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ADVANCED SMART BRACELET FOR ELDERLY: COMBINING TEMPERATURE MONITORING AND GPS TRACKING

Sugondo Hadiyoso[1*], Indrarini Dyah Irawati[2], Akhmad Alfaruq[3], Tasya Chairunnisa[4], Muhamad Roihan [5], Suyatno[6]
School of Applied Science, Telkom University, Bandung, Indonesia[1234]
School of Applied Science, Telkom University Jakarta, Jakarta, Indonesia[56]
sugondo@telkomuniversity.ac.id, indrarini@telkomuniversity.ac.id, contact@akhal.org, tasyachairunnisa5@gmail.com, roihani@telkomuniversity.ac.id, suyatno@telkomuniversity.ac.id

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**Corresponding Author*

ABSTRACT
Indonesia is entering an aging population period, marked by an increase in the number of elderly individuals, accompanied by a rise in dementia cases. This situation leads to higher dependency among the elderly on others for assistance or long-term care. Dementia can cause elderly people to lose their sense of direction, often wandering aimlessly, making them difficult to track. To address this issue, a wearable smart bracelet is proposed to monitor the location and a vital body parameter such as body temperature. The system is equipped with a tracking application that can send an alert if the user is outside a designated area. It automatically sends a warning message to the caregiver's or family member's smartphone when abnormal signs are detected. The bracelet is designed like a wristwatch, to be worn on the wrist. It is small, lightweight, and battery-operated. Temperature and location data can be transmitted in real-time using an internet network to mobile devices. The device can notify when the user is outside the specified area. Test results indicate that the device has high accuracy and reliability in monitoring location and body temperature with accuracy around 98.5%, as well as sending notifications through a Telegram bot when certain thresholds are exceeded. This device can work properly for up to 5 hours on a single battery charge. With this device, it is expected to help monitor and support the care of the elderly so that they can improve their quality of life. This device can also provide an emergency alarm if the elderly are outside the area.
Keywords: *Aging Population, Smart Bracelet, Temperature, Location, Monitoring.*

1. Introduction

The World Health Organization (WHO) predicts that by 2050, the population aged 60 and above will double, while those aged 80 and above will number 400 million people (Singh & Bajorek, 2014). In response to this issue, several global commitments have been made, including the World Health Assembly Resolution, the Regional Strategy for Healthy Aging, and the Response to Aging Societies and Dementia (Rudnicka et al., 2020). Indonesia is entering a period of aging population, where there is an increase in the number of elderly individuals (Mas'ul, 2023). According to the 2018 Riskesdas data, 74.3% of the elderly population is independent, and 22% have mild dependency (Kesehatan, 2018). The number of elderly people with dementia tends to increase along with the rise in non-communicable diseases (Rukmini Rukmini et al., 2021). This condition will affect the dependency of the elderly on assistance from others or the need for Long-Term Care (Martinez-Lacoba et al., 2021).

As the elderly population grows, so do healthcare costs, which is a global issue (Chen et al., 2023; Kallestrup-Lamb et al., 2024). One way to curb rising healthcare costs is by preventing the worsening of elderly patients' conditions that require long-term hospitalization (Abdi et al., 2019). To ensure optimal well-being, measures such as daily health management and early disease detection are essential (Kruk et al., 2018). At the same time, it is also important to secure the necessary human resources for healthcare and reduce the mental burden on family members. One promising solution to this issue is remote monitoring, a form of telehealth (SALMA et al., 2024; Serrano et al., 2023).

The type of remote monitoring needed for the elderly includes systems that allow doctors, caregivers, and family members to monitor vital signs such as heart rate, body temperature, and oxygen saturation (Ko et al., 2023). Monitoring vital parameters in the elderly is crucial for routine health management, disease prevention or early detection, and rapid emergency care (Fang & Ouyang, 2022; Kekade et al., 2018). The use of wearable technology-based health monitoring devices for elderly has become an effective solution (Al-khafajiy et al., 2019; Hou, 2023; Moore et al., 2021). Wearables are devices that can be worn daily and allow real-time monitoring of physical conditions, such as heart rate, blood pressure, oxygen saturation, and physical activity (Soon et al., 2020). With these devices, the elderly can access their health information without needing to visit healthcare facilities daily, making health monitoring easier in their daily lives (Olmedo-Aguirre et al., 2022; Teixeira et al., 2021).

