DEVELOPMENT OF A FACE MASK DETECTION SYSTEM USING SINGLE SHORT ALGORITHM: A CASE STUDY OF ELIZADE UNIVERSITY

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ABSTRACT

This paper discusses the development of a Face Mask Detection System using a Single Short algorithm for the prevention of the spread of COVID-19 in public places. Several works have been done in the detection of face masks; however, there is a need to increase the detection speeds while maintaining their high accuracy for large datasets. The developed system consists of both software and hardware components. The model of the system was developed with a Single Short algorithm with a total of Nine Hundred and Two (902) datasets with the faces of people with and without face masks, which were collected from Elizade University, Ilara-Mokin, Ondo State of Nigeria. The Single Short Detection MobileNetv2 Algorithm was used to develop a predictive model and deployed on the Raspberry Pi 4 microcontroller. Percentage accuracy, F1 score, Recall, and Precision were the performance evaluation metrics used for the work. Also, a questionnaire was distributed to fifty (50) participants, mostly students and staff of Elizade University, Ilara-Mokin, who tested the system with and without wearing a face mask. The result of the system's performance evaluation indicates an accuracy of 99.86%, an F1 score of 100%, a recall of 100%, and a precision of 100%. The developed system can be miniaturised and reproduced to make the entire system smaller and more affordable. With the availability of the system's prototype, the development of the system for access control in public places such as stadiums, shopping malls, and schools is possible.

Keywords: COVID-19, Single Short Detection Algorithm, Face Mask, Raspberry pi 4.

1. INTRODUCTION

The outbreak of the COVID-19 pandemic has called for more health consciousness across the world, and one of the means of curbing the spread of this deadly disease is nose and mouth covering because of how contagious the disease can be. When an infected person sneezes or communicates with another person, the virus spreads through the air as water droplets from the nose or mouth disperse through the air and infect other people in the immediate vicinity [1]. Despite the importance of the face mask amidst this pandemic, the majority of the population does not put on the mask, even when there is a large gathering. Another case is the situation where some people do not know the proper way to wear a face mask. Wearing a mask during this pandemic is a crucial preventive measure, and it is particularly important in times when maintaining social distancing is difficult [2]. A mask is required for everyone who is at risk of severe illness from COVID-19 disease, particularly those who are at higher risk. COVID-19 is found to spread primarily among people who are near one another (nearly 6 feet), but it can also be spread by people who do not have symptoms and are unaware that they are infected [3]. As a result, the Centres for Disease Control and Prevention (CDC) advised all people aged two (2) and above, especially the elderly, to put on proper face masks in public places, especially when other social distancing measures are difficult to sustain [4].

This paper presents the development of a face-masked detection system for the prevention of the spread of COVID-19. The system consists of a model developed with the Single Short Detection (SSD) algorithm. SSD is a single-stage object detection method that discretizes the output space of bounding boxes into a set of default boxes over different aspect ratios and scales per feature map location. Multibox is used in a single shot to recognise many objects in an image. Real-time object detection is one of the features of SSD. By removing the need for the region proposal network, SSD increases detection speeds. SSD implements a few improvements, such as multi-scale features and default boxes, to make up for the loss in accuracy. These enhancements enable SSD to match the Faster R-CNN's accuracy while employing images of lower resolution, significantly increasing speed. The system can detect individuals with and without a face mask, thereby granting access to those who put on a face mask correctly. The development of the system would ease the determination of people who are in face mask compliance and prevent anyone who refuses to put on a face mask from accessing such places. Several works have been done in the detection of face masks; however, there is a need to increase the detection speeds while maintaining their high accuracy.

2. RELATED WORKS

One of the technologies that is now advancing the most rapidly is image processing. It is also a vital area of study for engineers and computer scientists. The three phases that constitute image processing are as follows:
Importing an image using image acquisition software; analysing and altering the image; and producing an output that could be an altered image or a ort based on image analysis.
Analogue and digital image processing are the two types of image processing methods employed. Analogue image processing can be applied to hard copies of images, such as prints and photographs. When employing these visual tools, image analysts employ a variety of interpretive fundamentals. Digital image processing techniques allow for computer-assisted alteration of digital images. Pre-processing, augmentation, and presentation, as well as information extraction, are the three general processes that all sorts of data must go through when using digital techniques [5].

