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Analysis of Heart Rate and Body Temperature Data Retrieval in Smartband Design with Android Applications Using the Multiplexing Method

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ABSTRACT The use of two sensors for smartband requires the use of the multiplexer method so that data does not collide with each other due to the similarity of the two sensor systems. Monitoring and recording of the patient's medical record is very necessary if there are symptoms of a disease that must be treated immediately so that the patient's condition does not get worse and knows how the pattern of a disease attacks the body's condition, this is so that the patient's condition history data can be examined by a doctor to facilitate and improve the accuracy of the diagnosis doctor. The implication in this research is that due to the many cases where the sensors collide with each other and cannot be used because the data output by the sensors collide with each other, this can be overcome by one method, namely the multiplexing method where sensor data is taken alternately at different times so that making sensor output data retrieval not at the same time, the time lag in multiplexing is required to be as little as possible so that the data display does not experience too long a delay causing the data display to be further away from real time. The purpose of this study was to examine and determine the effect of multiplexing speed on data retrieval of 2 sensors. In this study, the Wemos D1 Mini microcontroller was used to process BPM and temperature data, as well as process time using a multiplexer from both sensors, then the BPM and temperature values were displayed on the OLED screen. Based on the results of the research that has been done, it can be concluded that smartband has the lowest error of 0.06% while the biggest error is 1.71%. This study has the advantage of a portable device design and is very suitable for everyday use to monitor patient conditions, so that patients are not disturbed by the presence of this smartband. This research has a development, namely the use of a larger battery so that its use can last longer, then the use of a medical grade standard temperature sensor.

INDEX TERMS Smartband, Multiplexer, SEN0203, MLX90614, BPM, Temperature

I. INTRODUCTION

Monitoring and recording the patient's medical record[1][2][3][4] is very necessary if there are symptoms of a disease that must be taken quickly so that the patient's condition does not worsen and knows how the pattern of a disease attacks the body's condition. Monitoring and measuring body temperature and BPM is very important to know the patient's condition . The body that is not affected by any disease has a normal body temperature and bpm. Body temperature and bpm will be constant even though environmental conditions change, and when the body's immune system is fighting a certain virus or disease, symptoms such as erratic BPM and rising body temperature will appear . This monitoring and storage system utilizes an android application that is connected to the module through the BLE[5][6][7]BLE android application will display the data read by the module and store it in the android database, this is so that the patient data history can be checked by the doctor to make it easier and increase the accuracy of doctors' diagnoses. In the application of the use of two sensors for the smartband, a method is needed so that the data does not collide with each other due to the similarity of the sensor system, many cases where the sensors collide with each other and cannot be used because the data that the sensor outputs collide with each other, this can be overcome by one the method is the multiplexing method where sensor data collection is carried out alternately at different times so as to make sensor output data retrieval not at the same time, the time lag in multiplexing is required to be as little as possible so that the appearance of the data does not experience too long a delay, causing the appearance of the data to be further away from the real word. time. Based on the problem above, the researcher will examine the effect of multiplexing[8][9] speed on sensor data retrieval.

Previous research has discussed the application of using two sensors for the smartband method so that data does not collide with each other due to the similarity of the sensor systems. there are many cases where sensors collide with each other and cannot be used because the data issued by sensors collide with each other, this can be overcome by one method, namely the multiplexing method where sensor data retrieval is carried out alternately at different times so that sensor output data retrieval is not the same, so time lag in multiplexing, try to minimize as much as possible so that the appearance of data does not experience too long a delay, causing the appearance of data to be farther from real time.

In 2018 a tool was made by Istiono Majid from the Surabaya Health Polytechnic's Electromedic Engineering Research Monitoring BPM, Temperature and Respiration Showing PC via Bluetooth and Sending Data via SMS. This tool is made with the aim of making it easier for doctors to monitor the condition of the patient's condition even though the doctor is far from the patient. However, this tool has drawbacks, namely the distance that can be achieved by bluetooth is no more than 30 meters and the sensor response to temperature cannot detect it directly, but there is still a delay and because patient data is sent when normal and abnormal conditions with SMS it will spend a lot of time pulses for each monitoring activity[10][11][12][13].