Several previous studies have implemented device vital sign monitors. However, to the best of our knowledge, there are still few that integrate it with a locator device and consider the size of the device. Therefore, in this preliminary study, we proposed device in the form of a wristband will monitor location and body temperature. The wristband design includes a biosensor that can measure vital signs such as heart rate, body temperature, and oxygen saturation, as well as a tracking system. The wristband will process and analyze data accurately, transmitting the information through a cloud network between hospitals, homes, or care clinics. The system will automatically send alert messages to a caregiver's or family member's smartphone if abnormal vital signs are detected.

2. Literature Review

Vital sign monitoring for elderly people has become a critical issue of research due to the growing aging population and the rise in chronic diseases. Continuous monitoring of physiological parameters such as heart rate, body temperature, and oxygen saturation plays a key role in preventing emergencies and ensuring better health management (Jegan & Nimi, 2024; Ming et al., 2020). In recent years, wearable technologies have shown great promise in this field. Study by Gao et al. developed a biosensor wristband capable of real-time analysis of biomarkers in sweat, which is particularly useful in monitoring the health of elderly patients (Gao et al., 2016). Other studies, examined the use of photoplethysmography (PPG) signals in wearable devices to continuously monitor heart rate. (Kim & Baek, 2023; Wu et al., 2023).

The advent of telemonitoring systems has further enhanced remote healthcare solutions (Anawade et al., 2024). Wang and Hsu, proposed a cloud-based telemonitoring system that gathers data from wearable devices and transmits it to healthcare providers, enabling timely interventions (W.-H. Wang & Hsu, 2023). In a similar vein, Naeim et.al, explored the potential of IoT-based health monitoring systems, which continuously track multiple vital signs of elderly patients in real-time, offering a comprehensive solution to remote elderly care (Naeim et al., 2023).

Fall detection is another critical aspect of monitoring elderly individuals, as falls are a common and dangerous occurrence in this population (Giovannini et al., 2022). Joshi and Nalbalwar, developed a fall detection system that incorporates accelerometers and heart rate sensors to monitor elderly patients, alerting caregivers when falls occur (Joshi & Nalbalwar, 2017). Other related study by, Greene et al., designed a smart home sensor system that integrates fall detection with vital sign monitoring, ensuring comprehensive care for elderly at home (Greene et al., 2016).

Machine learning has also become a valuable tool in improving the accuracy and effectiveness of health monitoring systems for the elderly (Ahmed et al., 2023; Qin et al., 2020). Sheela and Varghese, developed a wearable sensor with predictive model using machine learning algorithms to detect abnormal heart rates, pressure, temperature and position detection patterns (Gnana Sheela & Rose Varghese, 2020). Kulurkar et al., proposed a wearable device with a three-axis accelerometer captures real-time movement data, processed by a machine learning model on an IoT gateway for accurate fall detection (Kulurkar et al., 2023).

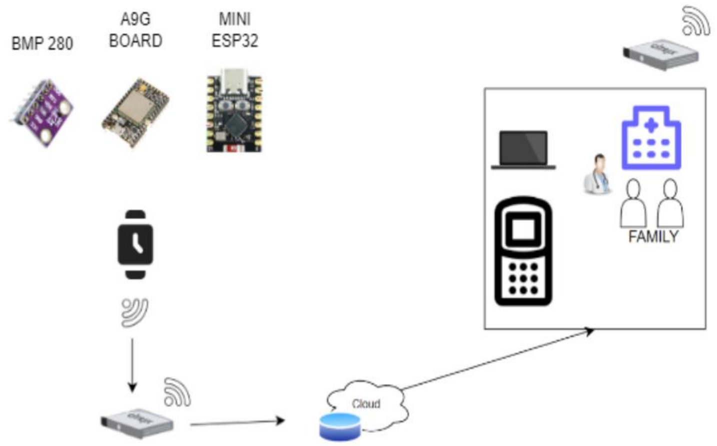
The role of vital sign monitoring is especially important for elderly patients with dementia, who are at higher risk for health complications (Rocha et al., 2024). Iaboni et al. (2019) explored the use of remote monitoring systems to track changes in heart rate and skin temperature, detecting agitation and other behavioral changes in dementia patients (Iaboni et al., 2022). Silverio et al., further emphasized the importance of monitoring physiological signals to address the unique healthcare needs of elderly individuals with cognitive impairments (Silverio et al., 2020).

