images with accurate and consistent annotations of the primary facial components. A total of 20 community records added to the FACID web application under an educational institution was tested using this dataset and a part of it as shown Fig. 4. For testing purpose, 20 images consist of individuals from different races and genders in various age groups, including children (5 years to 12 years), teenagers (13 years to 19 years), and adults (20 years to around 65 years) were chosen. In addition, the system tested the efficiency of face recognition by including images of identical twins and images which were captured from different angles.

4. RESULTS AND DISCUCCION

The proposed FACID system has been successfully developed and validated. FACID has been developed in a web application using PHP Laravel Framework and MySQL for the database. The web application users are super admin who will manage the system's web application and institution administrator. Super admin is the only person who has access to add other administrators from other institutions and able to create, edit and delete.

4.1 Graphical User Interface (GUI)

The graphical user interface (GUI) of FACID is depicted in Fig. 5. Fig. 5(a) displays the FACID system homepage, while Fig. 5(b) represents the administrator login page. Fig. 5(c) provides a view of the administrator dashboard and Fig. 5(d) allows the super administrator to observe the list of institutions that have been added. The system begins with the super administrator, who adds the educational institution administrators into the system and the list of all added institutions as depicted in Fig. 5(d).

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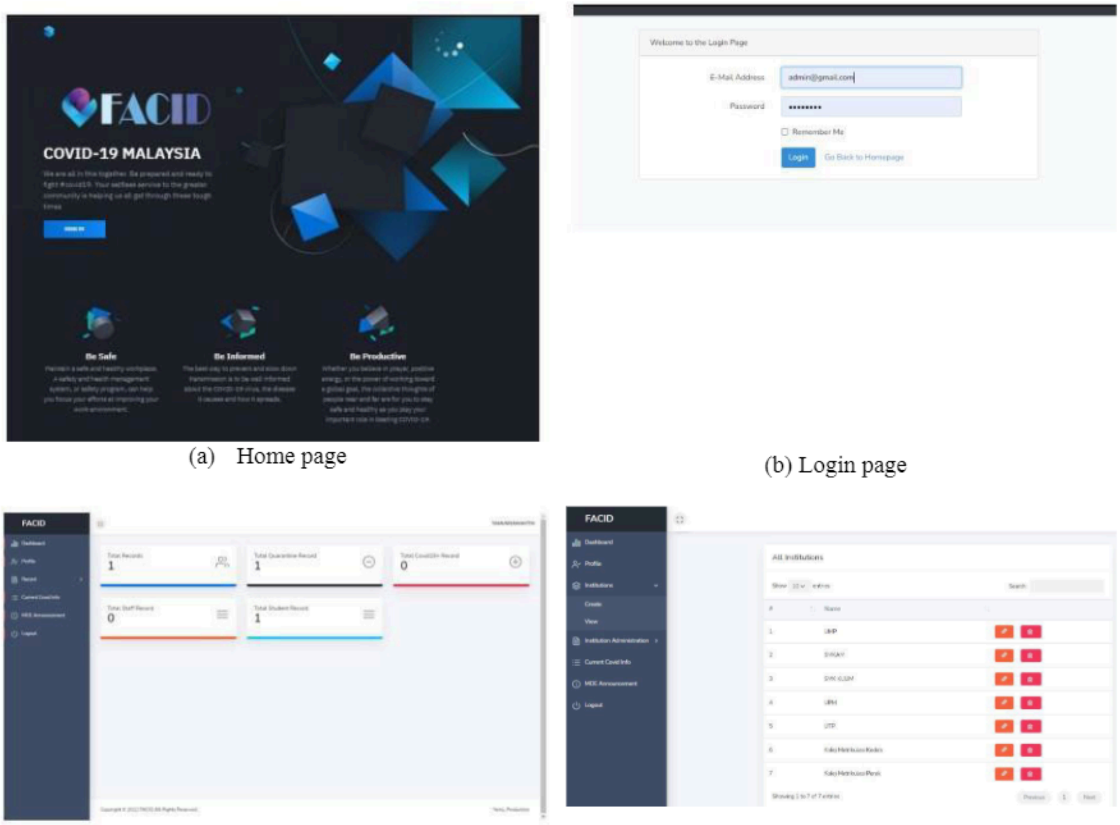