In the same year, a tool was developed by Haris Isyanto et al from the Department of Electrical Engineering, Faculty of Engineering, University of Muhammadiyah Jakarta to create a research Monitoring of Two Parameters of Patient Medical Data [14](Body Temperature and Heart Rate). This tool is designed to monitor the patient's body temperature and heart rate. This tool as well as the program is very useful for doctors and medical personnel to be able to quickly and precisely find out the heart rate and body temperature of each patient as well as data from the patient can be automatically stored immediately. However, this tool has a large physical form and is not simple due to the use of the Arduino Mega and the Ethernet Shield module which is large, making it difficult to carry everywhere.

In the next 2 years, in 2020, Diah Eka Savitri, the Physics Study Program, Syarif Hidayatullah State Islamic University, Jakarta, made a research Bracelet for measuring heart rate and human body temperature based on the Internet of Things (IOT)[15]. This tool is designed to monitor the patient's heart rate and body temperature. This tool is also in the form of a portable bracelet that can monitor patients from afar. However, this tool still has shortcomings in its delivery using bluetooth which can only send data to android with a maximum distance of 46.5 meters and there is still a delivery delay to android. And also the shape of the bracelet is still too big because it still uses a character LCD on the display and still uses a lot of jumper cable connections. In the same year, a monitoring tool in the form of a bracelet was also developed by Gde Bagus Marten Giri Pramana from the Electrical Engineering Poltekkes Surabaya with the research Smartband Design Equipped with BPM and Temperature Monitoring with Android Display[16][17], The device in the form of a bracelet with an OLED display that displays the BPM and Temperature values from the patient is equipped with sending notifications on the BLYNK [18][19]application and an email that has been determined if the patient's condition is not normal. It's just that this tool still has shortcomings in sensors and data retrieval. Where this tool still uses the Ds18b20 temperature sensor which results from this sensor are still affected by the temperature of the device around the sensor, and also BPM data collection on this tool is still done on the fingers, so this tool still requires a connection to be placed on the fingers to retrieve BPM data. In the same year, Anna Nur N. C. et al., conducted research on monitoring heart rate and temperature using pulse sensors and infrared which will be processed on Arduino[3]. The display of heart rate and temperature values will also be displayed in graphic form on the web server and there is a storage system. However, the delivery in this study still uses Bluetooth so that it is only a maximum distance of 25 meters .

In 2017, Sharanbasappa S. et al., conducted a study on the integration of wireless instruments for measuring heart rate and temperature. This research uses Zigbee network as the delivery system. This research is also equipped with a data analysis system that will notify the patient if there is more or less data than the preset. However, there is no explanation regarding the analysis of the data results from this study . In 2016, Salomi S. Thomas et al., conducted a study on the detection of heart beat and body temperature using the Bluetooth module delivery HC-05 [20][21][22]to display on Android. However, there is also no analysis of the resulting data and the graphs displayed also still need to be improved. In 2019, Rangga Adi F. et al. conducted research on IoT-based heart rate and temperature monitoring. This study takes the BPM value from the Lead II signal and temperature using the DS18B20 sensor[23][16][24][25][26]. This system uses ESP32 as a microcontroller which will process the data and send it to Thingspeak for display. However, in this study there is still a large error value as well as obstacles related to delay in the delivery system. Plus, from some of the studies above, the method used tends to be less comfortable when worn because of the fairly large size of the device.

Previous research has discussed the application of using two sensors for smartband methods so that the data does not collide with each other due to the similarity of the sensor system. there are many cases where the sensors collide with each other and cannot be used because the data that the sensor outputs collide with each other, this can be overcome by one method, namely the multiplexing method where sensor data retrieval is carried out alternately at different times so as to make sensor output data retrieval not at the same time, the time lag in multiplexing is required to be as little as possible so that the appearance of the data does not experience too long a delay, causing the appearance of the data to be further away from real time. Based on the problems and studies that have been carried out, the author will make a study entitled "Analysis of the Use of Multiplexing Methods in BPM and Temperature Data Collection in Smartband Design With Android Applications" which aims to examine and determine the ability of the influence of multiplexing speed on data retrieval 2 sensors.

This study aims to examine and determine the ability to influence the speed of multiplexing on data retrieval of 2 sensors.

