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Portable Smart Door base on Arduino and Artifical Neural Network for Temperature and Face Mask Detection

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ABSTRAK

Pemeriksaan suhu dan pemakaian masker merupakan salah satu upaya untuk mengurangi penularan Covid-19. Pemeriksaan manual tidak praktis dan menghabiskan waktu untuk memeriksa banyak orang di tempat umum. Penelitian ini merancang pintu pintar portabel yang secara bersamaan mendeteksi suhu tubuh dan masker. Pendeteksian suhu menggunakan sensor MLX90614 dan Arduino, sedangkan pendeteksian masker menggunakan kamera digital dengan jaringan syaraf tiruan (JST). Tes komponen dan tes penyelesaian dilakukan untuk menguji kinerja pintu pintar yang melibatkan 20 relawan. Pintu tersebut diujikan untuk mengukur suhu tubuh para relawan dengan dan tanpa masker dan hasilnya dibandingkan dengan pengukuran thermal gun. Pintu akan terbuka secara otomatis jika suhu di bawah 37,2°C dan memakai masker, sedangkan tetap tertutup jika di atas 37,2°C atau tidak memakai masker. Sensor bekerja dengan baik dengan deviasi kecil dan menghemat waktu pengukuran hingga hampir separuh waktu penukuran suhu menggunakan thermalgun. Akurasi pendeteksian masker oleh sistem JST juga beraa pada level kepercayaan tinggi. Hasil penelitian ini menunjukkan penerapan pintu pintar untuk mendeteksi suhu tubuh dan masker di area publik agar lebih cepat dan tepat.

ABSTRACT

Temperature checks and wearing masks are an effort to reduce the transmission of Covid-19. Manual checking is impractical and spent time screening many people in public areas. This work propose a portable smart door that simultaneously detects the body temperature and mask of the people. Temperature detection uses MLX90614 sensor and Arduino, while mask recognition uses digital camera with artificial neural network (ANN). Component test and completion test are conducted to examine the smart door performance involving 20 volunteers. The door was tested to measure the body temperature of the volunteers with and without a mask. The measured temperature was compared with measurements of a thermal gun. The door will open automatically if the temperature is below 37.2°C and wearing a mask, while remaining closed if above 37.2°C or not wearing a mask. The temperature sensor works properly with a small deviation and saving time almost half of thermalgun response time. The accuracy of mask detection by the ANN is also at a high level of confidence. These findings demonstrate the applicability of the smart door for screening body temperature and mask in public areas for faster and precise.

1. INTRODUCTION

In March 2020 the world health organization (WHO) declared that the new type of corona virus, SARS-CoV-2, as a pandemic. The virus spreads globally and causes a coronavirus disease 2019, so called as Covid-19 (Jun et al., 2021; Lwin et al., 2020; Qiu et al., 2020). The virus can cause mild, moderate or severe symptoms. The main clinical symptoms that appear are fever (body temperature more than 37.2 °C), cough and breathing difficulties. The spread of the Covid-19 virus is very fast and can transmit from one person to another in close proximity. SAR-CoV-2 can infect a person through the mucosal surfaces of the face (eyes, nose, mouth)(Parry, 2020; Yuliana, 2020). The transmission also occurs in most share-used, such as banknotes and doorknobs. The study revealed that the virus can survive for 2-8 hours on aluminum surface, including doorknobs, trellises, and train posts. The government is trying to contain the virus transmission by establishing several health protocols in accordance with the WHO guidelines (Kampf et al., 2020; Xiao & Torok, 2020). The health protocols recommended by the government include washing hands with soap, wearing masks, maintaining distance and checking body temperature.