Despite significant advancements, challenges remain in the implementation of wearable and remote monitoring systems. Rodríguez et al., discussed issues a flexible wearable device adaptable to different positions may best meet users' preferences and highlighting the need for ergonomic designs (Rodríguez et al., 2017). Other issue is addressed the challenge of integrating data from multiple sensors into a cohesive system, emphasizing the need for user-friendly interfaces and robust data analytics tools to handle the complexity of multi-sensor monitoring (Uddin & Koo, 2024).

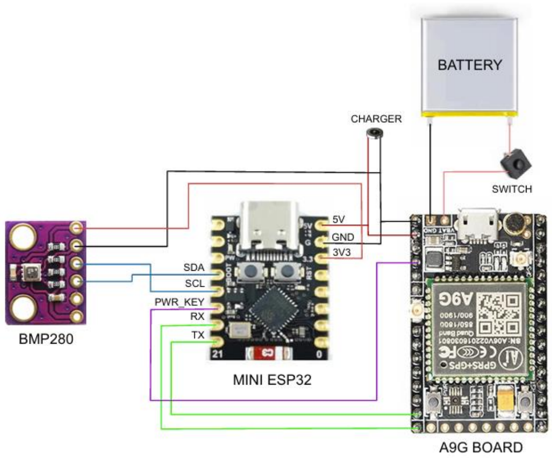
The ongoing development of wearable sensors and remote monitoring systems promises to reduce healthcare costs and improve the quality of life for elderly people. As the field continues to evolve, integrating machine learning, telemonitoring, and AI-driven systems with ergonomic design will become crucial for addressing the healthcare needs of aging populations worldwide. Another issue related to elderly is dementia which can cause memory loss so that often misorientation. Therefore, in this study a device was designed in the form of an ergonomic bracelet that resembles a watch that can scan body temperature and current location.

3. Device Implementation

The following Figure 1 provides an overview of the proposed device. Figure 1(a) is a diagram of the proposed system, while Figure 1(b) shows the wiring diagram between modules in the device. This device uses an A9G Board, BMP 280, and Mini ESP32. The A9G board functions as a GPS to detect position and send coordinate data. The BMP 280 acts as a temperature sensor designed using a thermistor. The Mini ESP functions as a microcontroller responsible for processing and communicating data via cellular internet through GPRS network on A9G. Data transmission via cellular communication was chosen because it is a public network, does not require specific settings and has wide coverage. The sensor modules are selected by considering the size and power consumption, especially the A9G module is integrated with the cellular communication interface.



(a)



(b)

Figure 1. (a) General design of the system (b) wiring diagram each sensor and microcontroller

BMP280 sensor is connected to the Mini ESP32 microcontroller, with: SDA (Data) and SCL (Clock) pin on the Mini ESP32. A9G board which includes GPS and GPRS is connected via RX and TX lines on ESP32 for communication. A lithium-ion battery provides power 3.7 Volt and 800 mAh to the circuit, and it is connected through a magnetic wire charging module. The power is managed with a switch, which allows the circuit to be turned on or off.

