Prototype of Wearable Glasses for Body Temperature Monitoring for COVID-19 Mitigation

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Abstract. Fever is one of the initial presentations that a suspect of COVID-19 might have. Fever is indicated by body temperature higher than normal, which is more than 37.12°C. A thermometer gun is one device that is utilized to measure body temperature. But it requires a short line-of-sight distance between the device and the subjects (< 30 cm). In public facilities like shops, malls, schools, colleges, hospitals, and airports, the device’s use can initiate crowded or queue that higher the COVID-19 infection potential. In this research, wearable glasses is designed to replace such device. The prototype was built to display the thermal-map and body temperature of a single suspect. It can measure body temperature up to 2.5 meters. Based on the evaluation, the average error was about 0.57°C. Recalling that the used thermal array sensor’s inaccuracy is ±2.5°C, then the prototyping has a high potential for further use.

1. Introduction
At the end of the year 2019, the novel coronavirus, namely Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) or 2019-nCoV, has caused a disease named COVID-19. It was started in Hubei province of China with unknown origin spreaders. The disease has spread worldwide and caused mild symptoms to severe illness, even death to the human being. Until today, treatment to infected patients highly depends only on available antiviral drugs. Meanwhile, vaccine development to stop the spread is still in progress.

Up to October 2020, confirmed cases and death according to WHO reports are 36,002,827 and 1,049,810, respectively [1]. Meanwhile, 320,564 confirmed cases had been confirmed in Indonesia with 11,580 death cases, as reported in [2]. The presence of COVID-19 can be recognized from several symptoms like cough, fever, shortness of breath, weakness, malaise, respiratory distress, muscle pain, sore throat, loss of taste and/or smell [3][4]. Fever that can be inferred from body temperature is one of the commonly found aspects in COVID-19 patients (initial presentation or developed during the disease). According to [5], the overall mean of normal body temperature (BT) was 36.59°C regardless of ages and genders. Based on their research, normal BT could be categorized based on ages and gender. For younger adults, which is < 60 years old, the average BT was 36.35 – 37.03 °C, while older adults (≥ 60 years old) was 36.02 – 36.98 °C. Gender differences also contribute to normal BT categorization, of which the average normal BT for females was 36.19 – 37.11 °C and for males was 36.26 – 37.12 °C.
According to some research, the BT of COVID-19 patients was found higher than normal BT either at initial representation or developed during the course of the disease. The [6] observed that of 7614 patients, there were 50% had a BT > 37°C, and 21.5% of those had this in initial representation. It means that the other fifty percent exhibited lower BT but confirmed cases. Even though lower BT at initial presentation could be a marker of poor prognosis, but still higher BT gives a higher chance of someone being infected by the coronavirus. Another observation [7], which also included the relation between BT and confirmed cases, stated that all children under observation had BT ranging from 37.5 – 38.5 °C. The degree of BT, for some patients, reaches a higher degree than the average.

The tendency of confirmed cases in Indonesia is still going up even if the government had restricted society’s activities for three months after the first group cases. Even if there were several cusps on the curve, unfortunately, they were never the peaks. Despite that, some local governments of high confirmed cases districts have to loosen societies’ restrictions to feed their lives and avoid the potential of recession’s national economy. Along with that, a set of mandatory rules for the communities has been set up, such as wearing masks, washing hands, social distancing, body temperature measurement, etc. Any business center, shops, colleges, schools, and other public offices must provide all facilities like hand sanitizer, hand washing, mark sign for social distancing, and body temperature measurement device (most probably is thermometer gun). The use of a thermometer gun is quite enough to help BT detection. However, the measurement requires a short line-of-sight distance between an officer and the subject. In several cases, the checking causes queue that can be worst when the number of subjects is enormous such as in public service facilities. Furthermore, the device lacks routine calibration that makes it suffers from accuracy.

This research aims to provide a device that can overcome the shortcomings of the aforementioned device. This device is in wearable glasses form called SVisiGM, which is abbreviated from Sekolah Vokasi - Vision - Universitas Gadjah Mada. It can produce a thermal-map of a body as it’s equipped with 8 x 8 thermal array AMG8833 sensor. Further, the thermal-map can be used to calculate high temperature detected inside its view of angle with a far distance between an officer and the subjects. The device prototype is already equipped with a reliable microcontroller, TFT touch screen, SD Card, and one touchkey.

