The Application of Humanoid Robot as COVID-19 Symptoms Checker Using Computer Vision and Multiple Sensors

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***Abstract* – Novel Corona Virus (nCoV) infects human's respiratory system. It spreads easily when an infected person makes a close contact with another. To prevent the massive spread of it, we have to make sure that anyone comes into a certain place is not infected. This can be done by checking whether a person shows any symptom or not. There are at least two symptoms, one is the raising of body temperature to be above 37 °C. The other one is the decreasing of oxygen saturation level to be below 95%. This day, most places only check the human body temperature. In this way, the authors are interested to make an attempt to design a system that is able to measure both human body temperature and oxygen saturation level. In addition, this system will detect the coming of visitors by using face detection. The result shows that the system requires 7.35 seconds to detect the face of a visitor that is wearing a mask, and 1.38 second when the visitor wears no mask. The body temperature measurement is done using GY-906 temperature sensor with 0.48% error sensor read. For the oxygen saturation level measurement, MAX30100 pulse oximeter module is applied and shows 0.12% error measurement. Next, upper body humanoid robot is also used. In conclusion, the overall system has been tested and showed success rate up to 80%.**

Keywords: ESP32-CAM, Human Body Temperature, nCoV, Oxygen Saturation Level, Upper Body Humanoid Robot

I. Introduction

Novel Corona Virus (nCoV) is a type of virus that infects human's respiratory system. The number of patients that are currently being treated due to this virus is not small, because the spreading can happen easily when we are close to someone that has been infected [1]. To make sure the spreading of this virus is at its slowest rate, the government of Indonesia has taken several ways, and one of them is to announce the physical distancing [2]. Besides, another solution offered is to obligate everyone to obey the health protocols [3].

Another way to suppress the spreading is to check whether a person has been infected or not, especially before they get into a crowded place. To do this, there are one symptom that can be easily detected, which is the human body temperature. The normal value of it is ranging between 35 °C and 37 °C [4]. If a person has a higher temperature than this, then they have a possibility to be infected. As the implementation, many places checked the temperature of its visitor at the entrance gate, to make sure all people inside it are safe.

There are also several improvements made for this process. Several researches have been conducted to improve the tools or the system to check the human body temperature. For instance, author in [5] focuses on making a system where the result of the checking is sent automatically via Bluetooth connection to a PC or smartphone. However, this system is limited to the range of the Bluetooth connection. Author in [6] focuses on making a system that sends the data to a smartphone via Wi-Fi connection automatically. However, the implementation is not too efficient for mass usage, since the sensor is mounted to the smartphone. Author in [7] made a system that is able to send the result via MQTT protocol automatically. Author in [8] made a system that is able to send the data to Firebase. This way, the authorized people could access the data from anywhere as long as they have the access to the database.

However, that is not the only symptom that an infected person shows. Another characteristic shown is the lower value of oxygen saturation level [9]. Normally, the oxygen saturation level is in the range between 95% and 100% [10]. By having more parameters to be checked, we can be more accurate at detecting the infected person, thus providing a safer environment to the other healthy people.

Based on this condition, the authors decided to create a system that is able to check the temperature and also oxygen saturation level. Additionally, the system is fast enough to be implemented in the public places' entrance. This system is done automatically with a humanoid robot, so no officer is needed. This way, the officer's health can become safer since they will not need to have a close contact with all people. Table 1 shows the result comparison between the Authors' work and past researches work.

The rest of this paper is organized as follow. Chapter 2 focuses on discussion of the flowchart and wiring diagram that is used to finish this project. Next, chapter 3 focuses in the result presentation and discussion of it. Finally, chapter 4 concludes this work.

Table 1. Comparison with Past Researches

No	Authors	Function	Data Transfer
1	R. Wulandari [5]	Temperature Checking	Bluetooth
2	B. A. Setyawan et.al. [6]	Temperature Checking	Wi-Fi
3	D. I. Saputra et. al. [7]	Temperature Checking	Wi-Fi (MQTT)
4	I. Gunawan et. al. [8]	Temperature Checking	Wi-Fi (Firebase)
5	Authors	Temperature and Oxygen Saturation Level Checking	Wi-Fi

II. Methodology

In this section, the discussion starts with brief explanation on several key components for the system. It covers the Arduino UNO, ESP32-CAM, UART communication, GY-906 temperature sensor, MAX30100 pulse oximeter, as well as the upper-body humanoid robot. After that, the flowchart of the system is discussed, then followed by the wiring diagram. Finally, the upper-body humanoid robot's gestures are presented, especially the one resembling allowance and its opposite to the visitor.