3.1 Hardware

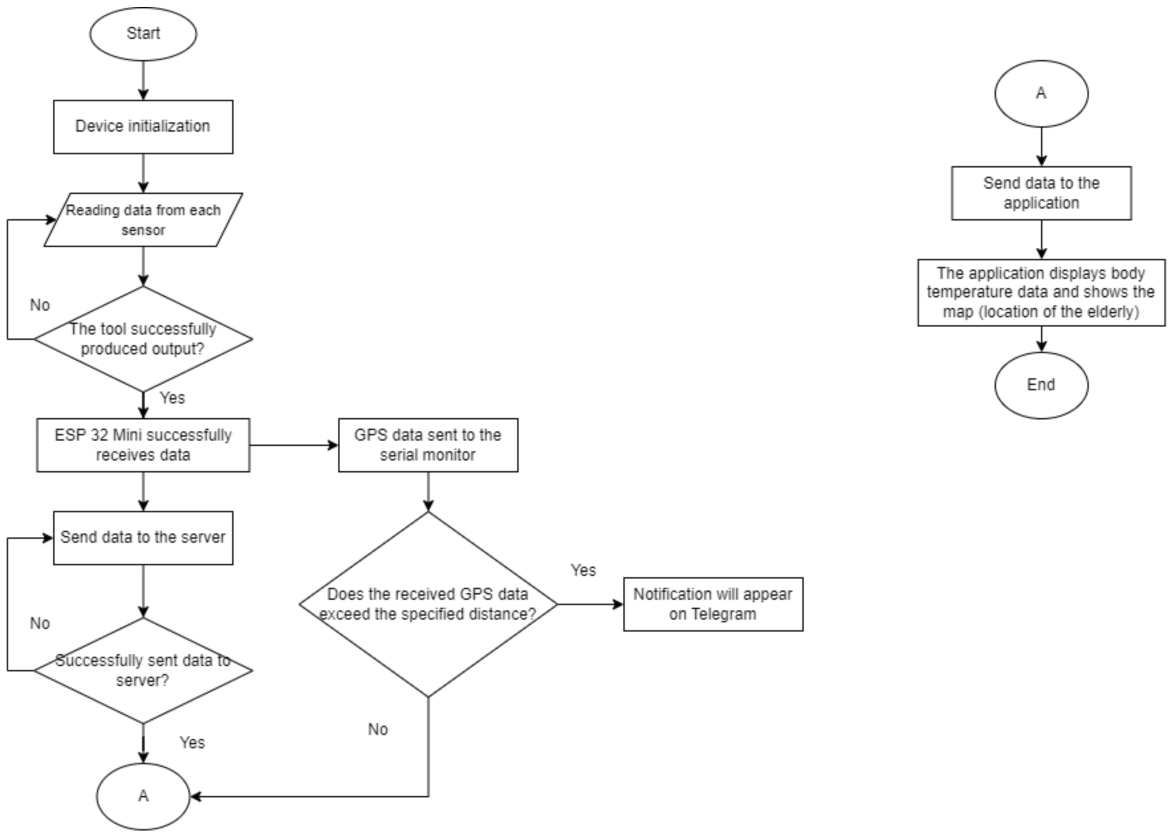
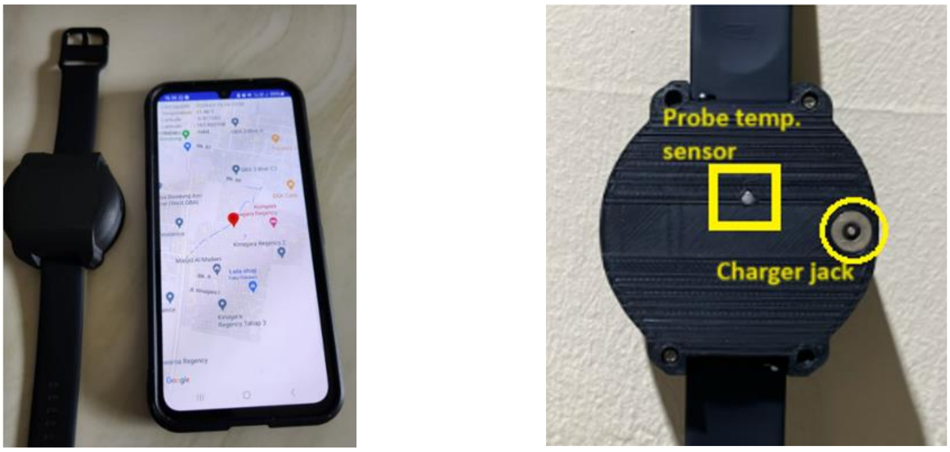


Figure 2. The workflow of proposed system

Figure 2 illustrates the detailed workflow of the system. The ESP32 Mini receives temperature and GPS data, which is then sent to the server via GPRS. This data is visualized on a mobile application. When the device is powered on, the sensors initially read the temperature and position coordinates. Normal temperature values and coverage radius are set as thresholds. The sensor data is processed by the ESP32 microcontroller and then sent to the cloud server through the GPRS module. Data transmission occurs continuously every 30 seconds.

The tracking feature functions by continuously checking whether the received GPS data exceeds the predefined distance. For instance, in this experiment, the system is set so that if the distance is more than 30 meters from the specified point, an alarm and a notification are triggered on the Telegram app. The application continuously updates the body temperature data and coordinates indicating the elderly person's location. All these processes ensure that temperature sensor and GPS module data are received, sent to the server, displayed on the application, and trigger a notification if the elderly person is outside the predetermined distance.

