Body Temperature Classification System Based on Fuzzy Logic and The Internet of Things

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Abstract –Health technology has become more efficient thanks to telecommunications and information technology. One of the utilizations is IoT detecting a person's body temperature condition. This research aims to produce a tool that can classify human body temperature by implementing fuzzy logic methods and the Internet of Things so that early prevention can be carried out against hyperthermia and hypothermia sufferers and can be used as advice for further examination to doctors. The phases in this study are analysis requirement, system design, implementation, and testing. The tools incorporated in this system are intended to measure body temperature and can classify the measured body temperature into specific categories. This research utilizes the Sensor Proximity E18-D80nK to detect the presence of an object concerning the sensor. Additionally, the system employs MLX90614 sensors for temperature measurement. The results of this research are that the use of the DHT22 sensor for measuring room temperature and the MLX80614 sensor for non-contact body temperature respectively produces a high level of accuracy, namely 98.22% and 98.29%. In addition, the implementation of the fuzzy logic algorithm succeeded in achieving 100% accuracy in classifying body temperature data, showing the effectiveness of this method in detecting human body temperature.

Keywords: Fuzzy logic, IoT, Health Technology.

I. INTRODUCTION

Hospitals are highly expected to provide excellent and fast services so patients feel safe and comfortable conducting medical examinations[1]. Health is essential in all human activities. Regular health monitoring is required to ensure that indicators of failing health can be discovered and treated as soon as possible[2]. Body temperature is one of the crucial indicators of human health[3].

Body temperature is also affected by the temperature and humidity level of the surrounding air. Higher air temperature is proportional to higher air humidity levels. The high level of both forces the body to fight it[4]. The same thing is also described by[5], environmental temperature has a considerable impact on a person's body temperature. At a certain level, a person can be exposed to hypothermia and hyperthermia, where these conditions can endanger a person if not treated quickly. Direct, unprotected exposure to extreme temperatures affects the processes and mechanisms living things use to maintain constant conditions. This condition is known as homeostasis, meaning the body functions generally despite changing environmental conditions [6]. Most deaths or illnesses associated with exposure to ambient temperatures are preventable, but the wrong choice of casualties or late reporting of patients often causes them [7].

Health technology has become more efficient thanks to telecommunications and information technology. Disease testing should be completed as soon and efficiently as possible[8]. Most body temperature measurements use widespread thermometers that meet SNI standards[9].

Several previous studies are related to detecting a person's body temperature. [7] also researched the application of fuzzy logic to see hypothermia and hyperthermia in IoT-based humans using DS18B20 and pulse sensors. As for this research, it succeeded in catching a person's body temperature. [10] researched IoT-based body temperature detection using Node MCU and LM35 sensors to measure a person's body temperature. By using Android as an interface, a detection system has been created. [11] researched implementing a heart rate and body temperature monitoring system using pulse sensors and DS18B20 and Blynk Applications for the interface. This research does not use fuzzy logic based on existing inputs as decision support.

Based on these studies, the author wants to modify and improve the tool by applying fuzzy logic and adding an environmental temperature measuring sensor. It can be seen that no one has done research using the MLX900614 body temperature sensor and the DHT11 sensor to detect room temperature. Room temperature is included as one of the indicators because, according to [5] environmental temperature impacts a person's body temperature. By using fuzzy logic, the assessment decision can be more accurate.

The urgency of this research is the existence of a tool that can classify human body temperature non-contact and send body temperature data via the internet to web monitoring for early detection of a person's body condition. If the body temperature is abnormal, it can be used as an indicator for immediate treatment by a doctor. The tool is expected to classify body temperature using the fuzzy logic method. Fuzzy logic is very appropriate for use in microcontroller-based systems. The microcontroller used in the system is the ESP32 node MCU, while the sensors used in the system are the MLX900614 non-contact temperature sensor and the DHT11 environmental temperature sensor. There is an early warning using a buzzer.

This research aims to produce a tool that can classify human body temperature by implementing fuzzy logic methods and the Internet of Things so that early prevention can be carried out against hyperthermia and hypothermia sufferers and can be used as advice for further examination to doctors.

II. METHODS

A. System Block Diagram

The temperature classification system in this research operates as elucidated in the block diagram in Figure 1. The stages employed in this study encompass analysis, system design, device fabrication, and testing. The tools incorporated in this system are intended to measure body temperature and can classify the measured body temperature into specific categories. This research utilizes the Sensor Proximity E18-D80nK to detect the presence of an object concerning the sensor. Additionally, the system employs Thermocouple Type K and MLX90614 sensors for temperature measurement.

