Volume 8, Issue 9, pp. 1-5, 2024.
International Journal of Scientific Engineering and Science
ISSN (Online): 2456-7361

# Prototype of Non-Contact Clinical Thermometer Calibrator Device Using Mamdani Fuzzy Logic Control System

Fakhrul Dewantoro[1], Bustanul Arifin[2]
[1,2]Department of Electrical Engineering, Universitas Islam Sultan Agung, Semarang, Indonesia

***Abstract*****—** *Elevated body temperature is a common sign of various medical conditions, including viral or bacterial infections such as SARS-CoV-2 and influenza. Non-contact thermometers provide a safe way to measure temperature without direct contact, reducing the risk of spreading disease. However, measurement accuracy and consistency require proper calibration tools. This study developed a prototype of a non-contact thermometer calibrator using the Mamdani fuzzy logic control system. This tool is designed to improve the efficiency and flexibility of the calibration process compared to conventional methods that heat water. Mamdani fuzzy logic control is applied to the Positive Temperature Coefficient component to regulate temperature through fuzzification, rule base, and defuzzification stages. The results showed that the calibrator tool with the Mamdani fuzzy logic control system can calibrate a clinical non-contact thermometer with an accuracy of ±0.5°C over a temperature range of 35°C, 39°C, and 42°C. This system proved effective in controlling temperature during the calibration process, achieving the research objective of applying the Mamdani fuzzy logic method in a temperature control system to obtain a stable temperature.*

***Keywords*****—** *Fuzzy Logic Control, Non-contact Thermometer, and Temperature Calibration.*

## I. INTRODUCTION

Increased body temperature or fever can be a common symptom of a medical condition, such as a viral or bacterial infection, and SARSCoV-2 or influenza. People with high fever symptoms can be recognized simply by touching their hands to distinguish between normal and high temperatures, but this method is less accurate so it requires a body temperature measuring tool. The body temperature measuring tool or thermometer commonly used today is a contact thermometer, which must be attached to the human body to be used. In addition to contact thermometers, there are also non-contact thermometers where the distance between the tool and the object being measured is 3-5 centimeters [1]. Non-contact thermometers allow measuring the temperature of a body or object without direct contact. Non-contact thermometers can reduce the risk of spreading disease and contamination and are fast in helping to diagnose patients [2].

Temperature measurement using a non-contact thermometer has clinical effectiveness when compared to contact thermometers which are currently often used in hospitals and various industries. Non-contact thermometers require high accuracy so they require a calibrator that can guarantee the accuracy and consistency of measurement results. Calibration is an important process to ensure that the measuring instrument operates according to the established standards by comparing the thermometer to the non-contact thermometer calibrator. Without proper calibration, measurement results can be inaccurate, which can have a negative impact on decisions or diagnoses [1].

To carry out calibration activities, it is carried out at room temperature conditions of 25 ± 5°C. The maximum temperature that is still acceptable for calibration activities is usually no more than 30°C. If it exceeds 30°C, it can cause inaccurate measurements due to the thermal effects on the instrument and the object being measured [2]. Non-contact thermometer calibrators are widely available on the market, but these calibrators still use conventional methods by heating water to a certain temperature and then carrying out calibration measurement activities [3]. This is considered less flexible and often takes longer for the calibration process. The calibrator for the non-contact thermometer in question is a calibration bath with a temperature range of 35.5°C- 42°C which uses liquids such as water may require periodic fluid replacement and attention to fluid quality to prevent corrosion or contamination [4].

## II. THEORETICAL REVIEW

Prototype of Non-contact Thermometer Calibrator Tool by implementing fuzzy logic as its temperature control, This is where the role of Mamdani fuzzy logic control system becomes relevant. This fuzzy logic control system is expected to be able to control the temperature on the calibrator tool so that it can operate stably and accurately.