The proposed device is designed to be compact, wearable, and ergonomic. It is made to resemble a wristwatch, with a rubber strap to ensure comfort during use. A single button on the side serves as the power on/off switch. The rear of the device houses a temperature sensor probe and a charging port. The actualized device is depicted in Figure 3.



(a) (b)

Figure 3. Realized device (a) front view (b) back view

To operate this monitoring system, a platform is required to display the data collected from the sensors. The libraries used for programming the controller unit include:

a. #include <GyverBME280.h>: includes the GyverBME280 library to use the BME280 sensor, which is used for reading temperature data.

```
#include <GyverBME280.h>
```

b. The code snippet below is a function called getLocation(), which is used to obtain location data from the GPS device.

```
String getLocation() {
  String msg = sendData("AT+LOCATION=2", "OK", 2000);
  if(msg != "") {
      msg.replace("OK", "");
      msg.trim();
      #ifdef DEBUG
      Serial.println("GPS Data: " + msg); // Debug print
      #endif
  }
  return msg;
}
```

3.2 Mobile Application

The design of the Android application, later named "MyTrack," uses Android Studio with Java as the programming base.

1. Login menu
   On the login menu, users are required to enter their email and password. Users must be registered and validated by the system. Figure 4 shows the login page of the application.

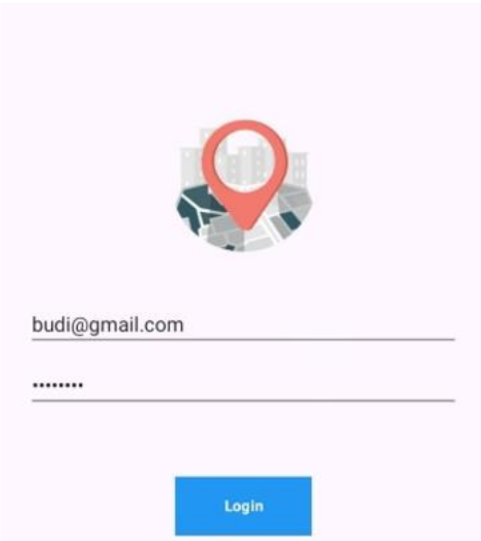


Figure 4. Login page view

2. My device menu
   The "My Devices" page in the application displays a list of smart wristbands being monitored. For example, in this study, there are two users: Mr. Jaja and Mr. Budi. The application monitors the users' body temperature and location, as well as the data validity status to ensure the accuracy of the information received. Figure 5 shows the my device which are monitored.

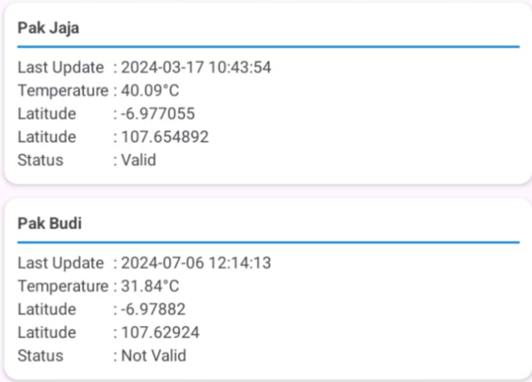


Figure 5. My device menu

3. Main feature
   The main page displays a map showing the location of the smart wristband user. Information such as the last update time, body temperature, latitude and longitude coordinates, and data status is displayed at the top of the map. This map helps visualize the user's location in real-time, making it easier for family members or relevant parties to monitor. Figure 6 shows the main interface of the application, containing a visualization of the location and other information.