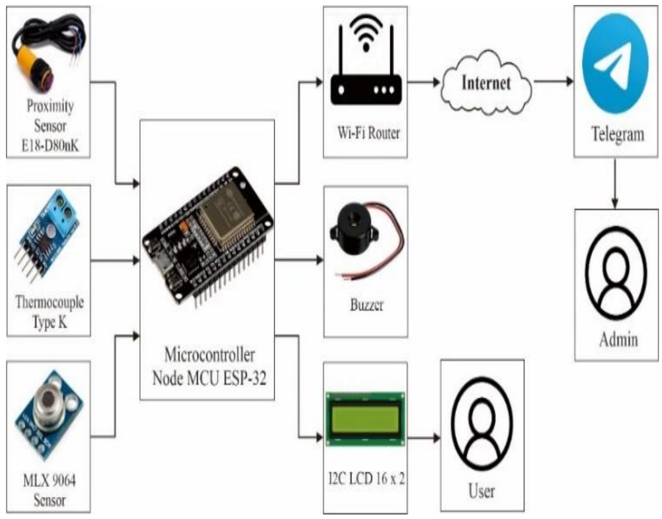

Figure 1. System Block Diagram

B. Designing of Hardware

In this study, a hardware system was developed as depicted in Figure 2. The hardware design in Figure 2 displays the wiring diagram, while Figure 3 illustrates the schematic diagram of each electronic component when integrated into a system within this research. The objective of this design is to discern the wiring configuration of each utilized device. The electronic components employed include ESP32, Thermocouple, LCD 16×2 I2C, Proximity Sensor, MLX9064, and Buzzer.

C. Node MCU ESP32

Node MCU is applied as a central data processing device, receiving data from sensors, processing analaog data and digital data. Giving commands to output devices. NodeMCU is used in systems that implement the Internet of Things (IoT) in the system built [12]. The NodeMCU32 incorporates the ESP32 module (ESP-WROOM-32) manufactured by a company named ESPRESSIF. This NodeMCU32 outperforms the Node MCU8266 as it is equipped with both Wi-Fi and Bluetooth modules on a single board, enhancing its practicality and usability. [13]. The NodeMCU32 has several GPIO (General Purpose Input/Output) pins to process both input and output [14]. The specifications of the NodeMCU32 can be found in Table 1.

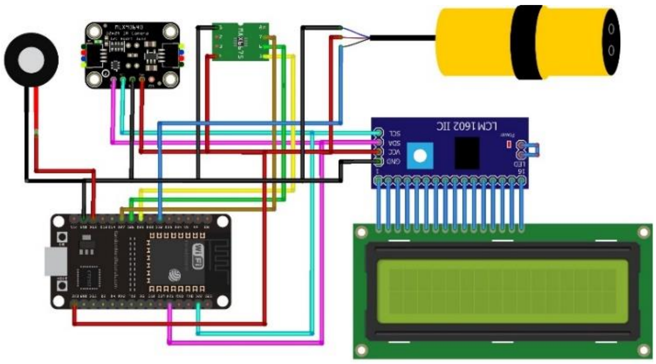

Figure 2. Wiring Diagram Hardware design

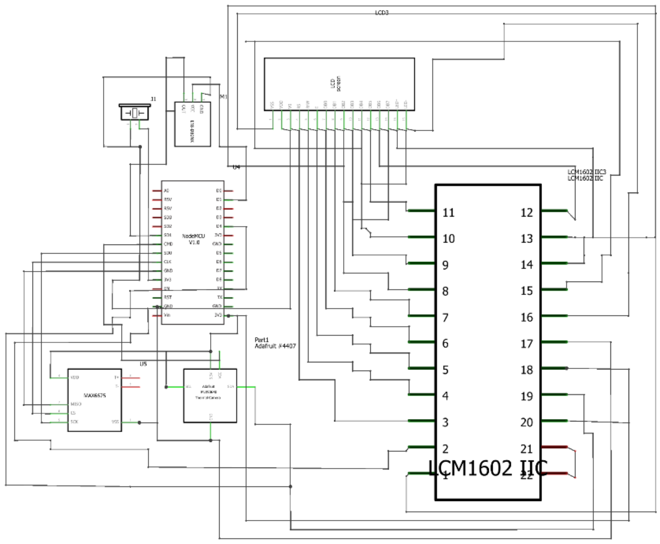

Figure 3 Hardware Design Schematic Diagram

Table 1. NodeMCU32 Specification

No.	Specification	Description
1	CPU	Tensilica Xtensa LX6 32-bit microprocessor
2	Board Type	DOIT ESP32 V.1
3	Voltage	2.7-5 Volt DC
4	Module	ESP-WROOM-32
5	GPIO	30 ports
6	Board Size	52 x 28.5 mm
7	ROM	448 KiB
8	SRAM	520 KiB
9	Bluetooth	Bluetooth 4.2 dan BLE
10	Wi-Fi	2.4 GHz