### A. Non-contact Thermometer

Thermometer measurements are divided into three main types of thermometers that measure temperature, namely electronic contact thermometers, chemical / infrared thermometers, and time thermometers. An infrared thermometer is a measuring instrument that has the ability to detect temperature optically (when an object is observed), measure infrared radiation energy radiation and describe it in the form of temperature. A digital thermometer can be used to measure the temperature of the eardrum, armpit, or ear canal. The results of temperature measurements can be detected in about 1 second. Temporal thermometers use infrared scanners to measure the temperature of the anterior artery [5].

### B. Non-contact Thermometer Calibrator Tool

Calibration Bath is a tool that allows calibration at various temperatures with liquid or solid media that can be heated or

International Journal of Scientific Engineering and Science
Volume 8, Issue 9, pp. 1-5, 2024. ISSN (Online): 2456-7361

cooled according to calibration needs. By using a non-contact thermometer calibrator regularly, users can ensure that their instruments provide reliable and accurate results [6].

### C. Fuzzy Logic Control System

Fuzzy logic is a method used to connect input space to output space. In fuzzy logic, a value has only 2 possibilities, namely whether it is a member of a fuzzy set or not. Fuzzy logic contains Fuzzy sets are a group that represents a certain state in a fuzzy variable. In a strict set, each element in its universe is always determined explicitly whether the element is a member of the set or not. However, in reality, not all sets are defined explicitly [12]. Fuzzy logic is an approach used in system control that allows for imprecise decision making and can handle uncertainty in data. Fuzzy logic consists of three main components: fuzzification, inference based on a knowledge base, and defuzification [7].

Some of the advantages of using fuzzy logic control (FLC) compared to conventional controls such as PID (Proportional-Integral-Derivative) control are that FLC is more efficient and robust. FLC can follow changes in plant parameters well. FLC consumes lower energy. FLC can handle input uncertainty with better efficiency. FLC can overcome the weaknesses of conventional control by using a rule base that allows individual manipulation of control surfaces[8].

### D. MLX 90614 Sensor

The MLX 90614 sensor is a non-contact infrared sensor used to measure the temperature of an object without any physical contact with the object. This sensor was developed by Melexis and is often used in various applications, including thermal systems, environmental control devices, and medical devices. The MLX90614 sensor has two outputs, namely room temperature and object temperature. The MLX90614 sensor module has an IR-sensitive thermopile detector circuit and signal processing ASIC integrated into the TO-39 sensor package. Signal conditioning in the form of a low-noise amplifier, 17-bit ADC, and a powerful DSP unit ensure high accuracy and resolution of the thermometer. The sensor is calibrated with a digital SMBus output that measures total temperature with a resolution of 0.02 °C [9].

### E. Microcontroller

In this prototype using the Arduino Nano microcontroller, the Arduino Nano is equipped with a pin header that allows easy installation to a breadboard and is equipped with a USB Mini-B connector. The Arduino Nano board has an ATmega328 IC clocked at 16 MHz featuring more or less the same functions as the Arduino Duemilanove. The board offers 22 digital input/output pins and 8 analog pins. The Arduino Nano is equipped with a bootloader program, so that programmers can directly upload code to the Arduino Nano board without going through an intermediary board or other hardware [10].

### F. Heater

In this prototype using Heater Positive Temperature Coefficien (PTC) often also called element or heater that emits heat or causes other bodies to reach higher temperatures. Heater as a tool used to convert electrical quantities into heat quantities (heat). The heat source of the element is obtained from wire / copper that has high electrical resistance (Resistance Wire) with a voltage of 5 VDC. This heater is suitable for use as a temperature heater on a warm Heater [11].

### G. Humidity sensor

There are various types of sensors that can be used to measure room temperature, one of which is the DHT22. The DHT22, also known as the AM2302, is a digital sensor that measures humidity and temperature. This sensor consists of a capacitive humidity sensing element and a thermistor for temperature sensing. For temperature measurement, the DHT22 sensor uses an NTC (Negative Temperature Coefficient) thermistor that changes resistance based on temperature. This thermistor is a temperature-sensitive resistor; changes in temperature result in changes in resistance value, which is then converted into a digital signal. With this combination, the DHT22 is an ideal choice for various applications, including room temperature measurement [12].