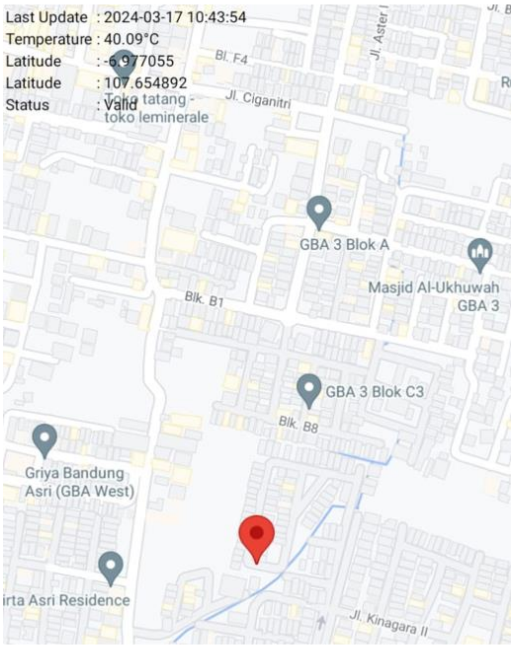


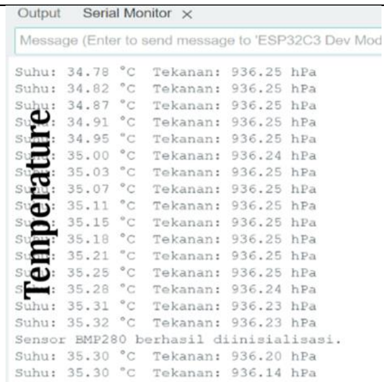
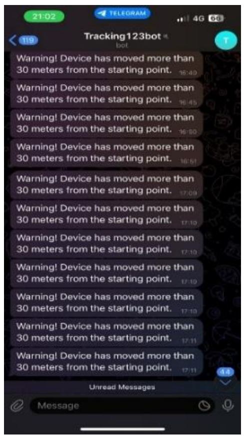
Figure 6. Map display

4. Results and Discussion

4.1 Hardware Testing

The hardware testing aims to evaluate the functionality and performance of each component, including the microcontroller, BMP 280 sensor, A9G sensor, and GSM/GPRS module, as well as to test the battery life. This testing process involves a detailed examination of how each component operates when connected in an integrated system. The testing ensures that each component functions properly according to its specifications and can communicate effectively with other components in the system. Every aspect of this testing is outlined in Table 1, which provides a detailed overview of the components tested and the results of each test, indicating the extent to which the components can be effectively used in the developed monitoring system.

Table 1. Hardware component testing results

No	Testing	Description	Result
1	Integration between ESP32 and BMP280 sensor in measuring body temperature	Well-integrated, data temperature sent properly	
2	Integration between ESP32 and A9Gboard Sensor in transmitting location data and ensuring that GSM/GPRS can transfer data to the cloud server	Coordinate data from GPS can be transmitted (outdoor), but indoors, the GPS data is not transmitted	
3	Integration of ESP32 in sending notifications via Telegram Bot when the user is outside the specified distance	Well-integrated, notification sent	
4	How long can this device operate?	Battery life about 5 hours	The device was turned on at 7:48 PM and stopped transmitting data at 12:43 AM.

From the test results presented in Table 1, it can be concluded that the proposed device can work well. It is proven that the device can read temperature and location, then send data to the server. In this test, battery life is also a critical issue of wearable devices (L. Wang et al., 2023). From the test, it is known that the device can operate within 5-hours. Battery life is still a shortcoming and also a challenge in the proposed device. Ideally a wearable device has a battery life of around 24 hours as an example of the Apple watch product (Vijayan et al., 2021). So, implementing potential methods to extend battery life, such as optimizing data transmission intervals (sleep mode) or using low-power modes, would be a choice for extend the battery life.

Table 2 shows the results of the temperature measurement comparison between the BMP280 sensor and a thermometer as a reference. Test results show that the device produces 98.5% accuracy in measuring temperature. The accuracy of the sensor was also tested mathematically using linear regression. The explanation that can be drawn from the data presented in Figures 7 and 8 is that there is a strong correlation between the temperature measured by the BMP280 sensor and the temperature measured by the thermometer. The regression model produced is quite effective in explaining this relationship, with an R-squared value of 0.777995 and a correlation value (Multiple R) of 0.88204. The graph also shows that most data points are close to the regression line, indicating that the BMP280 sensor measurements are fairly consistent with the thermometer measurements.

Table 2. Comparison between BMP280 Sensor and Thermometer

No	Temperature measured by BMP280 (°C)	Reference temperature (°C)
1	34.6	34.6
2	35.4	35.8
3	34.8	34.5
4	35.9	35.9
5	34.3	35.6
6	33.3	34.0
7	32.0	32.5
8	33.3	34.1
9	33.7	34.1
10	35.6	34.9

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.88204
R Square	0.777995
Adjusted R Square	0.750244
Standard Error	0.610916
Observations	10