D. Thermocouple

The function of a thermocouple is to detect temperature. A thermocouple is a temperature sensor composed of a pair of dissimilar conductors joined together either by welding or fused together on one end, forming a "hot junction." The measurement junction contains free ends that are connected to a "cold junction" or reference junction. The temperature difference between the measurement junction and the reference junction of this device functions as a thermocouple and can generate a small DC voltage. The output voltage of the thermocouple is directly proportional to the temperature difference between the measurement (hot) and reference (cold) junctions. The constant ratio is referred to as the Seebeck coefficient and ranges between 5 to 10 volts per degree Celsius [15]. This research utilizes a type K thermocouple due to its widespread use and cost-effectiveness. Type K thermocouples are available for temperature ranges from -200°C to +1200°C.

Their sensitivity is 41v/°C [15]. In this research, thermocouples are used to detect changes in body temperature.

E. E18-d80Nk Proximity Sensor

The E18-D80nK proximity sensor is designed to detect the presence of an object. The presence of an object is categorized into two logic states, labeled as "1" and "0." If the object is positioned outside the sensor's range, the sensor output will be "high" or "1," indicating the absence of an object. Conversely, when the object is in front of the sensor and within its range, the sensor output will be "low" or "0," indicating the presence of an object [16].

In this study, the Proximity Sensor E18-D80nK is utilized to detect the presence of an object, specifically individuals whose body temperatures will be measured and classified.

Table 2. E18-D80nK Proximity Sensor Specification

No.	Specification	Details
1	Detection Range	3-80 cm
2	Input Voltage	5 V DC
3	Output Voltage	5 V DC
4	Output Current	100 mA
5	Output Type	NPN NO (Normally Open)
6	Response Time	2 ms
7	Detection Angle	15 degrees
8	Type of Sensor	Infra Merah
9	Operating Temperature	-25 s/d +55 °C
10	Size	Diameter: 17 mm, Length: 70 mm
11	Cable	Brown: VCC +5 V DC, Blue: GND -5 V DC, Black: Output

F. MLX90614

The MLX90614 is an infrared thermometer used for non-contact temperature measurement. This sensor operates by absorbing infrared radiation emitted by an object. As it doesn't physically touch the measured object, it ensures object sterilization. It offers a wide measurement range from -70°C to +380°C. The IR-sensitive thermopile detector chip and ASIC signal conditioner are integrated within the same TO-39 sensor packaging. The integrated signal conditioner in the MLX90614 includes a low-noise amplifier, 17-bit ADC, and a powerful DSP unit, achieving high accuracy and resolution in temperature measurement. Infrared radiation spans a spectrum with wavelengths from 0.7 to 1000 microns, but only the 0.7-14-micron range is utilized for temperature measurement. The photosensitive detector in the sensor converts infrared energy into an electric signal that is proportionate to the object's temperature. Data output from the MLX90614 sensor can be read through the I2C/TWI protocol[16].

G. LCD 16×2 I2C

The LCD is an electronic component that serves as a display for data, letters, characters, and graphics. Additionally, an LCD is a type of electronic display formed using CMOS logic technology, which operates by not emitting light but rather reflecting the ambient light onto the front lit or transmitting light from a backlit source.

H. Buzzer

The buzzer is an electronic component capable of generating sound vibrations in the form of sound waves. It serves as a transducer typically used as an audible indicator for processes that have met certain conditions. Buzzer types are divided into two categories: Active buzzer (static) and passive buzzer (dynamic). In this study, the buzzer is employed to provide warnings when body temperature reaches a specific level categorized as dangerous. Further details regarding the specifications of the buzzer can be found in Table 2.

Table 3. Buzzer Specification

No	Specification	Details
1	Voltage	4-8 Volt DC
2	Frequency	2400 Hz

I. Hardware Design

The development of the body temperature classification system in this research requires software in the form of Node MCU programming with Fuzzy logic. Fuzzy logic is defined as a type of logic that deals with multiple values and relates to uncertainty and partial truth. Its objective is propositions or statements that express a fact. The steps of the fuzzy logic method include processes such as fuzzification, inference, and defuzzification, as illustrated in Figure 4.