[6] Modelled a face mask detection system using deep and convolutional learning algorithms. The scheme was designed in two stages. The first phase was using Resnet50 to extract features. In the second stage, typical machine-learning algorithms were applied to recognise face masks. Traditional machine learning algorithms for analysis include Support Vector Machines (SVM), Decision Trees, and Ensemble Algorithms. The proposed finding confirmed that the SVM classifier achieved the highest possible accuracy with the least amount of time required during training. [7] Proposed a deep learning technique as well as a quantization-based procedure for masked face recognition. The proposed approach could also be extended to better application areas, such as video surveillance and violent video retrieval. The initial job, according to the authors, was to remove the masked face region. Then use Pre-Trained Deep Convolutional Neural networks (CNNs) to extract the finest features from the chosen area (usually the eyes and forehead). Finally, the Bag-of-features technique was applied to the feature vectors of the last hidden layer to measure them and achieve a modest interpretation as compared to standard CNN's fully connected layer.

A system was developed to restrict COVID-19 growth by detecting people without facial masks in a smart city network. The system uses CCTV cameras to monitor public places and inform authorities of those without masks. A deep learning architecture is trained on a dataset of images, achieving 98.7% accuracy in distinguishing between mask-wearing and mask-less individuals. The study aims to reduce the spread of the communicable disease globally [8]. In the work of [9], an IoT-based hybrid deep learning approach was used to detect the use of a face mask by implementing a hybrid deep learning method. The model made enhancements in the detection and classification of faces. The model optimises the threshold parameters in the SSD, which makes it more effective when compared to the other existing approaches, but it is limited to IoT-based detection only. [10] also worked on a comparative analysis of different scenes for face mask detection based on YOLOv4. The work incorporates a number of tested deep learning improvements to reduce learning costs while maintaining accuracy. When the detection performance of the model was compared with scenes of different complexity, the detection accuracy decreased. Different approaches have been implemented to solve the issue of face mask detection. However, some of the major limitations of the existing approaches are the fact that the VGG16 method requires complex data training, using SVM to solve regression and classification problems is extremely challenging, and the computational resources for CNN are limited, which makes it difficult to use for large datasets. In order to overcome these challenges, a single short detection algorithm was employed in this research work, which provided great performance.

3. DESIGN AND IMPLEMENTATION

The development of the face mask detection system is in two stages. The first stage involves the development of the detection model, while the second stage involves the hardware design of the system.
Stage 1: Design of the detection model

The block diagram of the model is given in Figure 1. The model development is in two phases: training of the face Mask Detector and Application of the Face Mask Detector. In the first phase, a dataset containing nine hundred and two (902) faces of individuals collected with an HD camera was loaded and used in the training process. A total of four hundred and one (401) faces are without a face mask, while the remaining five hundred and one (501) faces are with a face mask. All the captured images are resized to 256 x 256 for uniformity. Training and testing datasets were generated randomly from the loaded dataset in a ratio of 3:1, respectively. Samples of the collected dataset are shown in Figure 2. The training was done with the Single Short (SSD) algorithm, which has the capability for real-time detection of an object, and the classifier was serialised onto a disc.

