Skin temperature monitoring with an instrument infrared sensors measuring based on direction and distance

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Abstract. Skin temperature represents human body temperature. Measurement of body temperature aims to detect body organs changes activity, including fighting bacteria or viruses in the human body. Measurement of non-contact/long-distance body temperature is an important requirement during the Covid-19 pandemic. Based on this background, the development of long body temperature remote based on an Infrared Array SensorGrid-EYE sensor was conducted through microcontroller control. Variable of experiments to measure body temperature were distances and the inclined angle of the skin surface. The method of designing skin temperature monitoring glasses begins with three main stages process. The first process of understanding and analyzing the characteristics of solar cells, the process of measuring the energy of these solar cells. The second process involves designing and manufacturing electronic systems. The third process is by conducting an experimental experiment on temperature detector glasses. The components of this temperature detector system generally consist of infrared-based temperature sensors, signal conditioning circuits, microcontrollers, and were equipped with software that makes easy controlling. The results of the experiment showed the accurate measurement with a maximum distance up to 4 meters could monitor the skin temperature of human body with percentage error 0.18%. More than distance 4 meters, the ability of sensors was not accurately to monitor skin temperature of human body.

1. Introduction

Body temperature describes a person's health status. Even a slight increase in body temperature can cause nerve function disorders and permanent protein damage. Core temperature in the body, including in the organs of the abdomen and thorax, central nervous system, and skeletal muscles is generally a relatively constant 37.8°C. This core temperature is considered as the body temperature and is subject to constant stability. In general, changes in human body temperature are characterized by symptoms of fever or chills before any further health effects [1]. Fever is a body temperature above normal (> 37.1°C), can be caused by abnormalities in the brain itself or by toxic substances that affect the body’s temperature regulation center. When the body temperature has reached 39°C the response experienced by the body is shivering [3].

The emergence of new diseases since early 2020 was caused by the coronavirus (Covid-19), a very deadly virus. One of the main symptoms of being infected with the coronavirus is the presence of a
This virus can be transmitted easily through interactions such as via airway droplets, such as coughing and sneezing, close personal contact [4], for example touching or shaking hands [2]. This is what causes everyone on the surface of the earth to always be alert and avoid transmission of the virus.

For that we need a body temperature detection system that is more accurate in the treatment action. Before determining treatment measures, the clinician usually measures the patient's temperature level using a thermometer (generally using a manual thermometer). Current technological developments encourage humans to use tools that can facilitate human work. One tool that follows current technological developments is the use of an infrared (infrared) thermometer to measure body temperature [5].

An infrared thermometer can detect temperature optically during the observed object, the infrared radiation energy is measured, and is presented as temperature [6, 9]. Infrared technology can perform a method of measuring temperature quickly and accurately with objects from a distance [7]. Measurement of body temperature is carried out in the part close to the internal organs of the body. Because it is closer to the core of the body, the more valid the temperature will be. So that temperature measurement with a thermometer through the oral or rectal cavity will be more precise than through the armpit. However, for the temperature sensor, body temperature measurements are still carried out in the armpit, which is considered to be the part closest to the core of the body. In homeostasis, humans maintain body temperature at optimal levels for the continuity of cellular metabolism. Even a slight increase in body temperature can cause nerve function disorders and permanent protein damage. The core temperature in the body, including in the organs of the abdomen and thorax, central nervous system, and skeletal muscles is generally a relatively constant 37.8°C. The body temperature is regulated to remain stable, balanced between the heat entering and the heat going out. Heat enters through the addition of heat from the external environment and internal heat production from metabolic activities [10, 11].

Changes in body temperature outside the normal range affect the hypothalamus set point as a body temperature regulating gland. These changes can be associated with excessive heat production, excessive heat dissipation, minimal heat production, minimal heat dissipation or any combination of these changes. The nature of these changes will affect the clinical problems experienced by the patient. Changes in body temperature can affect a person's heart rate. Normal human body temperature ranges from 36°C - 37.5°C. A person's normal body temperature actually varies depending on the time of measurement in the morning, afternoon, or night. Place of measurement in the oral cavity, in the armpit, or in the rectum. Factor age and metabolic rate before or after eating, before or after physical activity. The normal body temperature measured in the morning is ≤37.2°C and ≥37.7 °C.