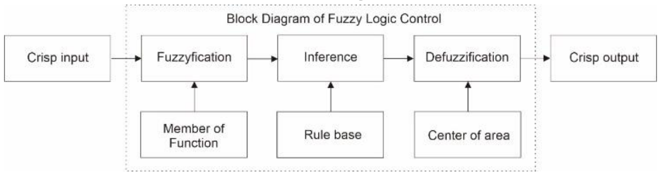

Figure 4. Diagram Fuzzy Logic Control

J. Fuzzification Process

This process involves inputting certain truth values which are then converted into fuzzy inputs in the form of linguistic values whose semantics are determined based on the membership function.

1. Body Temperature Membership Function (Sensor MLX900614)

The room temperature membership degree of the MLX900614 sensor has three linguistic variables: Low, Medium and High.

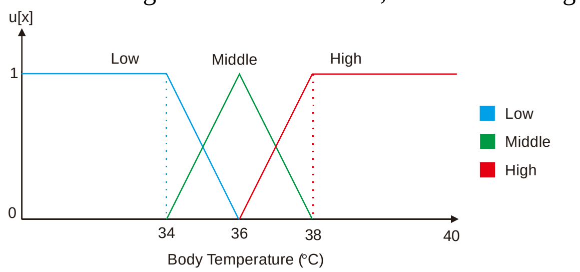

Figure 5. The membership function of body temperature

The fuzzy value of the membership function on Figure 5 is:

$$\mu\,[\text{Body Temperature (Low)}] = \begin{cases} 1 & ; x \leq 34 \\ \dfrac{36 - x}{36 - 34} & ; 34 \leq x \leq 36 \\ 0 & ; x \geq 36 \end{cases} \qquad (1)$$

$$\mu\,[\text{Body Temperature (Middle)}] = \begin{cases} 0 & ; x \leq 34 \text{ and } x \geq 38 \\ \dfrac{x - 34}{36 - 34} & ; 34 \leq x \leq 36 \\ \dfrac{38 - x}{38 - 36} & ; 36 \leq x \leq 38 \end{cases} \qquad (2)$$

μ [Body Temperature (High)] = $\begin{cases} 0 & ; x \le 36 \\ \frac{x-36}{38-36} & ; 36 \le x \le 38 \\ 1 & ; x \ge 38 \end{cases}$ (3)

2. Room Temperature Membership Function (Thermocouple K)

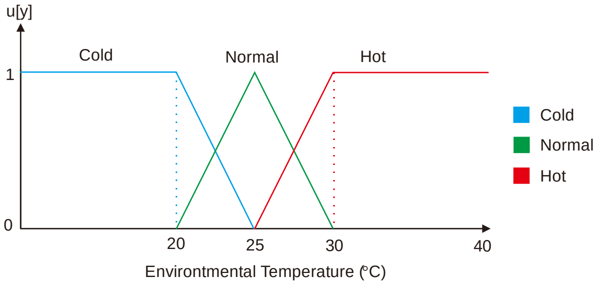

Figure 6. The membership function of environmental temperature

μ [Room Temperature (Low)] = $\begin{cases} 1 & ; x \le 20 \\ \frac{25-x}{25-20} & ; 20 \le x \le 25 \\ 0 & ; x \ge 25 \end{cases}$ (4)

μ [Room Temperature (Middle)] = $\begin{cases} 0 & ; x \le 20 \text{ and } x \ge 30 \\ \frac{x-20}{24-20} & ; 20 \le x \le 25 \\ \frac{30-x}{30-25} & ; 25 \le x \le 30 \end{cases}$ (5)

μ [Room Temperature (High)] = $\begin{cases} 0 & ; x \le 25 \\ \frac{x-25}{30-25} & ; 25 \le x \le 30 \\ 1 & ; x \ge 30 \end{cases}$ (6)

a. Inference Process

This process involves the creation of fuzzy rules.

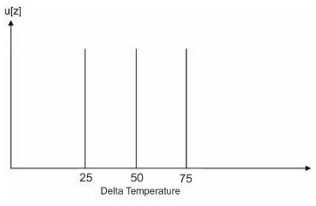

Figure 7. Fuzzy output

The designed fuzzy inference is divided into 3 categories: Hypothermia, Normal, and Fever. The designed rule base is as follows:

- If body temperature is low and room temperature is normal, then Hypothermia.
- If body temperature is low and room temperature is cold, then Hypothermia.
- If body temperature is low and room temperature is hot, then Hypothermia.
- If body temperature is medium and room temperature is normal, then Normal.
- If body temperature is medium and room temperature is cold, then Normal.
- If body temperature is medium and room temperature is hot, then Normal.
- If body temperature is high and room temperature is normal, then Indicated Fever.
- If body temperature is high and room temperature is cold, then Indicated Fever.
- If body temperature is high and room temperature is hot, then Indicated Fever.