Body temperature check is a simple and easy way to screening who is infected by the virus using

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contactless device such as a hand thermal gun. But, the device restrict one-by-one check and sometime can cause queues. Previous research on body temperature detectors and automatic doors has been carried out (Helmy Yudhistira Putra & Utomo Budiyanto, 2021; Nasution & Rasyid, 2021; Novianti, 2019). However, all these studies have not combined a body temperature and mask detection system with automatic door. Another work on health protocol screening device is also reported by previous study which is capable of detecting safe distancing, mask use, body temperature and hand-washing (Santoso et al., 2021). Other study also has been tested a prototype of authomatic door based on body temperature (Iskandar et al., 2021). The most current study has conducted research on door detecting body temperature and mask, but this door has not been designed to be portable (Teo et al., 2020; Varshini et al., 2021).

This work is proposed to design and test a prototype of portable smart door which combines temperature and mask screening for automatic system. The proposed door can be easily moved according to time and place, so that it can be efficiently implemented at crowded zone. The door will open if a person's body temperature is below 37.2 °C and using mask, so there is no need to hold the doorknob or the door contactly. If the measured body temperature exceeds the normal limit, an alarm from buzzer will issue and the door is remain close. This prototype was designed using low cost and open source components, such as MLX90614 infrared sensor, servo motor, LCD screen and door equipment. Masked face recognition uses the backpropagation artificial neural network (ANN) method for data training (Sudianto et al., 2020; Urbach & Wildian, 2019). This method has a good level of accuracy in recognizing facial input images. Hopefully, the smart door is expected to reduce physical contact and increase compliance with health protocols in public places so as to reduce the number of COVID-19 transmissions (Harizahayu, 2021; Marques & Pitarma, 2019).

2. METHOD

The stages of this research consist of system design (smart door design and circuit schematic), system development (hardware and software manufacturing), and testing phase.

Designing

This stage consists of the design of the system, and the schematic design of the system circuit. In general, smart door system is integration of temperature sensor and facial recognition using webcam as shown in Figure 1, and Figure 2. The schematic of the circuit is depicted in Figure 3. The block diagram in Figure 1 illustrates how the smart door system works. The object is detected by IR sensor module with a distance of ±5 cm, and the MLX 90614 sensor will active and detect human body temperature as an input. This input will be processed by the microcontroller to give commands the servo motor to open the door. The output will be displayed on the LCD screen in the form of the temperature and the buzzer as an indicator.

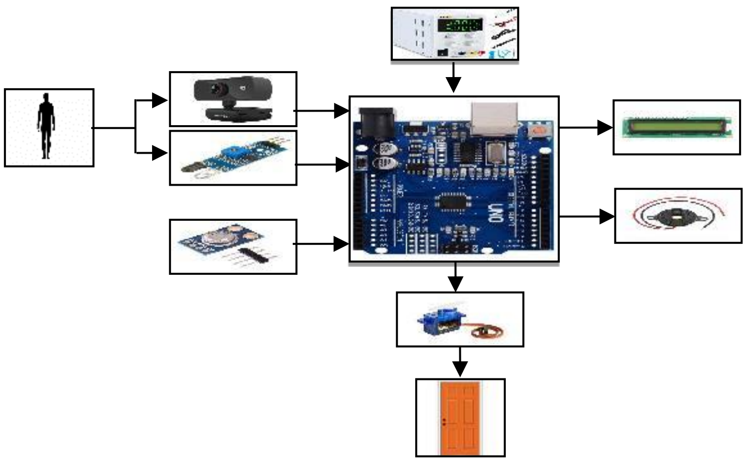

Figure 1. Block Diagram of the Smart Door System

Figure 1 shows an overview of the smart door. The door frame uses plywood with a size of 2m×0.8 m equipped with hinges. The door is equipped with hinges and treads that can be disassembled and installed. The components that have been tested are inserted into acrylic and the LCD is placed at the top of the door frame to make it easier to see the results of temperature measurements. Schematic design of the system circuit is show in Figure 3.