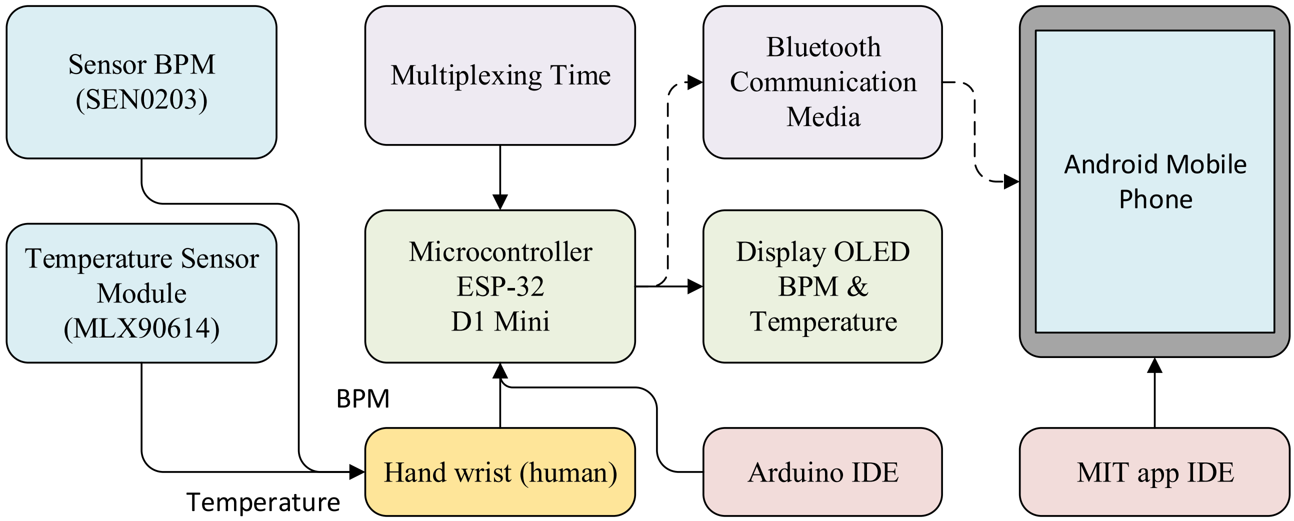

FIGURE 1. System Block Diagram in Research smartband with SEN0203 Sensor and MLX90614 sensor Using the Multiplexing Method

II. METHOD

This research was conducted at Moh. Saleh Hospital, Probolinggo City using a high-flow oxygen analyzer as a calibrator. The research design used in making the module is Pre-experimental with the After Only Design type. In this design the researcher only uses one group of subjects and only sees the results without measuring and knowing the initial conditions, but there is already a comparison group.

The independent variable in this study is the speed of switching multiplexing. the dependent variable is the value of BPM and Temperature from Sensor SEN0203 and Sensor MLX90614[27][28], and the controlled variable is the ESP32 microcontroller board.

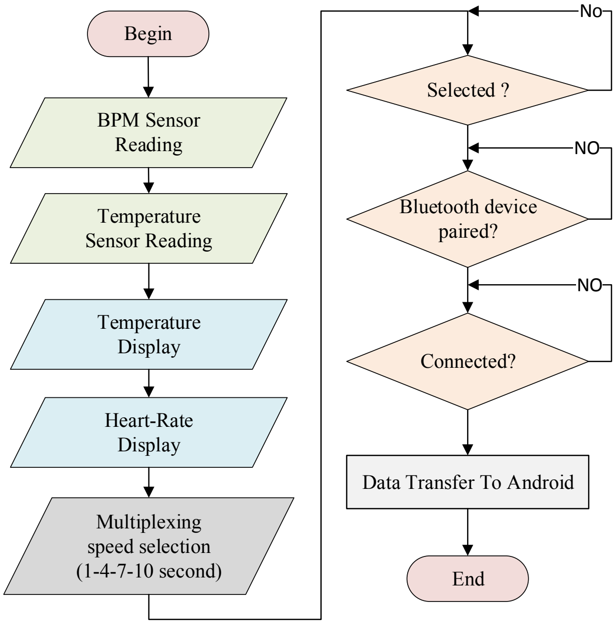

FIGURE 2. The system flowchart

This study uses a BPM sensor SEN0203 [29][30], temperature sensor MLX90614, then the data will be processed using a D1 Mini microcontroller, and the results of the BPM and Temperature Output will be displayed on the

OLED Display, and then will be sent to the android application[6][31][32]. This paragraph can explain **FIGURE 1** There are 3 main parts in the block diagram, namely input, process and output. In the input section there is a BPM and Temperature module which functions as input data on the multiplexer which functions as a timing controller for data retrieval between the BPM and Temperature sensors. In the process section there is a microcontroller, after the data is received, the microcontroller will perform data processing so that the data is ready to be sent. And finally, in the output section, there is an android application and a display that functions to display the results of the sensors that have been processed on the microcontroller.