## III. MATHODS

### A. Research

The temperature control system on the Heater uses a fuzzy logic approach implemented in three stages, namely: fuzzification, rule base evaluation (inference), and defuzzification. Fuzzification is the first phase of fuzzy calculation, namely changing fuzzy set inputs whose truth values are certain into fuzzy inputs in the form of membership levels / truth levels.

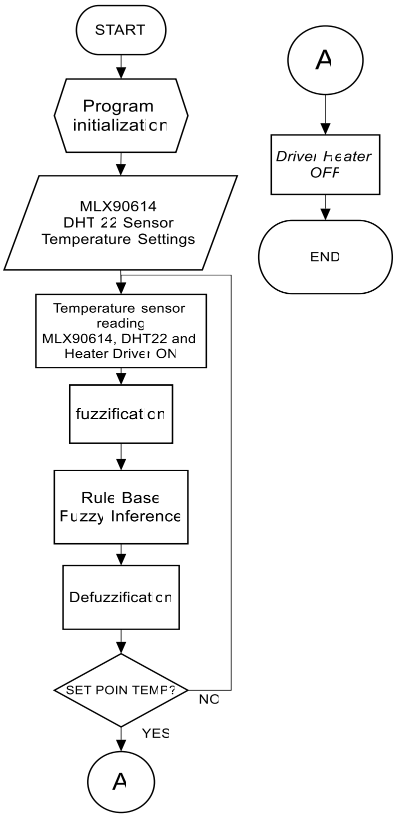


Fig. 1. Research Model Prototype of Non-Contact Clinical Thermometer Calibrator Device

Volume 8, Issue 9, pp. 1-5, 2024.

International Journal of Scientific Engineering and Science
ISSN (Online): 2456-7361

Based on the research model that has been created, below is a picture of the membership function of thermometer temperature, room temperature, heater and its table rule base.

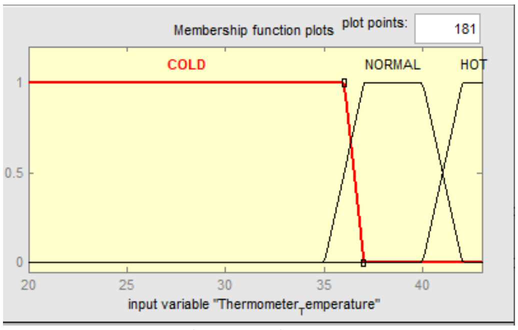


Fig. 2. Membership function of thermometer temperature

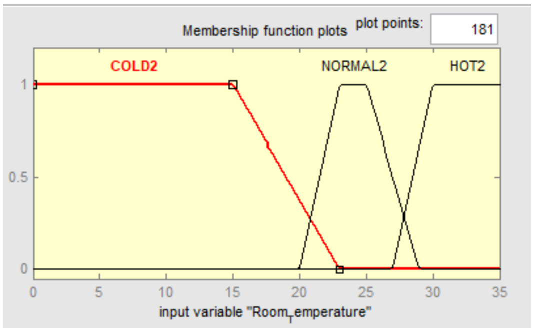


Fig. 3. Membership function of room temperature

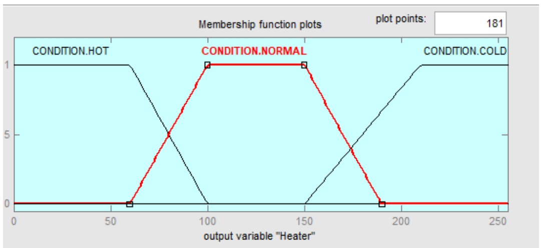


Fig. 4. Membership function of heater

TABLE I. Rule Base

| No | Temperature sensor reading input | Input Room temperature sensor reading | Output Heater | Temperature range (Celsius) |
|---|---|---|---|---|
| 1 | Cold | Cold | Condition Hot | x ≤ 35 |
| 2 | Cold | Normal | Condition Hot | x ≤ 35 |
| 3 | Cold | Hot | Condition Normal | 35 ≤ x≤ 37 |
| 4 | Normal | Cold | Condition Hot | x ≤ 35 |
| 5 | Normal | Normal | Condition Normal | 35 ≤ x≤ 37 |
| 6 | Normal | Hot | Condition Cold | 40 ≤ x≤ 42 |
| 7 | Hot | Cold | Condition Normal | 35 ≤ x≤ 37 |
| 8 | Hot | Normal | Condition Cold | 40 ≤ x≤ 42 |
| 9 | Hot | Hot | Condition Cold | x ≥ 42 |