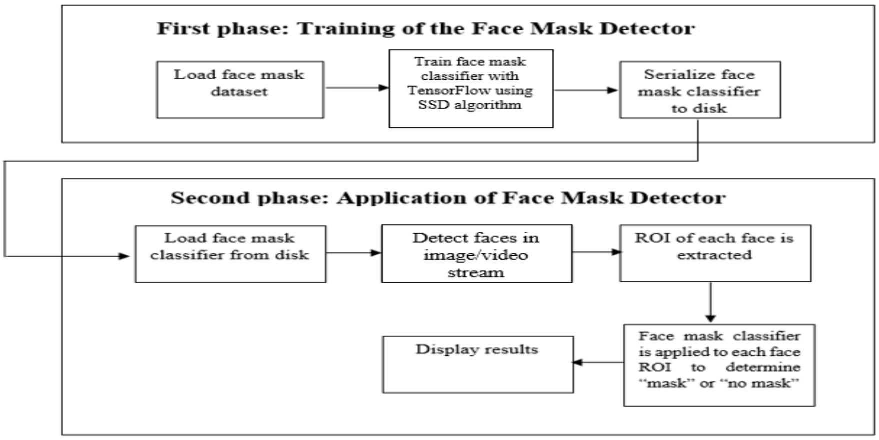

Figure 1: Block diagram of the predictive model of the system

The second phase is the application of the Face Mask detector. The application phase consists of different activities, from the loading of the face mask classifier from the disc to the display of the result. In the application phase, the classifier on the disc is first loaded from the disc when a human face is in front of the camera awaiting detection, and testing is done to determine whether faces are detected or not in the image or video stream. The next stage is the extraction of the region of interest (ROI). The regions of interest in this work are the eyes, nose, and mouse regions. The region extracted is then subjected to the predictive model to determine whether the image has a face mask or not. The last stage in the application phase is the display of the result.

Figure 1: Sample of the collected dataset

Classification of images using a Single short (SS) Algorithm

SSD Algorithm: A single-shot detection algorithm, particular to You Only Look Once (YOLO), was used in this work. YOLO is a multi-box, single-short detector that takes only one short to detect several objects present in an image. It has a much faster and more accurate object-detecting system. An SSD Algorithm is made up of two parts: a backbone model and an SSD head. As a feature extractor, the backbone model is commonly a pre-trained image classification network. The pre-trained image classification network used is MobileNetV2, a neural network-based classifier. Figure 3 shows the structure of a Single Short Detector.

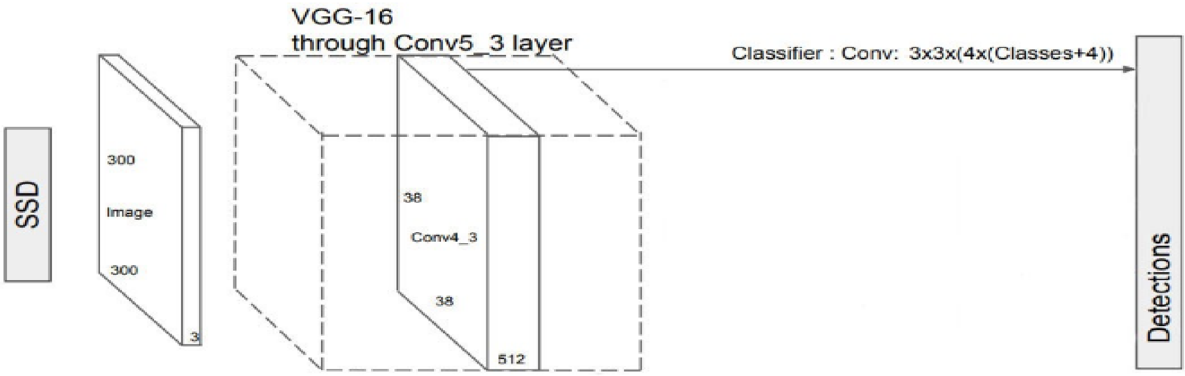

Figure 3: Showing Single Short Multibox Detector (Hui, 2018)

MobileNetV2: The Deep Neural Network MobileNetV2 was used to solve the categorization task. The Tensor Flow tool was used to load Image Net's pre-trained weights. To avoid the loss of previously learned characteristics, the base layers are frozen. Then new trainable layers were added, and these layers were trained on the acquired dataset to discover the features that could distinguish a mask-wearing face from a mask-free face. The model is then fine-tuned, and the weights are saved. A pre-trained model was customised by adopting it, adding more data, and retraining it. Figure 4 depicts the structure of MobileNetV2.