Figure 7. Summary of output linear regression

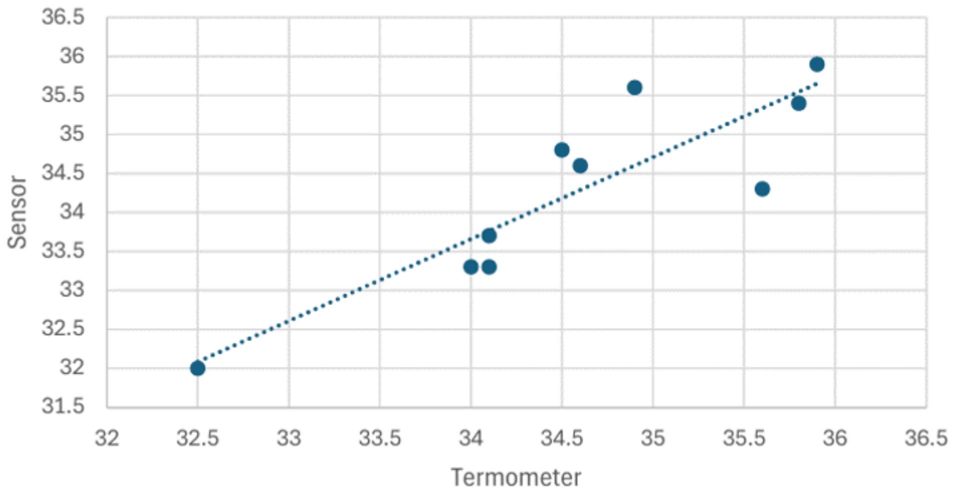


Figure 8. Summary of output linear regression

4.2 Database Testing

The following are the results when receiving data from the device, including a table containing the IP address, latitude and longitude from the GPS, location status (valid/invalid), temperature value, as well as the date and time the data was received from the sensor. Data is sent every 30 seconds, but may experience delays if the server is under load or the GSM network is disrupted. The results of this test are presented in Table 3.

Table 3. Database results from BMP280 and A9G sensors

No	*Ip_address*	*Latitude*	*Longitude*	*Is loc valid* 0/1	*temp*	*Alt:* *unit m*	*timestamps*
1.	10.147.40.238	-6.971317	107.630828	1	28.19	657.26	2024-07-06 16:46:36
2.	10.147.40.238	-6.971358	107.630230	1	27.88	657.27	2024-07-06 16:47:04
3.	10.147.40.238	-6.970962	107.628822	1	27.15	656.86	2024-07-06 16:47:34
4.	10.147.40.238	-6.969463	107.628857	1	26.67	658.10	2024-07-06 16:48:06
5.	10.147.40.238	-6.969405	107.628343	1	27.03	658.15	2024-07-06 16:48:34
6.	10.147.40.238	-6.969382	107.628322	1	27.73	658.13	2024-07-06 16:49:04
7.	10.147.40.238	-6.969338	107.628410	1	28.43	657.54	2024-07-06 16:49:35
8.	10.147.40.238	-6.969663	107.630120	1	29.08	656.48	2024-07-06 16:50:04
9.	10.147.40.238	-6.970652	107.631480	1	29.65	656.12	2024-07-06 16:50:34
10.	10.147.40.238	-6.970055	107.632378	1	30.35	654.69	2024-07-06 16:51:21

Database results which showed in Table 4, when the device is indoors or during rain causing GPS signal weakening.

Table 4. Database values when the device is indoors or in rainy conditions

No	*Ip_address*	*Latitude*	*Longitude*	*Is loc valid 0/1*	*temp*	*Alt* *unit m*	*timestamps*
1.	10.146.7.81	0.000000	0.000000	0	30.28	654.66	2024-07-06 17:31:38

2.	10.146.7.81	0.000000	0.000000	0	30.37	654.65	2024-07-06 17:32:07
3.	10.146.7.81	0.000000	0.000000	0	30.37	654.68	2024-07-06 17:32:36
4.	10.146.7.81	0.000000	0.000000	0	30.47	654.82	2024-07-06 17:33:08
5.	10.146.7.81	0.000000	0.000000	0	30.60	654.54	2024-07-06 17:34:06
6.	10.146.7.81	0.000000	0.000000	0	30.54	654.53	2024-07-06 17:34:38
7.	10.146.7.81	0.000000	0.000000	0	30.54	654.53	2024-07-06 17:35:37
8.	10.146.7.81	0.000000	0.000000	0	30.46	654.59	2024-07-06 17:36:07
9.	10.146.7.81	0.000000	0.000000	0	30.49	654.75	2024-07-06 17:36:36
10.	10.146.7.81	0.000000	0.000000	0	30.62	654.50	2024-07-06 17:37:06

4.3 Overall Performance Testing

The following are the final results of the designed application. The main focus is on the validity of the received location and temperature data, ensuring that the information displayed to the user is accurate and reliable. Figure 9 shows the data received from the server with a "valid" status.