There are 3 sets of output membership functions: Hypothermia, Normal, and Fever.

Table 4. Fuzzy role

Body Temperature (i)	Room Temperature (j)		
	Cold	Normal	Hot
Low	Hypothermia	Hypothermia	Hypothermia
Medium	Normal	Normal	Normal
High	Fever	Fever	Fever

The temperature parameter is referenced in the paper as a source for determining temperature. To enable the sensor to capture both body and room temperatures simultaneously, an existing library with I2C communication can be utilized.

b. Defuzzification Process

This process is a composition process, namely the result of clipping all the fuzzy rules so that we get a single fuzzy set.

y*= (rule00* Hypothermia) + (rule01* Hypothermia) + (rule02* Hypothermia) + (rule10*Normal) + (rule11* Normal) + (rule12* Normal) + (rule20* Fever) + (rule21* Fever) + (rule22* Fever) / defuzzy + rule[i][j]. (7)

In programming the body temperature classification system, the first step involves creating a flowchart as explained in the following Figure 8 :

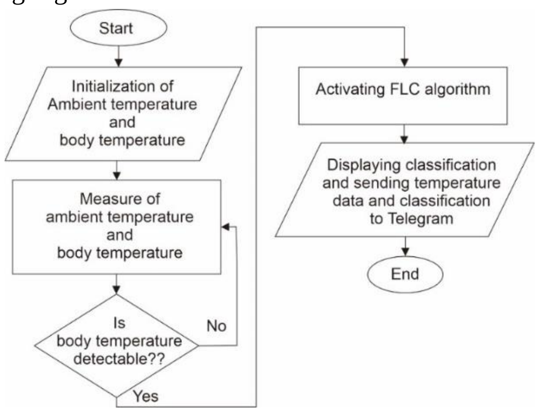

Figure 8. Flowchart of software design

III. RESULT AND DISCUSSION

A. Hardware Design Results

The design of a hardware system for the classification of body temperature measurements based on fuzzy logic algorithms has been successfully compiled. The components involved in the construction of this hardware include the Node MCU ESP32 microcontroller, 9-volt adapter, LM2596 step down regulator, DHT22 temperature sensor, MLX90614 infrared sensor, proximity sensor, and 16x2 LCD screen.

In the early stages, this system utilizes the Node MCU ESP32 microcontroller as the main brain that manages and processes data from the installed sensors. The 9-volt adapter is responsible for providing the power needed by the system as a whole, while the LM2596 step down regulator plays a role in stabilizing the voltage to match the needs of the microcontroller and other components.

The DHT22 temperature sensor is used to accurately measure the ambient air temperature, while the MLX90614 infrared sensor is tasked with measuring body temperature in a non-contact manner with high precision. The proximity sensor is used to detect the presence of objects or users around the device, providing the ability to adjust the system's response according to the situation. The 16x2 LCD screen serves as the user interface to display the measured temperature information as well as the classification results based on the applied fuzzy logic algorithm. The results of the hardware design can be shown in Figure x

With the integration of these components, the system is able to provide accurate and responsive body temperature measurements, as well as the ability to classify the temperature according to predefined fuzzy rules. This provides advantages in various applications, including in healthcare, security, and artificial intelligence.

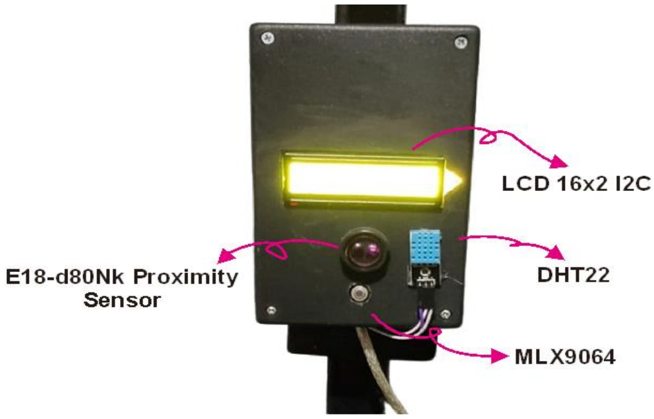

Figure 9. Hardware design result

B. Software Design Results

The construction of a body temperature classification monitoring application has been successfully completed. This application is a mobile solution that allows users to monitor body temperature in real-time remotely. Through this application, users can easily monitor their own or other people's body temperature without having to be in the same location. Software design results can be shown in Figure 10.

By using mobile technology, this application provides high ease of access for users. They can download the app on their mobile devices such as smart phones or tablets, and start monitoring body temperature instantly. Without being bound by distance, users can monitor their body temperature from anywhere, be it from home, workplace, or while travelling.