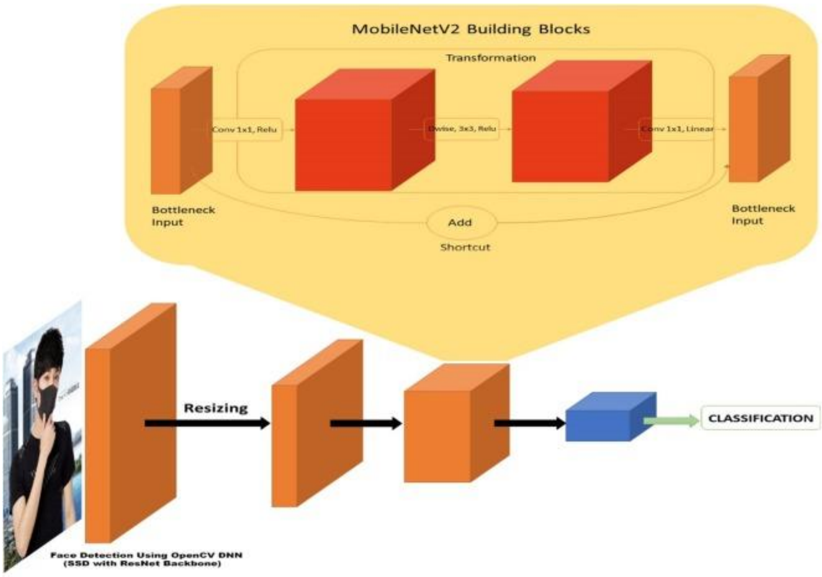

Figure 4: MobileNetV2 Building Block (Nagrath *et al*., 2021)

Stage 2: Hardware design

Figure 5 is the block diagram of the hardware design of the system. The block diagram contains the different hardware units of the system. It consists of a USB camera, power supply, Raspberry Pi 4, LEDs, and a buzzer. Each of the units is discussed as follows:

- **i. USB camera –** The input device for the system is a webcam. The webcam connected to the Raspberry Pi 4 via a USB port, captures the image of an individual standing in front of the camera and transmit it to the system for further processing. The Webcam used is Full HD with 1920 X 1080 pixels.
- **ii.** The Raspberry Pi 4 used has a clock speed of 700 MHz-1.5 GHz and a RAM size of 4 GB. In this work, we used six pins on the Raspberry Pi 4, which are GND and 5V pins for the display and GND, GPIO 14, GPIO 15, and GPIO 21 for the LEDs and buzzer.

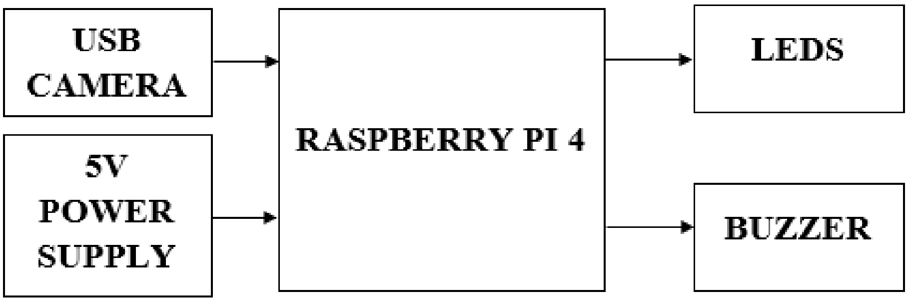

Figure 5: Architectural overview of the hardware design

1. **Power supply**: The power source for the Raspberry Pi 4 is a power supply with a 5V, 4A ON/OFF switch.
2. **LEDs and buzzers:** In the design of the system, LEDs are used to indicate whether the system detects a face mask or not. The green LED was used to indicate the detection of the face mask, while the red LED was used to indicate the non-detection of the face mask. For reliability, a buzzer was connected to the Raspberry Pi 4 via the GPIO 21 port. When a face mask is detected, the Buzzer sounds alarmed, but when a face mask is not detected, the buzzer is mute.
3. **Raspberry Pi display component:** To visualise the output of the system, a display unit was connected to the Raspberry Pi. The users can easily receive feedback from the system via the display unit.

The flowchart depicting the working operation of the system is in Figure 6. The flowchart begins with powering off the system, followed by camera focus. If the image is detected, the system proceeds to test if the region of interest is only covered with a nose mask. If the region of interest is not covered with a nose mask, then the system did not recognise it.