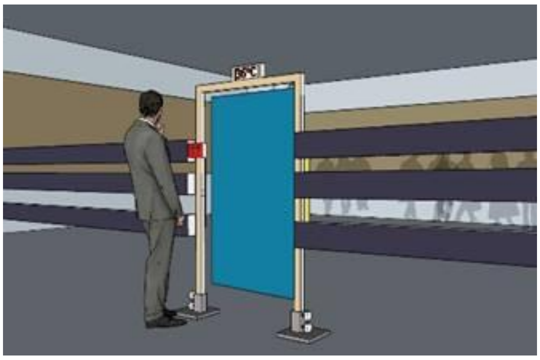

Figure 2. The Smart Door Overview

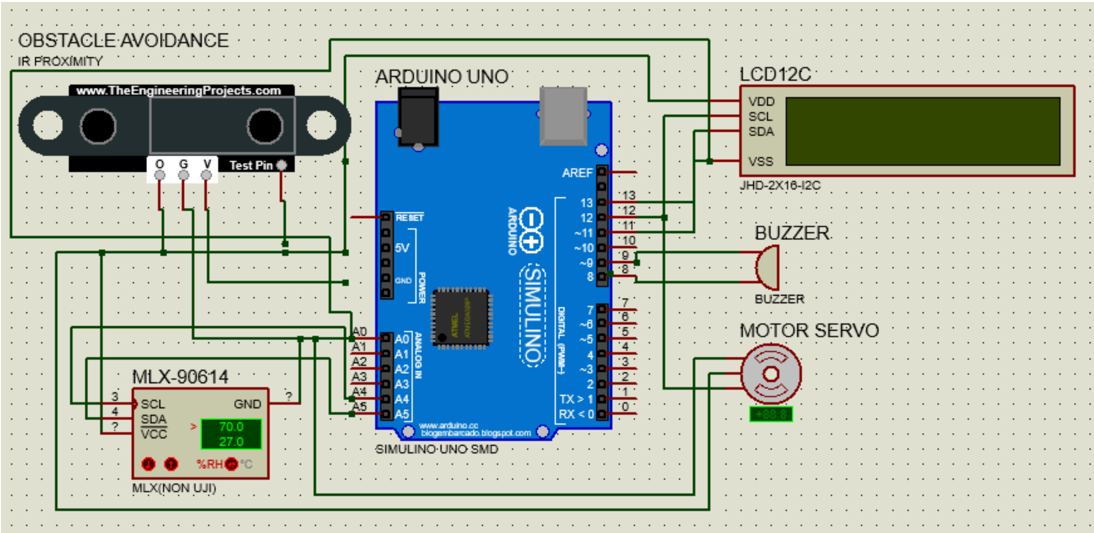

Figure 3. Schematic Circuit of the Smart Door

Figure 3 shows a schematic design of the system circuit using the help of Proteus® software, in order to obtain an image of the tool that will be assembled optimally.

Manufacturing the Smart Door

The smart door system consists of hardware assembly and software. Hardware manufacturing activities include the realization of a previously prepared design, which consists of installation of components circuit, building the door, and PCB mounting. Installation of components on the circuit board or PCB is according to the schematic circuit that has been made by Proteus®. The next stage is wiring installation according to the design. The program command is written in C language and compiled to the Arduino. The commands control MLX 90614 sensor, servo motor, LCD display, and buzzer.

Sampling of masked and unmasked faces was carried out using a Camera Webcam (Fantech Luminous C30) connected to a Graphical User Interface (GUI) system built using the MATLAB software version R2014a. The number of data samples obtained from the sampling process is 100 samples of facemask and 100 samples of faces without masks with a total data of 200 face samples. Processing of facial samples in the form of RGB images is converted into grayscale images as ANN input. The ANN architecture is built to recognize masked and unmasked face images. The ANN architecture in this study uses a multi-layer network model with 2 input variables, namely face images with masks and without masks, and 1 output variable, namely facial image identification.The ANN architecture in this study uses a multi-layer network model using one hidden layer, the ANN model made for masked and unmasked face image detection uses four variations in the number of neurons in the hidden layer to see the right number of neurons so that the model works well. The flowchart of this system software can be seen in Figure 4. The flowchart of face mask detection can be seen in Figure 5.