Refer to **FIGURE 2** Turn on the ON button after the module turns on the module will read the BPM and temperature readings then the multiplexer will adjust the data taken from the two sensors and display it on the display then the module will check whether the Bluetooth condition has been connected, When Bluetooth has not been connected to the module then the process will return to point sensor readings, and if Bluetooth is connected, the Bluetooth initialization will be processed, if the initialization process is complete, the module will check the data request and when there is a data request, the module will send data from the module.

A. DATA ANALYSIS

Measurement of each parameter BPM and Temperature, with multiplexer settings 1, 4, 7, 10 seconds. everything is repeated 5 times. The average value of the measurement is obtained by using the mean or the average by applying equation (1). The average is the number obtained by dividing the number of values by the number of data in the set.:

$$\overline{x} = \frac{x1+x2 \ldots +xn}{n} \quad (1)$$

where x denotes the mean (mean) for the n-measurements, x1 denotes the first measurement, x2 denotes the second measurement, and xn denotes n measurements. Standard deviation is a value that indicates the degree (degree) of variation in a data set or a measure of the standard deviation of the mean. The standard deviation (SD) formula can be shown in the equation (2):

$$\mathrm{SD} = \sqrt{\frac{\sum(xi-\overline{x})^2}{(n-1)}} \quad (2)$$

where xi indicates the number of desired values, x indicates the average of the measurement results, n indicates the number of measurements. Uncertainty (UA) is a doubt that appears in each measurement result[33][34][35]. The uncertainty formula is shown in the equation (3):

$$UA = \frac{SD}{\sqrt{n}} \quad (3)$$

where UA indicates the uncertainty value of the total measurement, SD indicates the resulting standard deviation, and n indicates the number of measurements. %error indicates a system error. The lower Error value is the average difference of each data. Errors can indicate deviations between the standard and the design or model. The error formula is shown in the equation (4).

$$\%\mathrm{ERROR} = \frac{(x_n - \mathrm{x})}{x_n} \times 100\% \quad (4)$$

where xn is the measured value of the machine calibrator. X is the measured value of the design.

III. RESULT

In this study, the module has been tested using a comparison tool Oximeter and Thermogun. **FIGURE 3** and **FIGURE 4** are a microcontroller circuit consisting of an Wemos D1 Mini[19], [36], a battery circuit, an envelope, and an amplifier circuit. The power supply circuit is made using Lithium Battery[37] which will enter the voltage up module.

FIGURE 3 . Smartband module display with heart rate, body temperature and battery capacity display

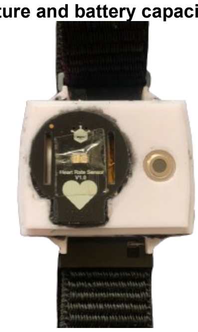

FIGURE 4. Smartband Module BPM and Temperature Design with SEN0203 Sensor and MLX90614 Sensor

Digital part consists of the Wemos D1 Mini microcontroller which is the main board of the device and the SEN0203 BPM sensor, and the MLX90614 temperature sensor. Process of collecting data on the module is carried out at RSUD dr. Mohamad Saleh Probolinggo City. The data retrieval process was carried out on the 1st, 4th, 7th, and 10th second multiplexer for 5 experiments using the BPM sensor SEN0203 and the MLX90614 Temperature sensor.

TABLE 1
Error value for each multiplexer setting in comparison of module values with oximeter and thermogun comparison tools

Setting Multiplexer	Error%	
	BPM	Temperature (°C)
1 second	31,34	0,38

4 second	1,48	0,06
7 second	1,34	0,06
10 second	1,56	0,11

Error is the difference from the actual value compared to the measured value of the module with units in this study, namely BPM for heart rate, and C for temperature units. It can be seen in the **TABLE 1** below that the largest error value from the smartband module measurement is in the 1 second multiplexer setting with an error value of 31.34% for the BPM parameter, and 0.38% for the temperature parameter. While the smallest error value is in the 7 second multiplexer setting with an error value of 1.34% for the BPM parameter and 0.06% for the temperature parameter.