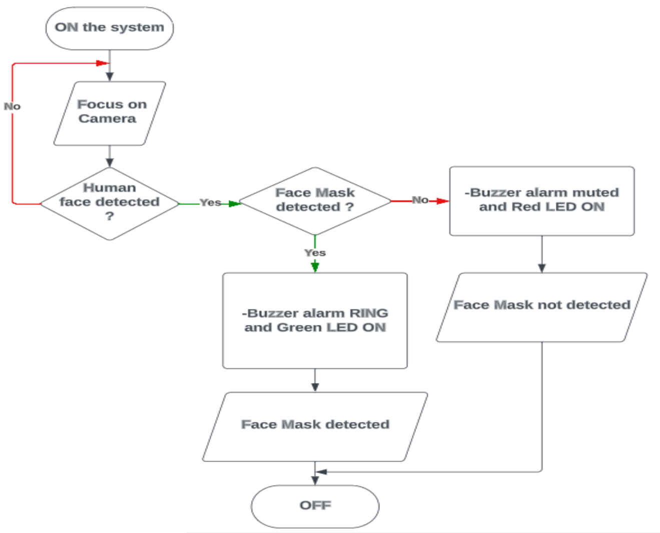

Figure 6: Flowchart for the operation of the face mask detection system

Implementation of the system

The coding of the model for the software part of this work was done using the Python programming language via the Tensor Flow framework. OpenCV was used to perform real-time face detection from a live stream, taking full advantage of our webcam connected to the Raspberry Pi 4. The running of the program calls functions FaceNet, a trained model to detect faces in an image, and MaskNet, a face mask classifier model. The components of the system were properly connected, as shown in Figure 7, and the system was tested to ascertain its functionality. The following metrics were used to evaluate the system: accuracy, precision, recall, and F1 scores with equations (1), (2), (3), and (4).

$$Accuracy = \frac{Tp + Tn}{(Tp + Fp + Fn + Tn)} \quad (1)$$

$$Precision = \frac{Tp}{(Tp + Fn)} \quad (2)$$

$$Recall = \frac{Tp}{(Tp + Fn)} \quad (3)$$

$$f1\ score = 2 \times \frac{Recall \ \times Precison}{(Recall + Precison)} \quad (4)$$