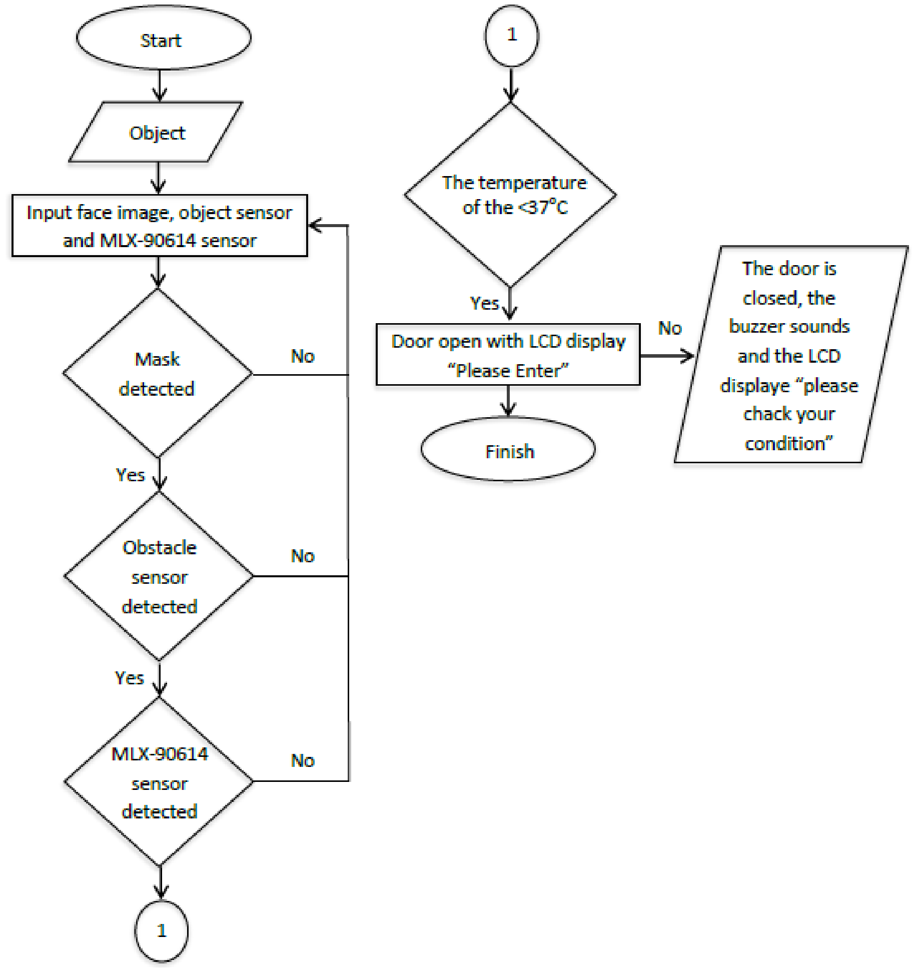

Figure 4. Workflow of Manufacturing and Installing the Smart Door

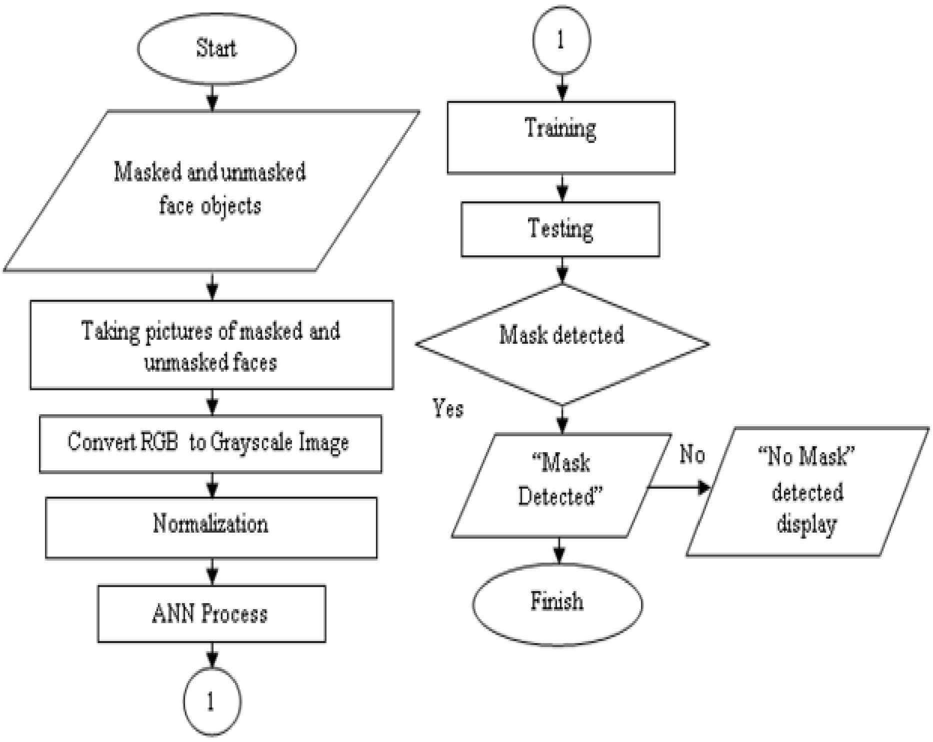

Figure 5. Workflow of Face Mask Detection

3. RESULT AND DISCUSSION

Result

Prototyping

The portable smart door can be seen in Figure 6. The position of the sensor is also adjusted according to field conditions,the box containing the sensor can be adjusted up and down according to the height of the object. This portable smart door is equipped with hinges and treads that can be disassembled and re-installed.

Figure 6. Overview of Portable Smart Door

Base on Figure 6, sensors and all hardware that supports the smart door system are housed in an acrylic case that is placed on the side of the door and an LCD on the top of the door. The series of system components can be seen in Figure 7.