Not only that, the app also enables automatic classification of body temperature based on pre-defined algorithms. By doing so, users can receive more detailed information on the status of their body temperature, such as whether it is normal, high, or even indicative of potential health issues that need further attention.

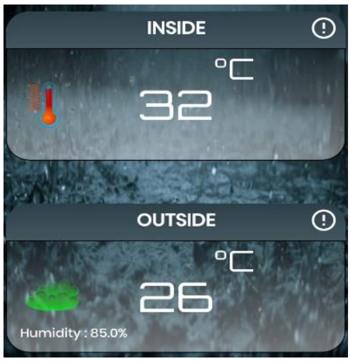

Figure 10. Software design result

The successful development of this application offers great benefits in a variety of contexts, including individual health surveillance, public health monitoring, and countermeasures against the spread of disease. By utilising mobile technology and intelligent body temperature classification, this app can be an effective tool in better monitoring and maintaining health.

C. Temperature and Humidity Testing

Testing room temperature and humidity using a DHT22 sensor aims to evaluate the extent of the accuracy and reliability of the DHT22 sensor in measuring certain environmental conditions. The test results will help determine the extent to which the DHT22 sensor is reliable for temperature and humidity monitoring applications.

In testing the room temperature and humidity using the DHT22 sensor, the materials used include a DHT22 sensor, digital thermometer, microcontroller (Node MCU ESP32) to read data from the DHT22 sensor, connecting cables, and a computer to monitor the measurement results. In addition, to ensure measurement accuracy, calibration of the digital thermometer and DHT22 sensor was carried out before testing.

The procedure for testing room temperature and humidity using a DHT22 sensor compared to a digital thermometer begins with the preparation of tools and materials, including calibration of the digital thermometer and DHT22 sensor. The DHT22 sensor and digital thermometer are installed at the same location in the room, and then connected to the microcontroller to read the data. Temperature and humidity measurements were taken simultaneously, and the results were recorded for comparison. Measurements are repeated several times at different times to ensure consistency of results. Next, the measurement results from the DHT22 sensor were compared with a digital thermometer, and the difference between the two was calculated. The analyzed results are used to determine the extent to which the DHT22 sensor is reliable, providing conclusions regarding its accuracy and consistency.

Table 5. Room temperature measurement results by thermometer and DHT22 sensor

No	Measurement of room temperature		Temperature difference (°C)	Error (%)
	Thermometer Digital (°C)	DHT22 Sensor (°C)		
1	29	30,8	1,8	6,21
2	30,4	31	0,6	1,97
3	30,6	31,2	0,6	1,96
4	30,9	31,5	0,6	1,94
5	31,3	31,7	0,4	1,28
6	31,7	31,9	0,2	0,63
7	31,9	32	0,1	0,31
8	32	32,1	0,1	0,31
9	32,2	32,3	0,1	0,31
10	32,4	32,5	0,1	0,31
…	…	…	…	…
…	…	…	…	…
45	36	37,1	1,1	3,06
46	36,1	37,3	1,2	3,32
47	36,2	37,4	1,2	3,31
48	36,4	37,6	1,2	3,30
49	36,6	37,7	1,1	3,01
50	36,7	37,8	1,1	3,00
Average			0,606	1,78

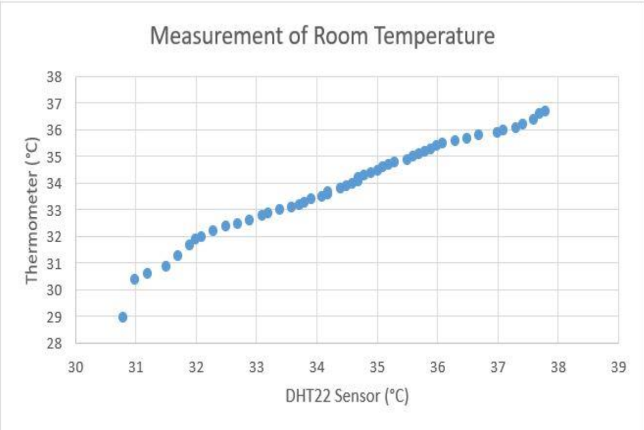

Figure 11. Room temperature measurement graph

Based on the test results in Table 5, there is a temperature difference of 0.6 degrees Celsius between the value measured by the DHT22 sensor and the digital thermometer. However, despite the temperature difference, the accuracy of the DHT22 sensor reaches 98.22%, which means that the sensor overall provides very accurate results in measuring temperature. Figure 9 shows that the temperature measured by the DHT22 sensor can follow the measurement made by the thermometer. The high accuracy indicates that the DHT22 sensor is reliable for applications that require precise temperature measurements. Possible causes of the difference could come from factors such as improper calibration, differences in the surrounding environment that affect sensor performance, or measurement errors. Therefore, further evaluation is needed to understand the exact cause of the discrepancy and ensure optimal use of the DHT22 sensor in the system.