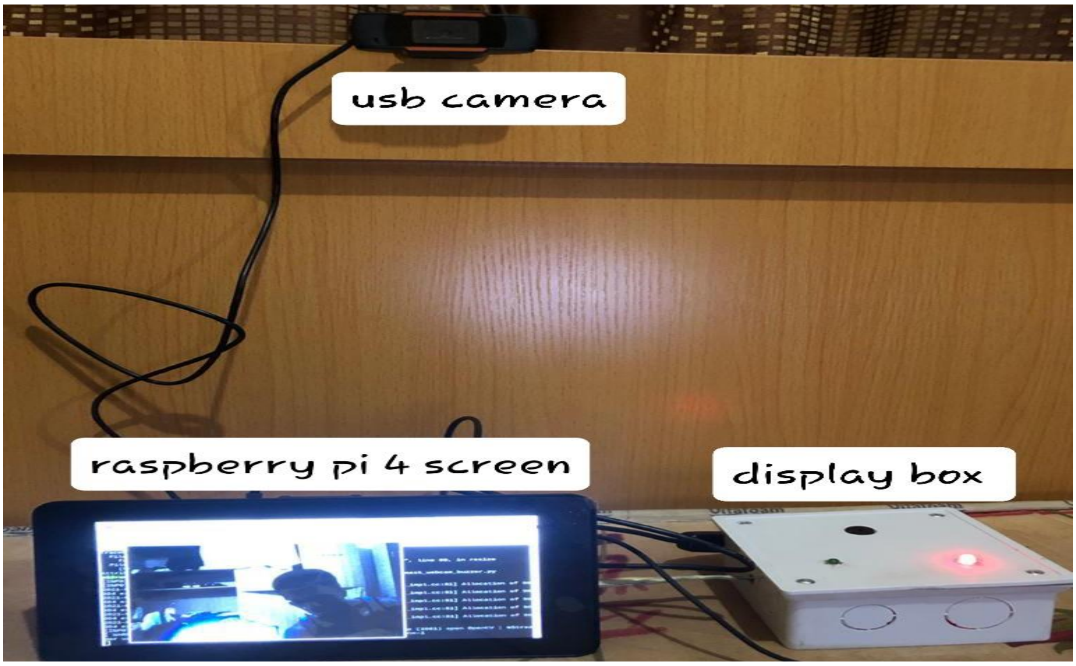

Figure 7: Complete System setup of the Face Mask Detection System

4. SYSTEM TESTING AND EVALUATION

(a) System testing

Alpha and beta testing were conducted on the system. The system was tested by the developers and also by fifty (50) users. Individuals with and without face masks stood in front of the camera, and the system was able to detect people with and without face masks. Once a face is detected on the ROI, a statement that reads "Thank you. Face Mask On" is displayed on the screen, and at the same time, a green LED comes on with an alarm from the buzzer, as shown in Figure 8a. When the face mask is not detected on the ROI, a message "No Face Mask Detected" is displayed on the screen, and at the same time, a red LED comes on with the Buzzer muted, as shown in Figure 8b. The wrong wearing of the Face Mask is seen as "No face Mask is detected" and the

Red LED is on as in Figure 8c.

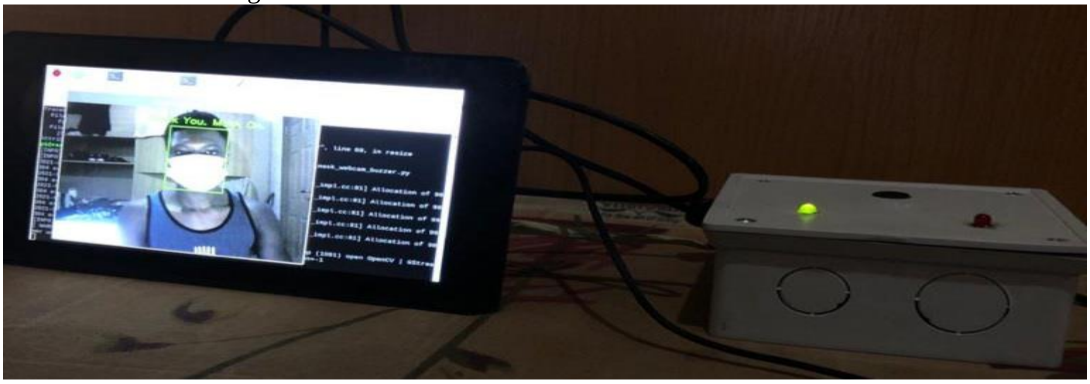

Figure 8a: The result of the human face and face mask detected.

Figure 8b: The result of a human face without a face mask.

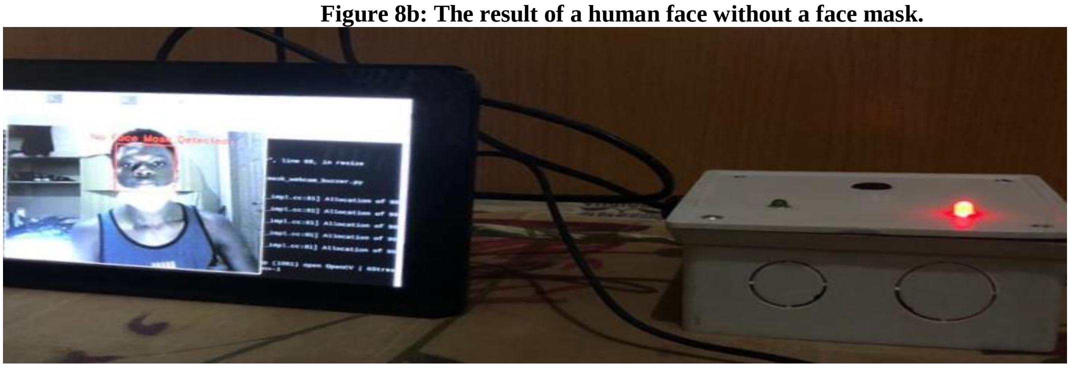

Figure 8c: The result of a human face wearing a face mask incorrectly.