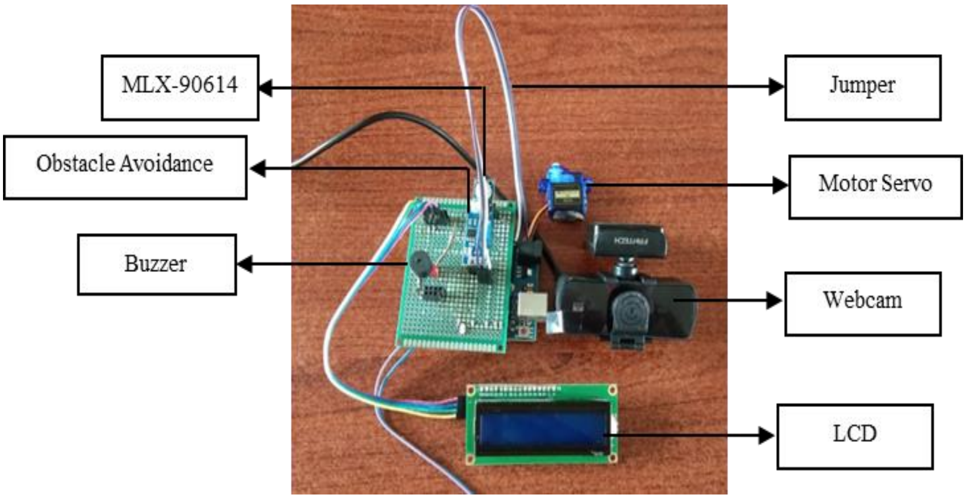

Figure 7. The Series of System Components

Figure 7, noted that the range of the sensor is limited to detect object bellow 5 cm by pairing with ultrasound sensor for avoiding fake obstacles. Theorically, the infrared sensor can range reach more than 30cm.

Characterization of MLX90614 Sensor

The characterization of the MLX90614 sensor with angle and distance variations is carried out to identify its limitation and the optimum position for measuring object temperature. The test is carried out for angle of 0-75° and distance of 1-5 cm. The results are compared to the thermal gun measurement as depicted in Table 1, and Table 2.