A. *Arduino UNO*

Arduino UNO is a microcontroller utilizing the ATmega328P. Its board is equipped with 14 digital input-output pins where 6 of them could provide PWM outputs, 6 inputs for analogue signal, USB port for computer connection, power jack, ICSP header, reset button, and also a ceramic resonator with frequency of 16 MHz [11]. Figure 1 shows an Arduino UNO.

Figure 1 Arduino UNO Microcontroller [11]

B. *ESP32-CAM*

ESP32-CAM is module of ESP32-S chip empowered with a tiny camera. A normal ESP32 has several GPIO ports to establish connection with sensors or actuators, while this module has additional feature of microSD card slot to store images taken by its camera or files for further process. This module does not embed with a USB connector, thus FTDI programmer is required to upload the code through serial pins of U0R and U0T [12]. Figure 2 shows the ESP32-CAM module.

Figure 2. ESP32-CAM Module [12]

C. *UART Communication*

Universal Asynchronous Receiver / Transmitter ─which is also known as UART─ is a serial communication between two devices, and it is meant only for two devices communication scheme. Figure 3 shows the UART connection schematic in simple form. As we can see, the transmitter part of one device ─which is denoted as Tx─ is connected to the other device's receiver part ─which is denoted as Rx─, and vice versa.

In Arduino UNO, pin 1 and 0 in digital section are meant for the Tx and Rx this communication type respectively. In general, the data to be sent is divided into packets with start bit, data bits, parity bit, and the stop bits [13].

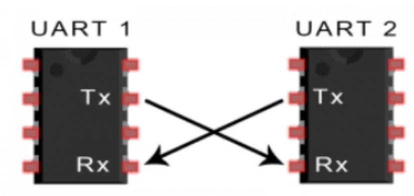

Figure 3. UART Communication Schematic [13]

D. *GY-906 Temperature Sensor*

906 is an infrared temperature sensor. This sensor is able to take measurement in the range between -70 °C and 383 °C, with the accuracy of 0.02 °C at field of view of 80°. Since it is a contactless sensor, it is advised to have a distance of 2 cm to 5 cm between the sensor and the object to have a good measurement. The basic working principle of it measures the infrared level radiated by the object according to Stefan-Boltzmann law [14]. Figure 4 shows the GY-906 temperature sensor.

Figure 4. GY-906 Temperature Sensor [14]

E. *MAX30100 Pulse Oximeter*

MAX30100 is a sensor to measure pulse oximetry and heart-rate which operates with a voltage ranging from 1.8 V to 5.5 V. The basic concept of its working principle is based on the fact that oxygenated blood is able to absorb more infrared light. This way, it is possible to measure the oxygen saturation level. Additionally, by measuring the delay between the increment and decrement of oxygenated blook due to blood pumping, this sensor is able to measure the pulse rate [15]. Figure 5 shows the MAX30100 pulse oximeter module.

Figure 5. MAX30100 Pulse Oximeter Module [15]

F. Upper-Body Humanoid Robot

The upper-body of humanoid robot resembles the whole body of human without legs. It comes with different sizes, starting from the small one, human-alike size, and even bigger, and it depends on the designated functionality. It is made of servos to make movement as detail as possible. For instance, the elbow can be represented by one servo, where it can move in one direction. To accommodate the other direction, another servo can be installed and programmed. This way, by installing some servos, it is able to make a movement resembling arms, body, and even legs. Those movements can be controlled by some ways, Bluetooth is one of them [16]. In addition, in this research the humanoid robot part that is used here is only the upper body. Figure 6 shows the upper-body humanoid robot used in this work.

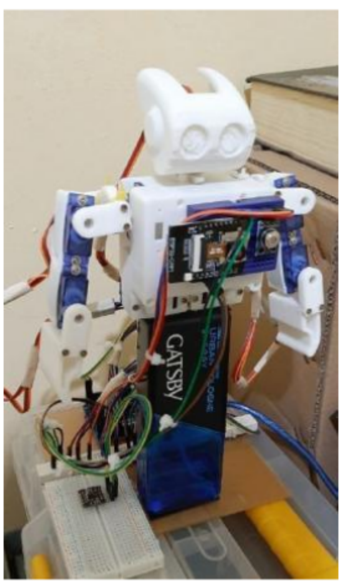

Figure 6. Upper-Body Humanoid Robot

G. Flowchart

The system will start by detecting the visitor's face using the camera of ESP32-CAM. After this attempt is successful, the GY-906 temperature sensor will measure visitor's body temperature, then followed by the MAX30100 sensor measuring visitor's oxygen saturation level. The visitor is only allowed to get in if the temperature is lower than 37.5 °C and the oxygen saturation level is 95% or higher. In this case, the upper body humanoid robot will make a gesture allowing the visitor to get in, otherwise, it will make a cross sign to indicate rejection. Next, the flowchart of this work is presented in Figure 7.