(b) System evaluation

(c) Evaluation of the system's performance was done in two phases: alpha and beta. At the alpha stage, equations (1), (2), (3), and (4) were used. The results indicate a 99.86% percentage accuracy score, a 1.00 F1 score, 1.00 recalls, and 1.00 precision.

Analysis of questionnaire respondents

The second phase of the evaluation was done through a survey. Questionnaires were distributed to 50 respondents, mainly staff and students of Elizade University, Ilara-Mokin. Each of the respondents used the system and reported their observations of it. Table 1 shows the distribution of respondents by profession, 84% were students, 14% were teaching staff in the university (Lecturer), and 2% of non-teaching staff in the university.

Table 2 presents the distribution of respondents by knowledge of the face mask auto-detection system. 76% of the respondents were aware of the face mask auto-detection system, while 24% were not aware of such a system. Table 3 shows the Confusion Matrix of the System's users' Evaluation. The system was able to detect individuals who put on a face mask correctly and those who did not. It means the true positive is 50, the True negative is 50, the false positive is 0, and the false negative is 0. Using equations (1), (2), (3), and (4), the values of percentage accuracy, precision, recall, and F1 score are 100%, 1.0, 1.0, and 1.0, respectively.

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Table 1: Respondents by profession

Professions	Frequency	Percentage
Students	42	84.0
Lecturers	7	14.0
Non-Teaching	1	2.0
Total	**50**	**100.0**

Table 2: Respondents by knowledge of face mask auto-detection system

Awareness	Frequency	Percentage
Aware	38	76.0
Not aware	12	24.0
Total	**50**	**100.0**

Table 3: Confusion Matrix of the System's users Evaluation

Number of the Actual people	Number of people detected by the system with face mask	Number of people detected by the system without a face mask
With mask	50	0
Without mask	0	50

Respondents were also asked to assess the system and recommend it if they found it useful in their institutions. Out of the fifty (50) respondents, forty-nine (49) were affirmative, while only one (1) declined to recommend the system. The summary of the analysis of the responses is presented in Table 4.

Table 4: Distribution of respondents by recommendation of the system for their institution based on the usefulness of the system.

Attribute	Frequency	Percentage
Yes	49	98.0
No	1	2.0
Total	**50**	**100.0**

Table 5 is a summary of the respondents' perspectives on the system. The following attributes of the system were considered by each of the users: response time, preference of the system to the manual method of access control based on the face mask, non-partiality of the system, user interface friendliness, and ease of use. The maximum weight of the questionnaire scale is 5, and its average is 2.5. In statistics, any weighted mean score (WMS) greater than 2.5 is a favourable response, while any value less than 2.5 is an unfavourable response. From Table 5, all the items have a WMS greater than 2.5, which indicates that the respondents' perception of the developed system is favourable to all the items. The attributes of the preference of the system for the manual method of access control based on the face mask and the ease of use of the system were ranked first with a WMS of 4.38. The system response time was ranked 3rd with a WMS of 4.36. The user-friendliness of the interface of the system was ranked 4th with a WMS of 4.35, while the non-partiality of the system was ranked 5th with a WMS of 4.34.

Table 5: Distribution of respondents' perspectives of the system

Attribute	Weighted mean score	Rank
The system's response time is fast	4.36	3rd
The system performs as expected	4.38	1st
The system guaranteed non-partiality in access control	4.34	5th
The interface is user friendly	4.35	4th
The system is easy to use	4.38	1st

5. CONCLUSION

This paper has discussed the design of a face mask detection system using a single short detection algorithm and other hardware components, which include a Raspberry Pi, a video camera, buzzers, etc. The system consists of the predictive model and hardware devices integrated to form the designed system. The developed system can detect an individual who puts on a face mask, and it can also detect an individual without or with the inappropriate wearing of a face mask. The system simply reported that no face mask was detected if either the face mask did not cover the ROI or there was no face mask at all. The output of the system detection is via a display on the monitor, LEDs, and a buzzer.
The evaluation of the system, both from system performance and the user's evaluation of the system, revealed an effective and very accurate system with very high speed detection. The developed system can be deployed and used at the entrance of higher institutions, government offices, airports, train stations, etc. to automate human accessibility based on the wearing of a face mask as a COVID-19 protocol.

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