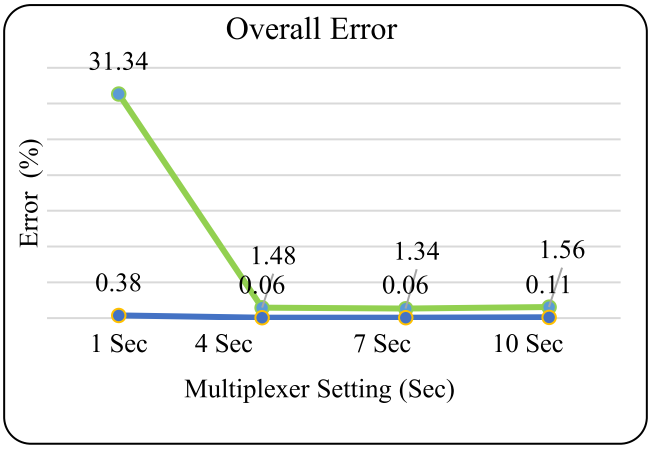

FIGURE 5. Graph of the error value of each setting in the comparison of the value of the High Flow Oxygen Analyzer module with the Citrex H3 comparison tool (green: BPM and blue: temperature).

In **FIGURE 5** From the measurement results, the overall error value obtained from the smartband module can be said to be good as a whole. It's just that there is 1 very large error in the 1st second multiplexer setting on the BPM parameter with an error value of 31.34%. In addition, errors in the BPM and temperature parameters in other multiplexer settings are still within the range of the calibration tolerance, which is ±5%. When viewed from the error value of each multiplexer setting in each setting, the longer the setting time on the multiplexer, the stable BPM and temperature values obtained.

TABLE 2
Comparison of standard deviation values for each multiplexer setting on the comparison of module values with comparison tools oximeter and thermogun

Setting Multiplexer	Standard Deviation	
	BPM	Temperature (°C)
1 second	9,24	0,18
4 second	7,04	0,20
7 second	3,05	0,13
10 second	3,21	0,13

It can be seen from the **TABLE 2** above that the standard deviation obtained from measurements with the smartband module with temperature parameters can be said to be good, because the results of the standard deviation value do not exceed the average value of the Smartband module measurement. However, in the BPM parameter, the standard deviation value can still be said to be large, with the lowest standard deviation value at the 7 second multiplexer setting with a value of 3.05.

TABLE 3
Uncertainty comparison value (UA) for each multiplexer setting on the comparison of module values with oximeter and thermogun comparison tools

Setting Multiplexer	Uncertainty	
	BPM	Temperature (°C)
1 second	4,62	0,09
4 second	3,52	0,10
7 second	1,52	0,07
10 second	1,60	0,07

It can be seen from the **TABLE 3** above if the uncertainty value (UA) is used to see how much deviation (accuracy) the Smartband module is in reading the BPM and Temperature values. Relative uncertainty is closely related to measurement accuracy, which can be stated if the smaller the uncertainty, the higher the accuracy. In this study, the largest deviation value was found at the 1 second multiplexer setting, which had a value of 4.62. While the smallest deviation value is the multiplexer setting at 7 and 10 seconds with a deviation value of only 0.07.

IV. DISCUSSION

After taking data and measuring the smartband module, data collection and analysis of the results are carried out to determine the stability and accuracy of the module manufacture. This study also has a purpose to examine and determine the ability of the effect of multiplexing speed on data retrieval of 2 sensors.

After conducting experiments on research to get the BPM value, the results obtained on the smartband module are as follows. Measuring the BPM value with multiplexer settings 1, 4, 7, and 10 seconds, the results obtained are BPM values which are quite stable at multiplexer settings 4, , 7, and 10 seconds. The BPM value in the 1 second multiplexer setting is a very large error. The BPM error value in the 1 second multiplexer setting is 31.34%, this is because at the time of BPM measurement, to read the BPM signal generated by the sensor it takes more than 1 second so that the output read by the microcontroller can be calculated into a stable BPM value. . The smallest error value is found in the 7th second multiplexer setting with an error value of 1.34%. For the distribution of data at each multiplexer setting, the 7 second multiplexer setting has the lowest value of 3.05, a value which is close to 0 compared to the value of the distribution of other data in each multiplexer setting. The lowest uncertainty value is in the 7 second multiplexer setting with a value of 1.52. An uncertainty value of 0 can be interpreted if the stability of the results is good because there is no change in each measurement.