Table 6. Room humidity measurement results by thermometer and DHT22 sensor

No	Measurement of room humidity		Humidity difference (%)	Error (%)
	Thermometer Digital (%)	DHT22 Sensor (%)		
1	75	77,4	2,4	3,20
2	73	77	4	5,48
3	73	76,5	3,5	4,79
4	73	75,7	2,7	3,70
5	73	75	2	2,74
6	73	74,4	1,4	1,92
7	73	74,1	1,1	1,51
8	73	73,8	0,8	1,10
9	73	73,2	0,2	0,27
10	73	72,7	0,3	0,41
…	…	…	…	…
…	…	…	…	…
45	62	60,9	1,1	1,77
46	62	60,2	1,8	2,90
47	62	60,1	1,9	3,06
48	61	59,7	1,3	2,13
49	61	59,4	1,6	2,62
50	61	59,1	1,9	3,11
Average			1,812	2,63

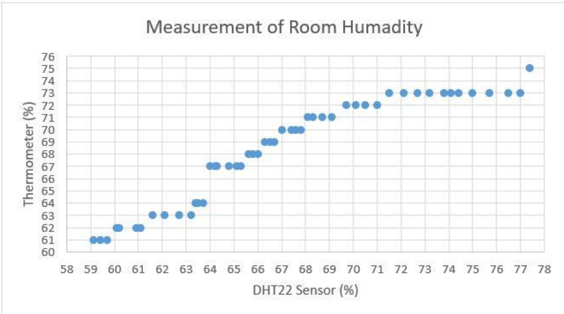

Figure 12. Room humidity measurement graph

Based on the data analysis listed in Table 6, it shows that there is a humidity difference of 1.812% between the value measured by the DHT22 sensor and the digital thermometer. In addition, there is a sensor measurement error of 2.63% with an accuracy level of 97.37%. Based on Figure 10, it shows that the humidity measurement produced by the DHT22 sensor is close to the humidity measurement results by a digital thermometer. Thus, it can be concluded that the DHT22 sensor shows a very good level of reliability, as evidenced by its high level of accuracy.

D. Non-Contact Body Temperature Testing

To conduct non-contact body temperature testing using the MLX90614 sensor, the materials used include the MLX90614 sensor which is a non-contact infrared device specifically designed to measure human body temperature with high accuracy. In addition, the test results of the sensor are compared with other non-contact body temperature measuring devices, thus allowing evaluation of the accuracy of the MLX90614 sensor. The required test object is a human subject whose body temperature will be measured using the sensor. In addition, the use of data processing software is required to record and analyse the measurement results more thoroughly. Through the use of all these materials, the test aims to evaluate the ability of the MLX90614 sensor to measure human body temperature non-contactly with sufficient accuracy and consistency, and verify its reliability for use in medical or similar applications.

The non-contact body temperature testing procedure using the MLX90614 sensor begins with the preparation of materials and calibration of the sensor according to applicable standards. The human subject whose body temperature will be measured is placed within a distance that matches the sensor specifications to ensure measurement accuracy. Body temperature measurements were taken using the MLX90614 sensor, followed by the same measurements using another body temperature measuring device for comparison. Measurement results from both methods were recorded and analysed using data processing software. The analysis was conducted to assess the accuracy, consistency, and reliability of the MLX90614 sensor in measuring human body temperature without direct contact.

The results of body temperature testing using the MLX90614 sensor are documented in Table 7, involving 25 respondents who supplied their body temperature data. The test data of the MLX90614 sensor was compared with the measurements of a non-contact digital thermometer. The highest error rate recorded in the body temperature measurement was 5.29%, while the lowest error reached 0%. The average error resulting from this test was 1.71%. The overall measurement accuracy of the MLX90614 sensor reached 98.29%. Further analysis shows that the MLX90614 body temperature sensor exhibits good stability in body temperature measurement, and exhibits a low error rate, as illustrated in the results presented in Figure 11.

E. Fuzzy Logic Testing Results

Fuzzy logic is a mathematical approach that can handle uncertainty and non-uniformity of data by replacing the binary approach (true or false) with membership values within a certain range. In the context of body temperature measurement, especially in the health aspect, having the ability to interpret data with higher levels of uncertainty is very important. For example, when taking a person's temperature, the results may not unequivocally indicate whether a person is experiencing a fever or not. Fuzzy logic allows us to address this uncertainty by assigning membership values to each category, such as hypothermia, normal, and faver.