2. Research methods

2.1. Thermal array sensor
The thermal array sensor used in the proposed device is 8x8 AMG8833 from Panasonic. It can sense radiated infrared up to 7 meters long (32 feet). It measures temperature ranging from 0 – 80 °C with an accuracy of ± 2.5°C, which is proper for human’s BT. The benefit of using this sensor is its small size and effortless installation as it communicates via I2C bus. This sensor can be fired up with 3.3 or 5 dc voltage. With proper placement on PCB, one can get an appropriate view of the human thermal-map. Improper placement causes the wrong picture on the screen. In this research, the module sensor used is produced by Seeed corp. The module is equipped with four pins, e.g., SCL_Clock, SCL_Data, Vcc, and Ground.

2.2 Microcontroller ESP32
The microcontroller used to read sensor data and control the screen is ESP32. The benefit of this microcontroller is its small size. It makes compact packaging for wearable glasses feasible. Of 30 pins available in ESP32, solely 11 pins are used to make the device works. The ESP32 can work on 3.3 dc voltage that makes it easier to link all parts. The connection of all components to get all features it provides is shown in Fig. 1(a) and (b). Several digital controllers have been evaluated like ATMEGAx, ESP8266, Teensy, ESP32, and Raspberry. The selection is based on the features it provides, easiness of program management (e.g., match to provided library for all components), ability to provide fast calculation to the required interpolation, possibility to be deployed in a compact single board for the future final release, and fitness to the design wearable glasses of which has been planned. According to the evaluation, the final decision went to the ESP32.
2.3 Interpolation

The producer has provided some libraries needed by ESP32 to access AMG8833. Cubic interpolation is used to form smooth flow in-between measured temperatures, as is shown in (1). This interpolation is utilized to create bicubic interpolation (2D interpolation). We also found that changing values for \( \text{interpolated_cols} \) and \( \text{interpolated_rows} \) to 40 enhanced the smoothness of thermal-map. The variables \( p_0 \ldots p_3 \) are the thermal matrix values at indices -2, -1, 1, and 2.

\[
f(x) = \left( \frac{1}{3} x^3 + \frac{3}{2} x^2 + x + p_1 \right) + \left( \frac{1}{2} x^2 + \frac{1}{2} p_1 \right)x^2 + \frac{1}{2} p_2 x + p_3
\]

2.4 Normal BT threshold

If we take out the minimum and maximum value from the categorization [5] as overall safe consideration, we conclude that normal BT ranges from 36.19°C up to 37.12°C. It also holds the range that [6][7] yielded. According to the range, sensed BT higher than 37.12 is considered as a suspect. This device is set to get only 1 suspect at a time based on the average of sensed high temperatures.

2.5 Discrete touchkey

To provide convenience to the officer (the one who will wear the glasses), we put one touchkey to dim the display whenever needed. The touch key is a discrete key that produces value 0 (off) and 1 (on). Based on our experiment, it is more robust compared to the threshold-based touch key that ESP32 initially provides. This touch key can operate on 3.3 or 5 dc voltage of which can be found easily on ESP32 pin.
2.6 FeatherWing TFT
The screen used in this device is Adafruit TFT FeatherWing 2.4". This screen is intended for ESP microcontroller that the same company has produced. Hence, they can work as a plug-and-play device. In order to make the screen works with ordinary ESP32, the circuitry has been changed. The screen operates on 3.3 dc voltage from the microcontroller. There are seven pins connection between the screen and ESP32 to provide screen and SD Card communication. The communication interface to read/write data is using SPI communication.

3. Results and discussions
The dc voltage source is driven from a lithium battery. The physical form is shown in Fig. 2. The main box (red-colored rectangle) is a thermal-map built from the thermal array sensor. The screen can display the temperature changes as fast as expected. The float number appears at the right-top corner is the average of detected maximum temperature at a time, called the temperature indicator. A trivial solution to get more than one suspect at a time is to set the upper-temperature threshold for thermal-map higher (higher than maximum normal BT). But we prefer to provide a non-trivial workaround which is involving the image processing method. The problem is the ESP32 couldn’t handle steps that are already provided based on image processing and makes the frame per second decreased. Hence, the single suspect detection is provided momentarily.