In measuring the temperature value with multiplexer settings 1, 4, 7, and 10 seconds, the temperature value is close to the comparison value of the thermogun and the value is stable. Multiplexer setting value which has the lowest error value of 0.06% is found in the 4th and 7th second multiplexer settings and the highest error value is at the 1 second multiplexer setting of 0.38%. Meanwhile, the distribution of data for each multiplexer setting is almost close to the standard deviation value, namely 0.13 for the 7 and 10 second multiplxer settings. An uncertainty value of 0 can be interpreted if the stability of the results is good because there is no change in each measurement. The lowest uncertainty value is found in the multiplexer setting 7, and 10 seconds of 0.07.

Due to various factors, the module made by the author is still far from perfect, both in terms of planning, manufacturing, and how the module works. So that there are several shortcomings that have been analyzed from the tool that the author made. The first is that the battery used has a small capacity, so the usage time cannot last for a long time. Then the error value in the 1 second multiplexer setting is still very large, because the BPM sensor must first read the BPM signal generated by the sensor it takes more than 1 second so that the output read by the microcontroller can be calculated into a stable BPM value.

The multiplexer method used by previous studies is to use multiplexer components in the form of hardware so that they have disadvantages in terms of the efficiency of the space used. whereas in this study the multiplexer used was directly from the Arduino microcontroller program, so it is efficient in terms of space used and more practical.

Previous research has discussed the application of using two sensors for smartband methods so that the data does not collide with each other due to the similarity of the sensor system. there are many cases where the sensors collide with each other and cannot be used because the data that the sensor outputs collide with each other, this can be overcome by one method, namely the multiplexing method where sensor data retrieval is carried out alternately at different times so as to make sensor output data retrieval not at the same time, the time lag in multiplexing is required to be as little as possible so that the appearance of the data does not experience too long a delay, causing the appearance of the data to be further away from real time.Based on the problems and studies that have been carried out, the author will make a study entitled "Analysis of the Use of Multiplexing Methods in BPM and Temperature Data Collection in Smartband Design With Android Applications" which aims to examine and determine the ability of the influence of multiplexing speed on data retrieval 2 sensors.

This study has the advantage of a portable device design and is very suitable for daily use to monitor the patient's condition, so that patients are not disturbed by the presence of this smartband. This research has a development that is the use of a larger battery so that its use can last longer, then the use of a temperature sensor that has a medical grade standard.

IV. CONCLUSION

Purpose of this study was to examine and determine the ability to influence the speed of multiplexing on data retrieval of 2 sensors by changing data retrieval with the multiplexing method with time lags, 1, 4, 7, 10 seconds. In measuring the BPM value with multiplexer settings 1, 4, 7, and 10 seconds, the results obtained are BPM values that are quite stable at multiplexer settings 4, , 7, and 10 seconds. The BPM value in the 1 second multiplexer setting is a very large error. The BPM error value in the 1 second multiplexer setting is 31.34%. The smallest error value is found in the 7th second multiplexer setting with an error value of 1.34%. The multiplexer setting value which has the lowest error value of 0.06% is found in the 4th and 7th second multiplexer settings and the highest error value is at the 1 second multiplexer setting of 0.38%. Meanwhile, the distribution of data in each multiplexer setting is almost close to the standard deviation value, namely 0.13 at the multiplexer setting 7, and 10 seconds. The lowest uncertainty value is found in the multiplexer setting 7, and 10 seconds of 0.07. Based on the testing of the smartband module that has been carried out by comparing the measurement results to the Oximeter and Thermogun comparison tools the results obtained have been said to be good and can perform their work functions. This study has the advantage of a portable device design and is very suitable for daily use to monitor the patient's condition, so that patients are not disturbed by the presence of this smartband. This research has a development that is the use of a larger battery so that its use can last longer, then the use of a temperature sensor that has a medical grade standard.

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