Table 1. Test Results of MLX90614 at a Distance of 1 to 5 cm

Distance (cm)	Repetition	thermal gun(℃)	MLX 90614(℃)	Error (%)
	1	36.0	35.8	0.56
1	2	36.0	35.7	0.83
	3	35.9	35.6	0.84
	1	36.0	35.2	2.22
2	2	36.3	35.7	1.65
	3	36.4	35.7	1.92
	1	35.5	33.4	5.92
3	2	35.5	33.4	5.92
	3	36.1	33.4	7.48
	1	36.4	32.3	11.2
4	2	36.0	32.3	10.2
	3	35.9	32.3	10.0
	1	36.0	31.4	12.9
5	2	36.0	31.4	12.9
	3	36.4	31.3	13.9

Table 2. Comparison of Body Temperature Measurement for MLX-90614

Distance (cm)	Angle (^{0})	Thermal gun	MLX-90614	LCD display
1	0	36.0	35.40	Temperature: 35.40 C Please Entry
1	15	36.0	33. 65	Temperature : 33.65 C Please Entry
1	30	36.0	0	Close Your Forhead Room Temperature 30 C
1	45	35.9	0	Close Your Forhead Room Temperature 30 C
1	60	36.5	0	Close Your Forhead Room Temperature 30 C
1	75	35.9	0	Close Your Forhead Room Temperature 30 C

Convert RGB Image to Grayscale

Converting an RGB image into a grayscale image is by finding the average value of the total RBG value. To convert an RGB image to a grayscale image in the Matlab using 'rgb2gray' command. The conversion results of 200 masked and unmasked face data will produce 200 grayscale data and 200 grayscale value data. Examples of grayscale results can be seen in Table 3.

Tabel 3. Data Table of Face Image Grayscale Value 10 Pixels

No.	Sample	Face Image Grayscale Value Data 10 Pixels									
1	Mask	95	31	73	135	157	156	117	45	52	133
2	No Mask	87	35	86	144	164	163	131	56	54	88

Backpropagation Architecture Training

The results of the training of masked and unmasked face image detection in ANN can be seen from the regression plot generated from the ANN running process. The regression plot shows the relationship between the output (identification of face image of ANN) and target (result of identification of face image of masked and unmasked) with the regression results can be seen that the trend of output and target. The results of the regression can be seen in Figure 8, and Figure 9.

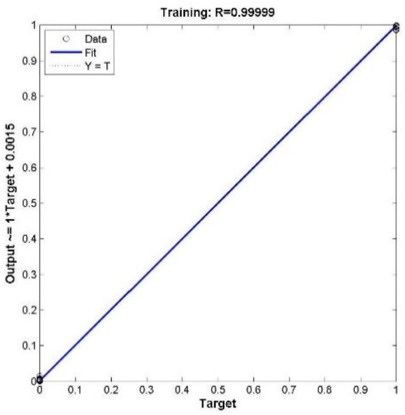

Figure 8. Regression Graph Layer 1 with 6 Neurons in the Training Method*dx*

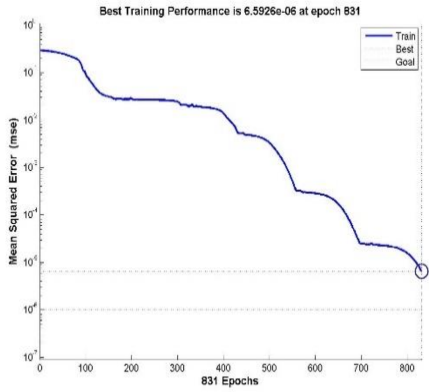

Figure 9. Performance Graph Layer 1 with 6 Neurons in the Training Method Trainingdx

Testing with Training Data

Training result on masked and unmasked facial images is show in Table 4.