Figure 9. Application view when receiving location and temperature data with "valid" status

Figure 10 shows the application display if the temperature data received from the server is “valid”, but the location data is “invalid”. This indicates that the bracelet is indoors or it is raining so the GPS signal is weak. In this case, the application will continue to display the last updated location before the GPS stopped sending data.

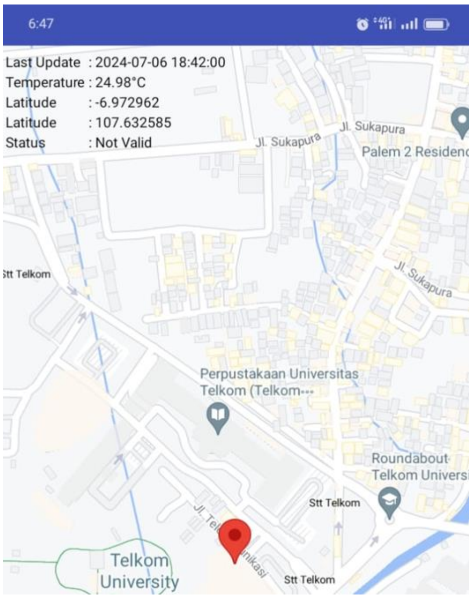


Figure 10. Application view when receiving location and temperature data with "invalid" status

4.4 Notification Testing Results via Telegram when User is Outside the Area

The following are the results of the notification test when the wristband is more than 30 meters away from the designated point. Figure 11 shows the warning notification on Telegram when the wristband user exits the specified area.

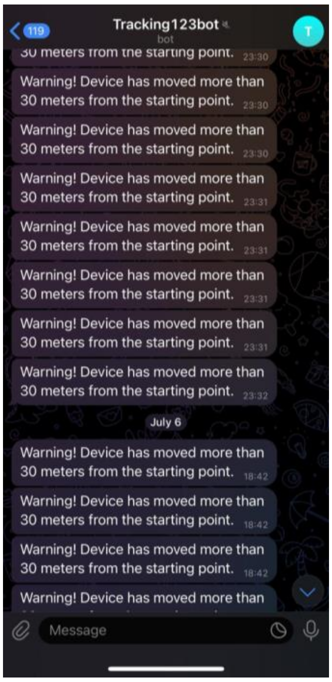


Figure 11. Warning notification when user out of specified area

From the tests that have been carried out, it can be concluded that the proposed device can work properly according to the initial design. In temperature measurement, the device produces an accuracy of 98.5% compared to the reference thermometer. In GPS testing, the device can send location coordinates accurately in outdoor conditions. However, in indoor device conditions, the latitude and longitude data are null which is marked with the status "not valid" in the application. When the device is outside the specified coverage, the system will automatically send an alarm to the concerned person via Telegram bot. Battery life testing shows that the device can run well in 5 hours. In this preliminary design, the vital parameter measured is only body temperature compared to similar devices that measure many vital parameters as reported in previous studies (Gao et al., 2016; Hadiyoso et al., 2021; Wu et al., 2023). However, perhaps the advantage of the proposed device is its ergonomic wearable design and has tracking features.

5. Conclusion

The research has successfully realized a smart wristband equipped with temperature and GPS sensors, as well as communication capabilities. The device integrates an A9G board, BMP 280 sensor, and Mini ESP32. Designed to resemble a wristwatch, it is compact, lightweight, wearable, and ergonomic. It operates on a rechargeable battery and transmits temperature and location data in real-time via GSM/GPRS network to a mobile application. The test results indicate that the device produces accuracy of 98.5% in detecting body temperature. The proposed device also provides consistent notifications through a Telegram bot when certain thresholds are exceeded or out of the specified area. The battery life test results show that the device can work properly for approximately 5 hours. Battery life is a serious concern for future research. Power saving methods and low power hardware designs can be alternatives to be developed. With this device, it is hoped that it can support elderly care, thereby improving their quality of life and reducing dependence on others.

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