(a) Home page

(b) Login page

(c) Admin dashboard

(d) List of institutions

Fig. 5. GUI of the FACID system

To initiate the system, the administrator proceeds to log in using their login details and will use the login page to access the web application. After logging into the system, the administrator can view the dashboard and can begin adding community data for individuals with quarantine records. By clicking the "View Record" button in the sidebar, the administrator can view the added data and also have the ability to add, edit or delete records related to the community. Generally, in the dashboard, the administrator can view all the records available.

The administrator also possesses the capability to access user profiles, as demonstrated in Fig. 6. This allows the administrator to make necessary edits to profile information, update images, and access various other available features. Usually, users of the FACID system are the ones who initiate the creation of their own profiles.

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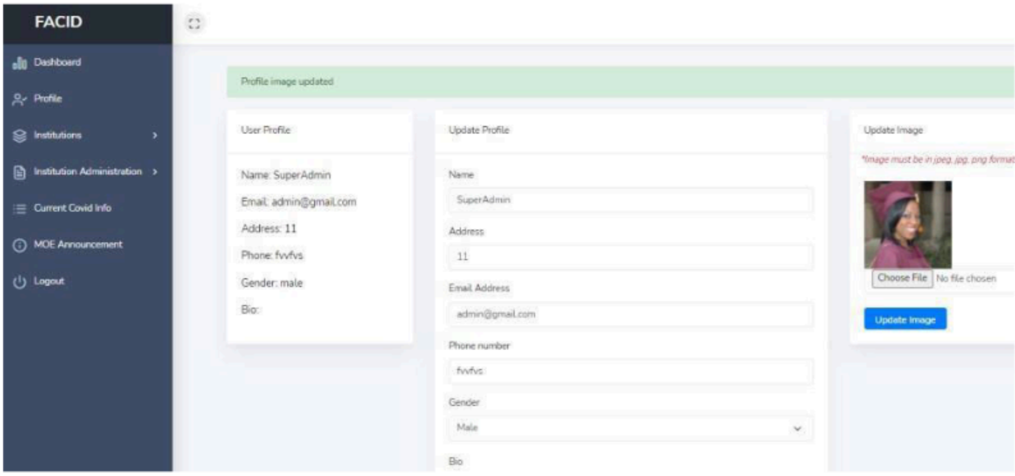
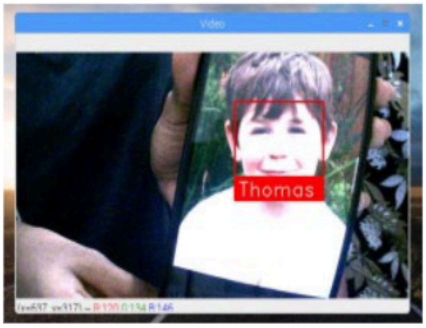


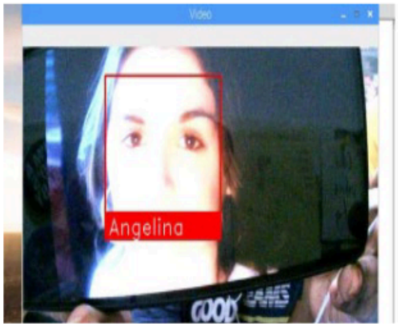
Fig. 6. An example of user profile administrator view

4.2 System Testing

The system testing has been carried out using the hardware configuration of a Raspberry Pi. It is important for the software and hardware components of the system to be correctly integrated, as any inconsistencies could lead to incorrect outputs from the Raspberry Pi hardware. According to the outcomes derived from the system, Fig. 7 demonstrates it has effectively identified the majority of images. As can be observed in Fig. 7(b) and (c), a record named Angelina's image was tested with different angles and it was successfully detected. The same outcome applies to Fig. 7(a) and (d), where the system has successfully detected images of Thomas and unknown face.