After fuzzification, the next stage is inference. Inference is reasoning using fuzzy input and fuzzy rules that have been determined to produce fuzzy output. This study will discuss decision making in temperature control using the Mamdani method. Fuzzy logic inference in temperature control can be seen in the mathematical equation below,

$$\mu_{Cold[x]} = \begin{cases} 1 & x \le A \\ \frac{A-x}{B-A} \;, & A \le x \le B \\ 0 & x \ge B \end{cases} \quad (1)$$

$$\mu_{Normal[x]} = \begin{cases} 1 & x \le A \\ \frac{A-x}{B-A} \;, & A \le x \le B \\ \frac{X-B}{B-A} \;, & A \le x \le B \\ 0 & x \ge B \end{cases} \quad (2)$$

$$\mu_{Hot[x]} = \begin{cases} 0 & x \le A \\ \frac{x-A}{B-A} \;, & A \le x \le B \\ 1 & x \ge B \end{cases} \quad (3)$$

Defuzzification changes fuzzy output into a fixed value based on a predetermined membership function. Defuzzification is an important method in fuzzy system modeling. There are three methods in fuzzy inference systems that are often used, namely the Mamdani method, the Mamdani method, and the Takagi Sugeno method. This study will discuss temperature control using the Mamdani Fuzzy Logic method. The following is the mathematical equation for defuzzification

$$Z = \frac{\sum_{j=1}^{n} Zj\mu(Zj)}{\sum_{j=1}^{n} \mu(Zj)} \quad (4)$$

Z = crisp solution obtained
Zj = domain number in fuzzy set
μ(Zj)= degree of domain membership in fuzzy set

## IV. Results and Discussion

Fuzzy Logic Control Testing setting 35°C shows the relationship between the fuzzy out of the tool displayed on the LCD with Matlab (Comparator software) as many as 30 tests. The difference in fuzzy out / Crips is caused by calculations behind the comma and different sensor readings so that when measuring there is a difference between the tool made with the comparison software which has an average measurement error of 0.12%. The tool reaches a setting temperature of 35.2°C, room temperature of 25°C, fuzzy output of 50.6, in 1 minute 00 seconds obtained from Figures 5.

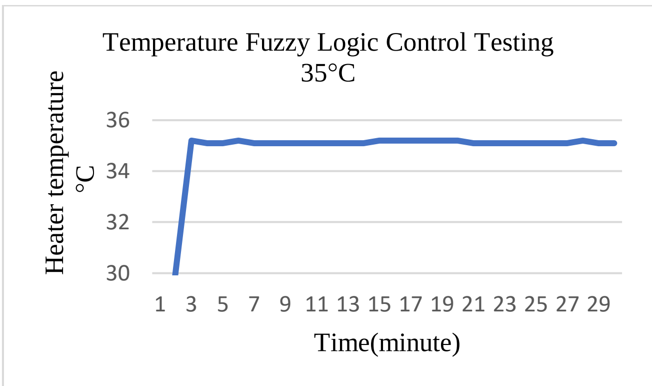


Fig. 5. graphs of Fuzzy Logic Temperature Control Testing setting 35°C

Fuzzy Logic Control Testing setting 37°C shows the relationship between the fuzzy out of the tool displayed on the LCD with Matlab (Comparator software) as many as 30 tests. The difference in fuzzy out / Crips is caused by calculations behind the comma and different sensor readings so that when measuring there is a difference between the tool made with the comparison software which has an average measurement error of 0.36%. the tool reaches a setting temperature of 37.1°C, room temperature of 28 °C, fuzzy output of 168, in 1 minute 30 seconds. Figure 6.