Table 4. Training Results on Masked and Unmasked Facial Images

Variation	Number of Neurons (Layer 1)	Performance	Training Accuracy (%)	Total Correct of 160 Data
1	5	0.00001	100%	160
2	6	0.00000659	100%	160
3	10	0.00000994	100%	160
4	45	0.00000995	100%	160

Table 4 shows the level of performance that each variation gets, from 4 variations of neurons in 1 network layer, the best is 'traingdx' on Layer 2 variation with 6 neurons. This is because this variation has a much smaller MSE value than other neuron variations, so it has an output value that is much closer to the expected target. The closer to error (0.00001), the better the network in recognizing training data. Training results on masked and unmasked face images is show in Table 5.

Table 5. Training Results on Masked and Unmasked Face Images

Variation	Number of Neurons (Layer 1)	Performance	Training Accuracy (%)	Total True of 40 Data
1	5	0.00001	92.5%	37
2	6	0.00000659	95%	38
3	10	0.00000994	90%	36
4	45	0.00000995	90%	36

Completion Test

Completion testing of the whole system is carried out before the sensor and servo motor is installed to the door. The data taken is temperature data with a thermal gun and temperatur data with a sensor. The distance between the object and the sensor is 2-5 cm, according to the data obtained. The distance of 2 and 5 cm has a small error. The data obtained from the test results of measuring the body temperature of 10 volunteers can be seen in Table 6.

Tabel 6. Test Results of MLX90614 and Thermal *Gun*

Volunteers	Temperature		Error (%)
	MLX90614(°C)	Thermal Gun (°C)	
1	35.99	36.7	1.93
2	36.25	36.7	1.23
3	36.45	36.7	0.68

Volunteers	Temperature		Error (%)
	MLX90614(℃)	Thermal Gun (℃)	
4	35.51	36.4	2.45
5	35.13	36.2	2.96
6	35.13	36.2	2.96
7	32.30	32.4	0.31
8	32.31	32.4	0.28
9	32.49	32.4	0.28
10	35.71	36.8	2.96

Performance Test

Testing of the whole system is carried out on the condition that the system is attached to the door. The test results for the system installed on the door can be seen in Table 7 and Table 8.

Tabel 7. Test Results of System Installed on the Door

Volunteer	Temperature (℃)	Mask Detection	The Door	buzzer
1	37.50	Mask detected	Close	Sound
2	37.20	Mask detected	Close	Sound
3	37.50	Mask detected	Close	Sound
4	38.00	Mask detected	Close	Sound
5	38.20	Mask detected	Close	Sound
6	34.25	Mask not detected	Close	Sound
7	34.05	Mask not detected	Close	Sound
8	34.13	Mask not detected	Close	Sound
9	34.63	Mask not detected	Close	Sound
10	34.67	Mask not detected	Close	Sound
11	34.29	Mask detected	Open	No sound
12	34.45	Mask detected	Open	No sound
13	34.59	Mask detected	Open	No sound
14	34.67	Mask detected	Open	No sound
15	34.21	Mask detected	Open	No sound
16	34.01	Mask detected	Open	No sound
17	34.13	Mask detected	Open	No sound
18	34.25	Mask detected	Open	No sound
19	34.63	Mask detected	Open	No sound
20	34.93	Mask detected	Open	No sound

Tabel 8. Comparison of Responding Times of Thermal Gun and the Proposed Door

Volunteer	Responding time(s)	
	Thermal Gun	Proposed Door
1	7.3	4.02
2	8.0	2.18
3	8.1	4.50
4	8.5	3.00
5	7.3	4.00
6	8.3	4.50
7	7.3	5.80
8	8.3	4.50
9	7.4	5.55
10	7.6	6.03

Discussion

The results of the tests that have been carried out show that the system is made and work properly. The sensor used in this system is the MLX90614 infrared sensor equipped with a supporting sensor for ultrasonic sensors to detect movement and measure the distance between the forehead and the temperature sensor so that the measurement of body heat temperature works optimally. The MLX90614 sensor can work contactless to the object (J & SY, 2018; Marques & Pitarma, 2019; Sheikh & Unde, 2012). The characterization of the sensor was carried out to examine the sensor performance as shown in Table