Infrared light is one of the radiations from electromagnetic waves. Radiation is a phenomenon or event that spreads electromagnetic wave energy or subatomic particles through vacuum or matter. Infrared (infrared / IR) light is in the frequency range of 300 GHz to 400,000 GHz. Infrared rays are produced by processes inside molecules and hot objects. Hot objects due to atomic and molecular activity (vibrations) in them are thought to emit heat waves in the form of infrared rays. Infrared rays have a longer wavelength than visible light, but shorter than radio wave radiation.

The technology of using infrared rays is currently very fast. In the health sector, the use of infrared rays is an alternative tool [14-16]. Currently, the medical field uses infrared radiation a lot. Research conducted shows that infrared light becomes a method of measuring or determining a person's body temperature more easily. Erickson and Kirklin [13] represent measurements using pulmonary artery temperature to distinguish oral and axillary temperature. Hsuan-Yu Chen, et al [12] purposed investigation of the impact of infrared sensors on core body temperature. The results show that the temperature that is measured using the BRAUN Infrared is 36.9°C ± 0.286°C and 36.937°C ± 0.301°C.

Research explains that, because infrared has characteristics that cannot be seen by humans, it cannot penetrate invisibility material, so it can be caused by components that produce heat, the wavelengths in infrared have an opposite or inversely proportional relationship to temperature. When
the temperature increases, the wavelength decreases. Thus this principle can be used in detecting body temperature.

The infrared property which can detect body temperature as already described is utilized in the use of an infrared thermometer. An infrared thermometer can detect temperature optically as long as the object is observed, the infrared radiation energy is measured, and presented as temperature. The infrared thermometer uses a fast and accurate method of measuring temperature with objects from a distance.

Infrared thermometers measure temperature using black-box radiation (usually infrared) emitted by the object. It is sometimes called a laser thermometer if it uses a laser to help with measuring work, or a touchless thermometer to describe the device's ability to measure temperature remotely. By knowing the amount of infrared energy emitted by an object and its emissions, the temperature of the object can be distinguished. The main design consists of an infrared energy focusing lens on the detector, which converts the energy into an electrical signal which can be represented in temperature units once adjusted for variations in ambient temperature. This temperature measurement facility configuration works remotely without touching the object. Thus, an infrared thermometer is useful for measuring temperature in circumstances where a thermocouple or other type of sensor cannot be used or does not produce an accurate temperature for some purposes.

This research carried out the development of a digital thermometer using an infrared system but prioritizing the effectiveness of use that can be used anytime and anywhere using a temperature sensor embedded in the glasses, when interacting with other people, measurement indicators will appear based on normal human body temperature parameters and in sick condition. Research related to measuring human body temperature can be seen in Figure 1.

\[\text{Figure 1. The development of measuring the human body temperature}\]

Based on Figure 1, It can be explained that technological developments, especially in the health sector in measuring the human body, are very sophisticated, therefore researchers are trying to conduct research that applies these advanced technologies but with more practical and effective use.

2. Experimental

The design of making temperature detector glasses has characteristics that can measure human body temperature accurately and precisely supported by a system that will be built using a control system using a microcontroller so that the measurement process can work faster and more efficiently. The components of this temperature detector glass system generally consist of infrared-based temperature sensors, signal conditioning circuits, microcontrollers, and were equipped with software that makes easy controlling, the results of the electronic system design were embedded in a lens. The research stages can be seen in the research flow chart in Figure 2.
Research in the first stage, the determination of the types of components and tools that have sensor capabilities was carried out, the schematic design of the signal conditioning system circuit, the measurement system design, the use of these components so that the operational process of the system does not damage the equipment and can produce optimum output. After determining the design and modeling of the mechanism and system planning to be built, the next step is the process of making how to realize the design or design of the tool. This research carried out at the Physics Laboratory, Universitas Negeri Padang. In its implementation, the process of making these temperature detector glasses uses properly calibrated equipment, so that each stage of this circuit can function optimally. The process of designing temperature detector glasses begins with three main stages, the first process of understanding and analyzing the characteristics of solar cells, the process of measuring the energy of these solar cells. The second process involves designing and manufacturing electronic systems. The third process is by conducting an experimental experiment on temperature detector glasses, according to the following scheme:

3. Result and Discussion

3.1. Sensor Characterization
The initial step used to build the system is to characterize the sensor used and optimize the characteristics of the sensor. Optimization of sensor characteristics has been carried out with variations in the distance of 1 meter, 2 meters, 3 meters, 4 meters, 5 meters, and 6 meters to see the extent of the visibility of the sensor in reading or detecting the temperature of an object. The first test that is carried
out is testing the human body temperature at different distances. Data from sensor optimization can be seen in the following table:

**Table 1.** Data on objects at rest at a distance of 1 - 2 meter

| Time (s) | The distance of 1 meter | The distance of 2 meter |
|----------|-------------------------|-------------------------|
|          | Measured Temperature (°C) | Actual Temperature (°C) | Deviation | Percentage Error | Measured Temperature (°C) | Actual Temperature (°C) | Deviation | Percentage Error |
| 1        | 36.3                    | 36.4                    | 0         | 0%               | 36.4                  | 36.3                  | 0         | 0%               |
| 2        | 36.4                    | 36.4                    | 0         | 0%               | 36.4                  | 36.4                  | 0.1       | 0.3%             |
| 3        | 36.3                    | 36.4                    | 0.1       | 0.3%             | 36.5                  | 36.4                  | 0.1       | 0.3%             |
| 4        | 36.3                    | 36.4                    | 0.1       | 0.3%             | 36.4                  | 36.4                  | 0         | 0%               |
| 5        | 36.5                    | 36.4                    | 0.1       | 0.3%             | 36.3                  | 36.4                  | 0.1       | 0.3%             |
| 6        | 36.3                    | 36.4                    | 0.1       | 0.3%             | 36.4                  | 36.4                  | 0         | 0%               |
| 7        | 36.4                    | 36.4                    | 0.1       | 0.3%             | 36.5                  | 36.4                  | 0.1       | 0.3%             |
| 8        | 36.3                    | 36.4                    | 0.1       | 0.3%             | 36.4                  | 36.4                  | 0         | 0%               |
| 9        | 36.2                    | 36.4                    | 0.2       | 0.5%             | 36.4                  | 36.3                  | 0.1       | 0.3%             |
| 10       | 36.3                    | 36.4                    | 0.1       | 0.3%             | 36.3                  | 36.4                  | 0.1       | 0.3%             |
| 11       | 36.4                    | 36.4                    | 0         | 0%               | 36.3                  | 36.4                  | 0.1       | 0.3%             |
| 12       | 36.3                    | 36.4                    | 0.1       | 0.3%             | 36.4                  | 36.4                  | 0.1       | 0.3%             |
| 13       | 36.5                    | 36.4                    | 0.1       | 0.3%             | 36.3                  | 36.4                  | 0.1       | 0.3%             |
| 14       | 36.4                    | 36.4                    | 0         | 0%               | 36.3                  | 36.4                  | 0.1       | 0.3%             |
| 15       | 36.3                    | 36.4                    | 0.1       | 0.3%             | 36.3                  | 36.3                  | 0         | 0%               |
| 16       | 36.4                    | 36.4                    | 0         | 0%               | 36.3                  | 36.4                  | 0.1       | 0.3%             |
| 17       | 36.5                    | 36.4                    | 0.1       | 0.3%             | 36.3                  | 36.4                  | 0.1       | 0.3%             |
| 18       | 36.3                    | 36.4                    | 0         | 0%               | 36.2                  | 36.4                  | 0.2       | 0.5%             |
| 19       | 36.3                    | 36.4                    | 0.1       | 0.3%             | 36.3                  | 36.4                  | 0.1       | 0.3%             |
| 20       | 36.3                    | 36.4                    | 0.1       | 0.3%             | 36.3                  | 36.4                  | 0.1       | 0.3%             |
| Average  | 36.35                   | 36.39                   | 0.075     | 0.2%             | 36.35                  | 36.39                  | 0.085     | 0.25%            |