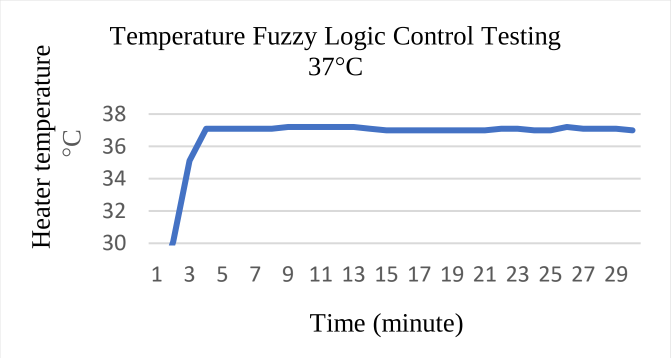


Fig. 6. graphs of Fuzzy Logic Temperature Control Testing setting 37°C

Fuzzy Logic Control Testing setting 42°C shows the relationship between the fuzzy out of the tool displayed on the LCD with Matlab (Comparator software) as many as 30 tests. The difference in fuzzy out / Crips is caused by calculations behind the comma and different sensor readings so that when measuring there is a difference between the tool made with the comparison software which has an average measurement error of 0.23%. the tool reaches a setting temperature of 42°C, room temperature of 27.5°C, fuzzy output of 209, in 1 minute 30 seconds. Figure 7

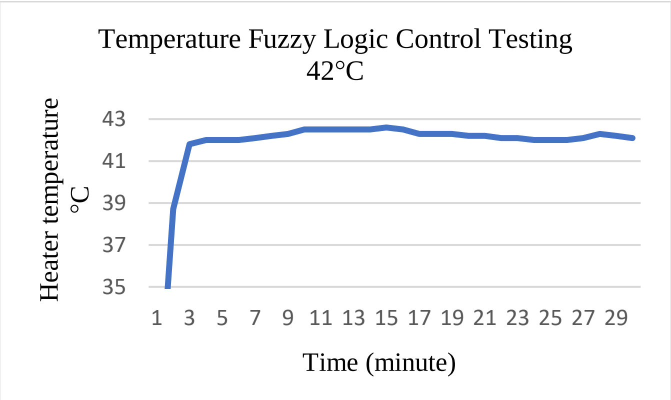


Fig. 7. graphs of Fuzzy Logic Temperature Control Testing setting 42°C

## V. CONCLUSION

Based on the results of the research that has been done, several conclusions were obtained, including:

1. This study proves that a non-contact thermometer calibrator with a Mamdani fuzzy logic control system can calibrate a non-contact clinical thermometer with an accuracy of ± < 0.5°C in the test temperature range (35°C, 39°C, and 42°C;
2. The calibrator developed shows a small difference in measurement results between manual testing and the measured tool, with a difference of around ± <0.5°C which is still within acceptable tolerance limits
3. The Mamdani fuzzy logic control system applied to the calibrator has proven effective in controlling temperature during the calibration process, producing accurate and reliable correction values;
4. From the results of the development of a non-contact thermometer calibrator using the Mamdani fuzzy logic control system, the research objectives have been achieved, namely Applying the Mamdani Fuzzy Logic Method in the Context of a Temperature Control System to obtain a stable temperature.

## VI. LIMITATION

In conducting this research, the obstacle faced is the size of the heater that matches the non-contact thermometer because the heater needed is not too big. This research was conducted by making a prototype and simulation using MATLAB Simulink. This research only focuses on testing the temperature control on the heater to calibrate the non-contact clinical thermometer.

## ACKNOWLEDGMENT

The author would like to thank his family, all lecturers, supervisors, employees, friends, and students of the Electrical Engineering Masters Program, Sultan Agung Islamic University, Semarang, Indonesia.