(a) Detecting the image of Thomas



(b) Detecting the image of Angelina

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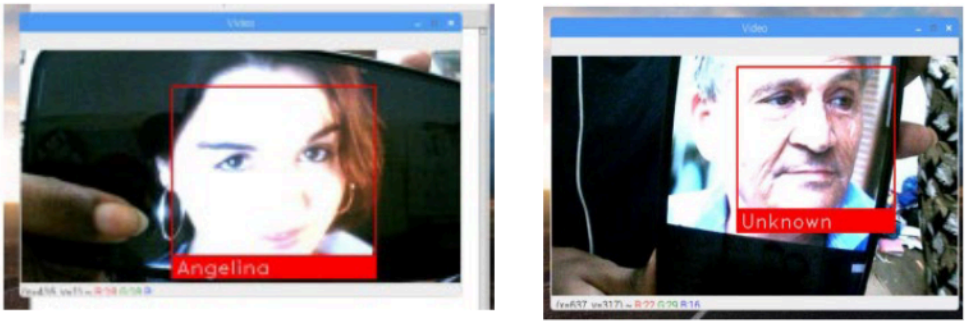

(c) Detecting the image of Angelina from different angles

(d) Detecting unknown image

Fig. 7. The results of detected images using the FACID system

A total of 30 images have been used for the testing phase to recognize both known and unknown faces. The functionality of the web application was verified through testing. The testing covered all the modules and functionalities, ensuring that all functions worked without errors or faults. Additionally, system testing was conducted to verify that the Raspberry Pi hardware configuration was connected and working seamlessly with the web application.

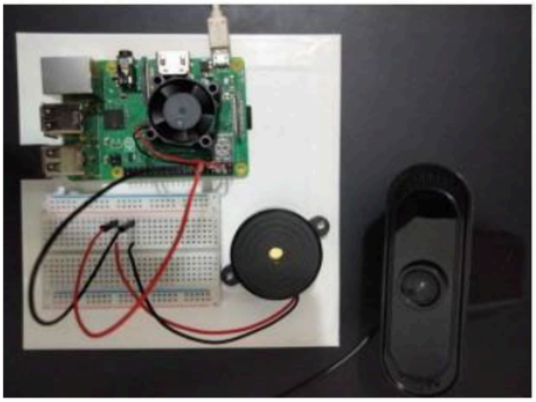

Fig. 8. The example of piezo buzzer set up for the FACID system

Once the image is detected, the piezo buzzer starts beeping to inform the system has detected any known faces. Fig. 8 provides an example of how the alert system is set up in this proposed system. To illustrate; when the system recognizes Thomas as in Fig. 7(a), it activates the piezo buzzer which results in a beeping sound.

5. CONCLUSION

In conclusion, although this system is unable to entirely prevent the transmission of Covid-19 in educational institutions, it can certainly help to establish a safer environment within the institution and potentially slow down the spread of the virus. Therefore, the utilization of this system can aid in the early detection of quarantine violators. The major impact of the proposed system is by employing contactless face recognition technology, it is possible to avoid workers like security guards and wardens from having to interact with

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people who are under quarantine order. The proposed future work is aimed to achieve other scope such as dataset which contains more images with different angles of images.

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7. CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted without any self-benefits, or commercial or financial conflicts and declare the absence of conflicting interests with the funders.

8. AUTHOR'S CONTRIBUTION

Yamunnawahthi a/p Somasundharam: Conceptualisation, methodology, system development and writing-original draft; **Suraya Abu Bakar**: methodology, supervision, system testing and editing; **Syifak Izhar Hisham**: Validation and editing.

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