In this research, the fuzzy variables used are human body temperature and room temperature. The human body temperature variable is divided into three linguistic categories, namely low, medium, and high, while the room temperature variable is divided into cold, normal, and hot. There are three sets of output membership functions that represent the condition of the human body, namely hypothermia, normal, and fever, so there are a total of nine rules in this study. defuzzification applied is to use the average method. The test results of the fuzzy algorithm for measuring body temperature can be shown in Table 8.

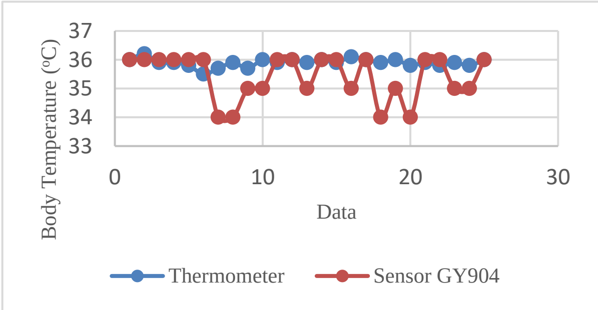

Figure 13. Body temperature test result graph

Table 7. MLX90614 body temperature sensor test results

No	Name	Temperature Thermometer	Temperature MLX90614 Sensor	Temperature difference	Percentage error
1	Wisnu	36	36	0	0,00%
2	Hadi	36,2	36	0,2	0,55%
3	Mia	35,9	36	0,1	0,28%
4	Fadli	35,9	36	0,1	0,28%
5	Memi	35,8	36	0,2	0,56%
6	Wijayanti	35,5	36	0,5	1,41%
7	Ferdinan	35,7	34	1,7	4,76%
8	Haikal	35,9	34	1,9	5,29%
9	Ardika	35,7	35	0,7	1,96%
10	Fatir	36	35	1	2,78%
11	Amelia	35,9	36	0,1	0,28%
12	Fadilah	36	36	0	0,00%
13	Rafa	35,9	35	0,9	2,51%
14	Lala	36	36	0	0,00%
15	Anggun	35,9	36	0,1	0,28%
16	Alfina	36,1	35	1,1	3,05%
17	Melinda	36	36	0	0,00%
18	Cahya	35,9	34	1,9	5,29%
19	Ririn	36	35	1	2,78%
20	Ivan	35,8	34	1,8	5,03%
21	Lutfi	35,9	36	0,1	0,28%
22	Kiki	35,8	36	0,2	0,56%
23	Fira	35,9	35	0,9	0,025%
24	Dinda	35,8	35	0,8	0,022%
25	Bidari	36	36	0	0%
	AVERAGE			0,612	1,71%
	AKURASI			98,29%	

In Table 8, there are records of 15 experiments that have been conducted. Through this series of experiments, the fuzzy algorithm was successfully used to categorise human body temperature measurements into three main categories, namely fever, normal and hypothermia. The fuzzy logic experiment can be shown in Figure 12. The results showed that the algorithm achieved a very high accuracy rate of 100%. This excellent performance shows that the fuzzy algorithm is able to cope with the uncertainty in human body temperature measurements very effectively and reliably in the context of classifying health conditions based on body temperature.

Table 8. The test results of the fuzzy algorithm for measuring body temperature

No	Body Temperature (ºC)	Room Temperature (ºC)	Fuzzy Output	Description
1	36	31	50	Normal
2	36	31	50	Normal
3	35	31	34	Hypothermia
4	36	31	50	Normal
5	36	31	50	Normal
6	36	31	50	Normal
7	36	31	50	Normal
8	37	31	50	Normal
9	36	31	50	Normal
10	36	31	50	Normal
11	37	31	50	Normal
12	36	31	50	Normal
13	38	31	75	Faver
14	36	31	50	Normal
15	36	31	50	Normal

Figure 14. Fuzzy logic testing

IV. CONCLUSION

From the results of the body temperature measurement classification research using the fuzzy logic method, it can be concluded that the use of the DHT22 sensor for room temperature measurement and the MLX90614 sensor for non-contact body temperature resulted in high accuracy rates of 98.22% and 98.29%, respectively. In addition, the implementation of the fuzzy logic algorithm achieved 100% accuracy in classifying the body temperature data, demonstrating the effectiveness of the method in detecting abnormal body temperature. The system equipped with a mobile application enables remote monitoring, providing convenience and flexibility for users. These findings confirm the potential use of fuzzy logic method in classifying body temperature is excellent and has high accuracy.

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