**Table 2.** Data on objects at rest at a distance of 3 - 4 meter

| Time (s) | The distance of 3 meter | The distance of 4 meter |
|----------|-------------------------|-------------------------|
|          | Measured Temperature (°C) | Actual Temperature (°C) | Deviation | Percentage Error | Measured Temperature (°C) | Actual Temperature (°C) | Deviation | Percentage Error |
| 1        | 36.6                    | 36.5                    | 0.1       | 0.3%             | 36.3                  | 36.4                  | 0         | 0%               |
| 2        | 36.4                    | 36.5                    | 0.1       | 0.3%             | 36.4                  | 36.4                  | 0         | 0%               |
| 3        | 36.3                    | 36.5                    | 0.2       | 0.5%             | 36.4                  | 36.4                  | 0         | 0%               |
| 4        | 36.4                    | 36.4                    | 0         | 0%               | 36.3                  | 36.4                  | 0.1       | 0.3%             |
| 5        | 36.3                    | 36.4                    | 0.1       | 0.3%             | 36.4                  | 36.4                  | 0         | 0%               |
| 6        | 36.4                    | 36.5                    | 0.1       | 0.3%             | 36.3                  | 36.4                  | 0.1       | 0.3%             |
| 7        | 36.4                    | 36.5                    | 0.1       | 0.3%             | 36.3                  | 36.4                  | 0.1       | 0.3%             |
| 8        | 36.4                    | 36.3                    | 0.3%      | 36.3              | 36.3                  | 0         | 0%               |
| 9        | 36.3                    | 36.3                    | 0         | 0%               | 36.3                  | 36.3                  | 0         | 0%               |
Table 1 and Table 2 are measurements of body temperature at a variation of the distance from 1 m to 4 m. In Table 1 for variations in the distance of 1 m - 2 m, the data obtained from the comparison between the actual temperature and the temperature on the tool within 20 seconds. The actual average temperature is around 36.35°C, while the average temperature read on the tool is 36.39°C. The percentage of test error at a distance of 1 meter is 0.2%. This value is quite small when compared to the percentage of test errors at a distance of 2 meters, which is 0.25%. However, this value does not show a significant difference. This means that at a distance of 1 meter to 2 meters the ability of the tool to detect the temperature of an object is still quite good.

Furthermore, testing was also carried out for distances of more than 2 meters, namely at a distance of 3 meters to 4 meters. Data from the measurement of objects at a distance of 3 meters to 4 meters can be seen in Table 2. The actual average temperature at a distance of 3 meters is 36.41°C while the temperature read on the object is 36.44°C. The percentage of testing error at a distance of 3 meters is 0.21%. Compared to measurements at a distance of 4 meters, the actual average temperature was 36.33°C while the temperature read on the object was 36.38°C. The percentage of test error at a distance of 4 meters is 0.18%. Compared to the four test data ranging from a distance of 1 meter to 4 meters, the smallest percentage of test error is obtained at a distance of 4 meters, where the percentage error is 0.18%. The results of this test show that the sensor on the device can measure body temperature without touching the maximum body part at a distance of 4 meters. However, on testing a distance of more than 4 meters, the temperature measurement is not accurate. The test data was also carried out at a distance of 5 m to 6 m as shown in Table 3 below.