## REFERENCES

[1] J. B. and J. D. Pušnik, "CALIBRATION OF NON-CONTACT THERMOMETERS I. Pušnik, J. Bojkovski and J. Drnovšek," Calibration of Non-Contact Thermometers, pp. 2–5, 2023.
[2] J. Setiyono, C. Sutowo, M. Sjahmanto, and A. Sebastian, "Pelatihan dan Praktikum Kalibrasi Alat Ukur Temperatur untuk Pendeteksi Suhu Tubuh Manusia di Pondok Pesantren Nurul Ihsan," J. Pengabdi. Kpd. Masy., vol. 1, no. 2, pp. 17–25, 2021.
[3] N. S. Yamanoor, S. Yamanoor, and K. Srivastava, "Low Cost Design of Non-Contact Thermometry for Diagnosis and Monitoring," 2020 IEEE Glob. Humanit. Technol. Conf. GHTC 2020, pp. 1–6, 2020, doi: 10.1109/GHTC46280.2020.9342853.
[4] S. Sijabat, D. G. R. Aruan, D. Antoni, and B. Simarmata, "Studi Akurasi Alat Termometer Non-Contact Dengan Menggunakan Infra Red Pada Termometer Digital," J. Mutiara Elektromedik, vol. 5, no. 2, pp. 72–79, 2021, doi: 10.51544/elektromedik.v5i2.4502.
[5] G. Nurdianto, M. Rahmat, and N. Nurrohman, "Uji Kinerja Movable Thermostatic Bath Sebagai Alat Kalibrasi Termokopel," AME (Aplikasi Mek. dan Energi) J. Ilm. Tek. Mesin, vol. 5, no. 1, p. 13, 2019, doi: 10.32832/ame.v5i1.2353.
[6] Kusumadewi, Artificial intelligence (teknik dan aplikasinya). 2003.
[7] B. Arifin and A. A. Nugroho, "Pengendalian Suhu dalam Ruang Berbasis Logika Fuzzy dengan Menggunakan National Instrument Myrio 1900," Semin. Nas. Pendidik. Sains dan Teknol., pp. 226–231, 2018, [Online]. Available: https://jurnal.unimus.ac.id/index.php/psn12012010/article/view/4221%0Ahttps://jurnal.unimus.ac.id/index.php/psn12012010/article/viewFile/4221/3916
[8] B. Arifin, B. Y. Suprapto, S. A. D. Prasetyowati, and Z. Nawawi, "Steering Control in Electric Power Steering Autonomous Vehicle Using Type-2 Fuzzy Logic Control and PI Control," World Electr. Veh. J., vol. 13, no. 3, 2022, doi: 10.3390/wevj13030053.
[9] Y. Mukhammad and A. S. Hyperastuty, "Sensitivitas Sensor MLX90614 Sebagai Alat Pengukur Suhu Tubuh Tubuh Non-Contact Pada Manusia,"

International Journal of Scientific Engineering and Science
Volume 8, Issue 9, pp. 1-5, 2024. ISSN (Online): 2456-7361

Indones. J. Prof. Nurs., vol. 1, no. 2, p. 51, 2021, doi: 10.30587/ijpn.v1i2.2339.
[10] S. Iksal, Suherman, "Perancangan Sistem Kendali Otomatisasi On-Off Lampu Berbasis Arduino dan Borland Delphi," Semin. Nas. Rekayasa Teknol., no. November, pp. 117–123, 2018.
[11] D. . Ningtias, M. . Sudarman, and I. . Harsoyo, "Rancang Bangun Bantal Terapi Berbasis Arduino," Elektrika, vol. 11, no. 2, p. 26, 2019, doi: 10.26623/elektrika.v11i2.1706.
[12] F. Puspasari, T. P. Satya, U. Y. Oktiawati, I. Fahrurrozi, and H. Prisyanti, "Analisis Akurasi Sistem sensor DHT22 berbasis Arduino terhadap Thermohygrometer Standar," J. Fis. dan Apl., vol. 16, no. 1, p. 40, 2020, doi: 10.12962/j24604682.v16i1.5776.