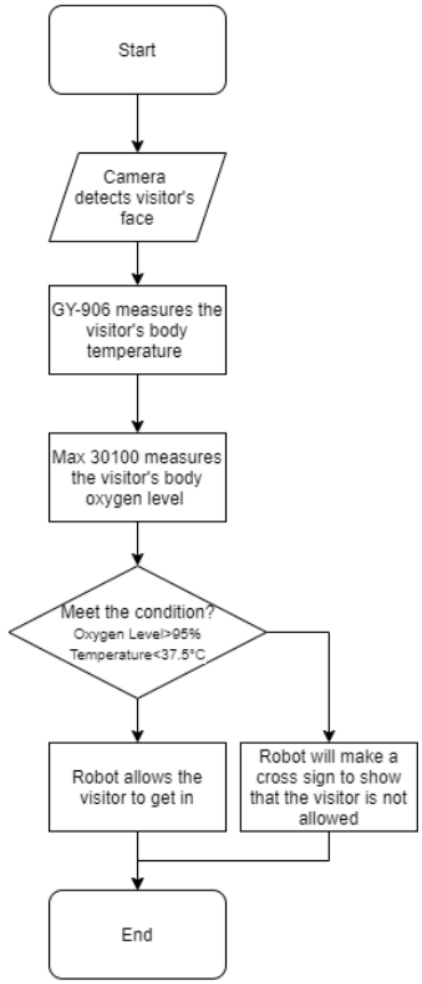

Figure 7. Flowchart to detect temperature, oxygen saturation level, and to allow or reject visitor

H. Block Diagram

All the sensors, MAX30100 and GY-906 are connected to ESP32-CAM Module. Where, the humanoid robot is actuated by using five servos and controlled by using Arduino UNO. In this research, ESP32-CAM will communicate with upper-body humanoid robot through UART communication. The detail block diagram is shown on the Figure 8.

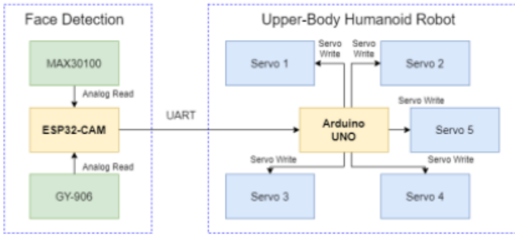

Figure 8. Block Diagram

I. Humanoid Robot Gestures

Finally, there are two gestures that can be made by the upper-body humanoid robot in this work. The first pose is shown in Figure 9, where the visitor is allowed to enter the place. Where, Figure 10 shows the gesture rejecting the visitor.

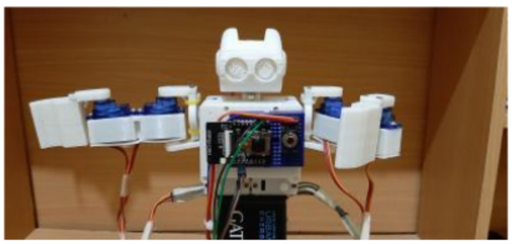

Figure 9. Upper-body humanoid robot's gesture allowing visitor to enter the area

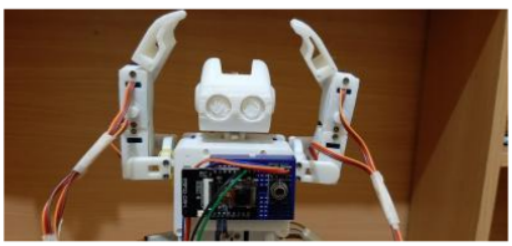

Figure 10. Upper-body humanoid robot's gesture rejecting visitor to enter the area

III. Results and Discussion

This chapter focuses in presenting and discussing the result achieved from the implementation of the flowchart and the block diagram elaborated in previous section.

In this work, the design has been successfully implemented into a real system. Next, the performance evaluation is going to be discussed in the following sequence. First is the face detection using ESP32-CAM. Then it is followed by the temperature sensor's performance, then the oxygen saturation level, and finally the success rate of the system considering the combination of all of the parameters.

The face detection process is done by using the camera in the ESP32-CAM. There are two cases in this section. The first one is when the visitor is not wearing a mask, while the second one is when the visitor is wearing a mask. Figure 11 and Figure 12 shows the condition when the visitor is not wearing a mask and wearing it respectively.