**Table 3.** Data on objects at rest at a distance of 5 - 6 meter

| Time (s) | The distance of 5 meter | The distance of 6 meter |
|---------|-------------------------|-------------------------|
|         | Measured Temperature (°C) | Actual Temperature (°C) | Deviation | Percentage Error | Measured Temperature (°C) | Actual Temperature (°C) | Deviation | Percentage Error |
| 1       | 36.2                     | 36.4                     | 0.2       | 0.5%             | 36                      | 36.3                     | 0.3       | 0.8%             |
| 2       | 36.6                     | 36.4                     | 0.2       | 0.5%             | 36.4                    | 36.4                     | 0         | 0%               |
| 3       | 36.2                     | 36.4                     | 0.2       | 0.5%             | 36.6                    | 36.2                     | 0.4       | 1.1%             |
| 4       | 36.3                     | 36.4                     | 0.1       | 0.3%             | 36.3                    | 36.4                     | 0.1       | 0.3%             |
| 5       | 36.7                     | 36.3                     | 0.4       | 1.1%             | 35.5                    | 36.4                     | 0.1       | 0.3%             |
| 6       | 36.6                     | 36.4                     | 0.2       | 0.5%             | 36.3                    | 36.4                     | 0.1       | 0.3%             |
| 7       | 35.5                     | 36.5                     | 0         | 0%               | 36.8                    | 36.3                     | 0.5       | 1.4%             |
| 8       | 36.3                     | 36.4                     | 0.1       | 0.3%             | 36.2                    | 36.4                     | 0.2       | 0.5%             |
Table 3 is the measurement of body temperature at the variation of the distance from 5 m to 6 m. In table 3 data for variations in the distance of 5 m - 6 m, the data obtained from the comparison between the actual temperature and the temperature on the tool within 20 seconds. The actual average temperature is around 36.22°C, while the average temperature read on the tool is 36.40°C at a distance of 5 m. The percentage of testing error at a distance of 5 meters is 0.41%. Whereas at a distance of 6 m the actual average temperature was around 36.21°C while the temperature read on the tool was 36.38°C on average. The percentage of testing errors at a distance of 6 meters is quite large, namely 0.53% This value is quite large when compared to the percentage of test errors at a distance of 1 m to 4 meters, namely 0.18% minimum error value and 0.25% maximum error value. This means that at a distance of more than 4 meters, that is, a distance of 5 m - 6 m, the ability of the tool to detect the temperature of an object cannot read accurately and is not accurate.

Based on the data obtained through measurement of distance variations, it is found that the effective measurement of body temperature is at a maximum distance of 4 meters. The tool designed also shows a high accuracy value, where the percentage of errors obtained ranges from 0.18% - 0.25%.

3.2. Analysis of Sensor Characterization

Analysis of sensor characterization based on experimental data for rest object data of 1 meter to 4 meters can be explained through the following graph.
Figure 4. Graph of temperature against time distance of (a) 1 meter (b) 2 meters (c) 3 meters (d) 4 meters
Figure 4 is a diagram showing the relationship between changes in temperature and changes in time. As previously found, the designed tool can measure the optimum body temperature at a distance of 4 meters. This is further clarified through the graphs in Figures 4 (a), (b), (c), and (d) which are graphs of changes in actual temperature and temperature read on the tool at a variation of a distance of 1 m - 4 m. The orange graph is the actual temperature data, while the blue one is the temperature read on the instrument. At a distance of 1 meter to 3 meters in Figure 4 (a) (b) (c), the temperature read on the instrument fluctuates when compared to the actual temperature. However, this difference in value is still quite small and is still close to the actual temperature value. Whereas in Figure 4 (d) the temperature read on the tool tends to be more stable and overall is almost close to the actual temperature value. Thus it can be said that the optimum temperature for body temperature measurement is at a distance of 4 meters. It is different if the measurement distance is widened to 6 meters. The results can be seen in Figure 5 below.

Figure 5 is a graph of temperature against time distance of (a) 5 meters (b) 6 meters

Figure 5 is a graph of temperature measurement at a time change of up to 20 seconds with a variation of the test distance of 5 m - 6 m. Based on the experimental data, it can be explained as follows. The sensor's ability to measure the temperature of an object at rest at a distance of 1 meter to 4 meters tends to be more stable than at a distance of 5 meters and 6 meters. At a distance of 5 meters and 6 meters the temperature of the object detected by the sensor system tends to fluctuate and these changes tend to be bigger than the actual data. This can be seen if the time used is extended to 20
seconds, the changes tend to be more visible. This shows that at this distance it is difficult to obtain optimal conditions in detecting the temperature of an object. It is hoped that in the future the range of distances that can be detected by the system is wider and wider and the resulting device is portable and is no longer integrated with a computer.

3.3. Tool Specifications

![Figure 6](image)

**Figure 6.** (a) Schematic of skin temperature monitoring, (b) Tool sensor system

This temperature detector tool that has been built can assist in measuring the temperature of the human body without touching the object. A system of tools like this is indispensable in detecting changes in body temperature caused by Covid-19. This tool can measure human body temperature at a maximum distance of 4 meters. The distance is sufficient to detect body temperature in a larger range accurately so that the risk of virus transmission can be minimized because there is no need to come into contact with the object to be measured. In general, the system tool will detect the color pixels of the object being measured. These color pixels will be translated into temperature values. However, this tool still has shortcomings, the ability to measure body temperature in a greater distance and a wider area cannot be reached. In the next development, a tool that uses sensors other than infrared can be developed so that the ability to detect human body temperature can be more accurate over a wider range of distances.