The temperature indicator has five different colors to inform the thermal level. They are white, red, yellow, green, and blue. Their corresponding thresholds are

![Figure 2. The illustration of wearable glasses (a) user view (b) right side view (c) left side view.](image-url)

(a) main box  
(b) touchkey  
(c) left-eye visibility

Red
Temp $\geq$ 37.1
Yellow
Green
Temp $\geq$ 33.1
Blue

White
Temp $\geq$ 36.0
Red
Yellow
Green
In order to understand the meaning of thermal-map colors, a color-bar is also provided on the screen below the temperature indicator.

The calibration was conducted by comparing the BT measured with the thermometer gun. Slight adjustment as a result of the calibration was planted in this device. To test the device, subjects were standing in line-of-sight in front of the device with three different distances. They are 1 meter, 2 meters, and 3 meters. The illustrations are shown in Fig. 3. The BT of a subject was initially measured using a thermometer gun, and the result was 36.4°C. The subject was then measured while standing in front of the device distances from 0.5 meter up to 3 meters away using the proposed device. For instance, based on the test, when the subject stood at 1 meter from the device, the measured BT was 36.1°C. When the subject took steps to 2 meters, the device gave 35.5°C. The accuracy of measured BT gradually decreasing when the subject stepped away from the device. Hence, an experiment to find the maximum distance that still gave reasonable BT value was conducted at 3 meters away from the device. It showed around 0.2°C lower than later. To be noted that when the subject was measured with a thermometer gun, the distance was < 30 cm, and BT was 36.4°C.

In fact, the BT displayed on the screen was frequently fluctuating. To overcome this problem, the displaying of the measured BT was conducted every $t$ seconds. Hence, the measured BT will be the sample average of BT value from $0 – t$ seconds. The BT value can be affected by ambient temperature. Hence, prior to measuring subject’s BT, the room temperature was measured around 26°C. Nine samples of measurement test are shown in Table 1. The measurement confirmed that inaccuracy was caused by distances between device and subjects. When a subject was standing with longer distance against the sensor, the accuracy of measured temperature falls of pretty significant.
Table 1. The BT Measurement Result

| Subject Number | Measured (°C) at Different Distances (Device and Subjects) in meter(s) | Actual (°C) |
|----------------|---------------------------------------------------------------------|-------------|
|                | 0.5  | 1   | 1.5 | 2   | 2.5 | 3   |               |
| 1              | 36.5 | 36.2| 35.8| 35.5| 34.8| 34.2| 36.5          |
| 2              | 36.6 | 36.5| 36.0| 35.8| 35.1| 34.6| 36.2          |
| 3              | 36.8 | 36.3| 35.7| 35.5| 34.8| 34.5| 36.4          |
| 4              | 36.5 | 36.0| 35.8| 35.3| 34.8| 34.5| 36.0          |
| 5              | 36.7 | 36.5| 35.4| 35.1| 34.9| 34.6| 36.6          |
| 6              | 36.9 | 36.3| 35.8| 35.5| 34.8| 34.2| 36.4          |
| 7              | 36.0 | 35.8| 35.6| 35.5| 35.0| 34.8| 36.0          |
| 8              | 36.1 | 35.6| 35.4| 35.5| 35.1| 34.6| 35.9          |
| 9              | 36.5 | 36.3| 35.6| 35.3| 34.8| 34.6| 36.3          |

In the measurement test, the distance between the device and subjects ranging from 0.5 – 3 meters. The average absolute error between farthest distance compared to actual value is 1.74°C. This error is acceptable according to the tolerance of thermal array sensor ± 2.5°C. However, it indicates that a mathematical relationship between the device and subjects should be found to automatically refine the estimation of thermal value sensed by the sensor.

The distance between the screen and eyes has also been observed. The ideal distance for normal eyes that fit the wearable glasses is 10 cm that makes the glasses looks like a VR glasses. From the result, it can be concluded that this device can give pretty accurate BT if the subject stands up to 3 meters.

4. Conclusions

The array sensor thermal is a solution proposed for human detection based on body temperature in the form of thermal-map. In this research, this sensor was utilized to provide a device for BT measurement. Based on the result, it was shown that the thermal array sensor could be used for the aim, as mentioned earlier, as it can measure BT nearly accurate. At a distance of 1 meter, the BT measurement error is 0.15°C. The error that the device had was gradually increasing when the distance between the device and subject increased. Hence, the maximum distance that still gives reasonable BT is selected to be 3 meters with average error is around 1.74°C. This error is smaller than the sensor tolerance that is ± 2.5°C. The device will be re-designed to be a single compact board that can fit the wearable glasses in the future with additional features that involve the image processing methods to detect multiple suspects at a time.

5. References

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