Figure 11. Face detection when visitor is not wearing a mask

Figure 12. Face detection when visitor is wearing a mask

In this evaluation, the system attempted to do ten detections for each condition. The time to detect visitor's face is then noted in Table 2. As we can see, the minimum time in detecting visitor's face with a mask is 4.00 second, while the maximum one is more than 10 seconds, which is denoted as not detected. As for the attempt of detecting visitor's face without a mask, the minimum and maximum time is 0.50 second and 2.55 second respectively. The average for the 10 attempts detecting visitor's face with a mask is 7.35 second, while the visitor without a mask takes 1.38 second on average. Additionally, there are two times when the face is not detected by the system in 10 attempts, which makes the face detection for visitor with mask to have a success rate of 80%.

Next, the temperature sensor is evaluated by comparing the result with commercial thermo gun. Table 3 shows the result of thermometer measurement using GY-906 temperature sensor and the thermo gun in nine attempts.

Table 2. Time to Detect Face of Visitor

No	With Mask (second)	Without Mask (second)
1	9.88	1.00
2	5.02	0.50
3	7.01	2.00
4	7.60	2.55
5	4.00	1.88
6	Not detected / more than 10 seconds	0.56
7	9.00	1.05
8	8.10	1.20
9	Not detected / more than 10 seconds	2.01
10	8.20	1.00

The table actually recorded ten attempts. However, since the sixth attempt encountered an error in the face detection, the sensors did not take any measurement. Thus, the table records nothing for GY-906 temperature sensor. This way, there are only nine records for the sensor's reading. The same thing goes for MAX30100 later.

The highest difference is shown in eight attempts at 1.11% at the measurement difference at 0.4 °C, while the lowest difference is shown at 0.00%, which means that there is no difference. On average, the difference between the two measurement devices is 0.48%.

As for the MAX30100 module, the highest difference is shown at 2.08% at the measurement difference at 2% of oxygen saturation level, while the lowest difference is shown at 0.00%, which means that there is no difference. On average, the difference between the two measurement devices is 0.12%.

Finally, the success rate of the system is to be analysed in this section. As mentioned in previous section, the upper-body humanoid robot will make a welcoming gesture and allow the visitor to come in only when the visitor's body temperature is lower than 37.5 ℃ and oxygen saturation level at least 95% at the same time. The "Real Result" in Table 3 is taken by considering the output from commercial thermo gun and pulse oximeter, and compare them with the threshold set in the beginning. The sensors readings are then evaluated and the upper-body humanoid robot is making a gesture based on it. These gestures are noted as the "Actual Result ".

There are two out of ten attempts where the system is not showing the same result as it should be. It is in the fifth and the sixth attempt.

In the fifth attempt, the system denied the access for the visitor due to low oxygen saturation level. It is only 94% where the minimum level should be 95%. However, the commercial pulse oximeter is showing the reading of 95%, which makes the visitor to be able to come in. Thus, the system makes wrong output due to the error from the pulse oximeter module, even though the temperature sensor is showing no problem

As for the sixth attempt, the system did not detect the visitor's face because it took too long to do it, at least longer than 10 seconds. Since the system did not detect any face, thus the sensors did not make any measurement. This way, no score is recorded in this attempt, and thus the system did not produce any response.

Overall, the system is able to produce success output in eight out of ten attempts, thus making the system to have success rate of 80%.

Table 3. Comparison between Expected and Actual Result

No	Time to Detect (second)	GY-906 (°C)	Commercial Thermo gun (°C)	MAX30100 (second)	Commercial Pulse Oximeter (%)	Expected Result	Actual Result
1	9.88	36.20	36.40	95	96	Open	Open
2	5.02	35.50	35.50	96	95	Open	Open
3	7.01	36.80	37.00	97	97	Open	Open
4	7.60	36.60	36.40	98	98	Open	Open
5	4.00	37.00	37.20	94	95	Open	Close
6	Not detected	-	35.80	-	97	Open	No Response
7	9.00	35.20	35.30	98	98	Open	Open
8	8.10	35.60	36.00	99	97	Open	Open
9	9.00	38.02	38.30	94	96	Close	Close
10	8.20	35.01	35.40	97	97	Open	Open

IV. CONCLUSION

To summarize, this work successfully designed a system to check visitor's body temperature and oxygen saturation level. It is also able to do face detection before conducting the measurement. The system takes 7.35 seconds to detect the face of a visitor that is wearing a mask, and 1.33 second when the visitor wears no mask. The body temperature measurement is done by implementing GY-906 temperature sensor, and it has error of 0.48%. As for the oxygen saturation level measurement, it is done by implementing the MAX30100 pulse oximeter module. It has error of 0.12%. The system also implements an upper body humanoid robot, and the overall system has a success rate up to 80%.

The computer vision of ESP32 Cam might still be limited. For instance, it took 7.35 seconds to detect face with mask. It is advised –for the future development– to apply Python to speed up the face detection process. In addition, it is possible to apply database and make a front-end to enable the data retrieving.

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