1. The sensor is capable of detecting body temperature with a distance of 1 cm to 5 cm from the sensor. The smallest error value is obtained at a distance of 1 cm and the largest error is at a distance of 5 cm. This finding is in line with research conducted that shows the sensor becomes less sensitive the further it is placed from the object. In this works, the data collection is limited at distance of 4 cm (Urbach & Wildian, 2019). Other study reported that the optimum distance for MLX90614 sensor is 2-4 cm. At these ranges, the sensor measurement is similar to a commercial thermometer (Goh et al., 2021). Another work shown that the minimum error of MLX90614 sensor is achieved at distance of 2 – 2.5 cm (Jovanovic et al., 2017). But this range is too close, so others suggested that places the sensor and object at a distance of 4 cm is better and the error is still acceptable (Karsono et al., 2022).

The position of the sensor placement for optimum measurement results. The optimum position is at an angle of 0° and 15°. According to this research conducted to detect human body temperature, the infrared temperature is placed in front of the forehead for a few seconds to get the measurement value (Liu et al., 2017). This work is proposed to design and test a prototype of portable smart door which combines temperature and mask screening for automatic system. For the mask recognition, an artificial neural network is added (Kumar & Verma, 2010; Milla & Kish, 2006; Teo et al., 2020). Backpropagation architecture training, the results of the ANN model training that has been carried out on masked and unmasked face images obtained variations in the number of layers and neurons in training with the traingdx method resulting in the level of performance (target error) all reaching the target with all levels of accuracy of each variation reaching 100%. The performance obtained within a minute (60 s) on the masked and unmasked face image has the smallest error value than the other variations with a value of 0.00000659 (Liu et al., 2017; Song et al., 2013; Sudharshan Duth & Mary Deepa, 2018).

Testing with training data, the accuracy of all network variations reaches 100%, it can be seen that the performance in the second variation with the number of neurons 6 in 1 hidden layer has a much smaller MSE value than the other variations, so it has an output value that is much closer to the expected target with a total of 160 correct data. Testing with test data, the accuracy of all network variations is obtained with different variations, it can be seen that the performance in the second variation with the number of neurons 6 in 1 hidden layer has a much smaller MSE value than other variations and has a greater accuracy rate than the other variations, namely 95%, so that it has an output value that is much closer to the expected target with a total of 38 data from 40 data. The second variation of the running ANN results is implemented into the masked and unmasked face detection system because it has better performance than the other variations. As reported by other study the proper dan good model can be trained and optimized using *backpropagation* ANN (Amelia et al., 2019; Finaliamartha et al., 2009). Completion testing in Table 6 shows that the MLX90614 sensor can detect body temperature with a small error rate ranging from 0.28%-2.96%. The small error rate indicates the MLX90614 sensor is working properly (Hikmah et al., 2020; Iskandar et al., 2021). According to other study the MLX90614 sensor has high sensitivity and fast response time (Chen et al., 2017).

To fulfill the study propose, the completion test is conducted and the outcome of the test is shown in Table 7 dan 8. These results indicate that the smart door system can work propely. The smart door can detect the body temperature, mask detection and open the door automatically, so that reduce physical contact. The buzzer alarming if the body temperature is more than 37.5°C and/or the mask is not detected so the door remains close. As shown in Table 8, the time response of the sensor is greatly fast up to 44% than the thermal gun. The faster time check can avoid a queue which often happen in manual screening in public places. The door also can easily move or re-install in another place. Furthermore, the proposed door can be developed dan integrated with any kind of improvement, i.e. manufacturing metal lightweigth or glass-based structure for the door, enhancing the database for ANN training, or adding more precise sensors, so that more features can be achieved.

4. CONCLUSION

A portable smart door system for screening body temperature and mask-use has been successfully carried out. The smart door consists of two main components, i.e. temperature sensor of MLX90614 and the ANN-assisted webcam for mask recognition. High accuracy is achieved by both the temperature and mask recognition systems. The completion test confirms that the proposed door can reduce time response. The smart door can easily be assembled and moved to other places, such as a portable door. These findings demonstrate the applicability of the smart door for screening body temperature and mask in public areas for faster and precise.

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