4. Conclusion

In this paper, we presented a device in the form of temperature sensor glasses to monitor human body temperature. At this time, this tool is needed in diagnosing human body temperature exposed to the Covid-19 virus. Body temperature is a condition that states a person's health, therefore an accurate tool is needed to check the temperature of the human body without making direct contact. The device of a temperature sensor glasses using an Infrared Array SensorGrid-EYE sensor. The results showed that the infrared sensor on the device could read the temperature of the body part by positioning the device perpendicular to the body part where the temperature will be detected. The infrared sensor system could detect body temperature without direct contact with a distance range of 1 m to 4 m, while at a distance of more than 4 m the device could not read precisely and accurately. The infrared sensor system takes about 10 to 15 minutes to get an accurate measurement.

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References

[1] M. F. Edy Mintarto, "Efek Suhu Lingkungan Terhadap Fisiologi Tubuh Pada Saat Melakukan
Latihan Olahraga," *Journal of Sport and Exercise Science*, vol. 2, pp. 9-13, 2019.

[2] N. F. Shalihah, "Hasil Penelitian: Virus Corona Sensitif dengan Suhu Tinggi, Bagaimana Penyebarannya," *Kompas*, Jakarta, 2020 [online].

[3] S. Kurniawan, "Waspada, penelitian baru menunjukkan, virus corona menyebar dengan mudah," 2020. [Online].

[4] Wolfgang, "Health Minister reviews further preparedness on COVID 19," Athena Information Solutions Pvt. Ltd, 2020.

[5] "NATHEALTH calls for a unified response to arrest the cascading impact of COVID-19," in *BioSpectrum*, Athena Information Solutions Pvt. Ltd, 2020.

[6] A. Nikolay, A. Léon and Schwamborn, "Process intensification of EB66® cell cultivations leads to high-yield yellow fever and Zika virus production," Springer Berlin Heidelberg, 2018.

[7] Z. K. Qin and H. P. Zhang, "Digital thermometer design based on single-chip AT89C2051," *Applied Mechanics and Materials*, vol. 684, 2014.

[8] H. Apa, S. Gözmen and Ş. Keskin-Gözmen, "Clinical accuracy of non-contact infrared thermometer from umbilical region in children: A new side," *The Turkish journal of pediatrics*, 2016.

[9] S. cui, "FoodPro Plus Infrared Thermometer and Probe," 2015.

[10] J. L. Vilela, J. Ascue and M. Callan, "PSX-13 Correlation between superficial body temperatures measured with an infrared thermometer in alpacas," *Journal of Animal Science*, pp. 463-464, 2019.

[11] E. N. Indra, "Adaptasi Fisiologis Tubuh Terhadap Latihan di Suhu Lingkungan Panas Dingin," in *Prosiding Seminar Nasional PORPERty UNY*, Yogyakarta, 2007.

[12] Hsuan-Yu Chen, et al, “Investigation of The Impact of Infrared Sensors on Core Body Temperature Monitoring by Comparing Measurement Sites”, *Journal Sensors*, vol.20, 2885, 2020.

[13] Erickson, R.S.; Kirklin, S.K. “Comparison of ear-based, bladder, oral, and axillary methods for core temperature measurement”. *Crit. Care Med.* Vol.21, pp. 1528–1534. 1993.

[14] M. Safitri, G. Arya Dinata, “Non-Contact Thermometer Berbasis Inframerah”, *Jurnal Simetris*, vol.10, 2019.

[15] Valentin Melnikov, et al, “System Dinamics of human body thermal regulation in outdoor environments”, *Building and Environment*, vol. 44, 2018.

[16] A. Ghahramani, et al, “Infrared thermography of human face for monitoring thermoregulation performance and estimating personal thermal Comfort”, *Building and Environment*, vol. 109, pp. 1-11, 2016.