EMITOR: Jurnal Teknik Elektro

Baby Room Temperature and Humidity Control System Using Fuzzy Logic

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Abstract – *The health and comfort of infants are highly sensitive to room environmental factors, particularly temperature and humidity, which play a critical role in supporting their well-being. Managing these factors becomes complex due to constant fluctuations in ambient conditions, necessitating the use of advanced technology to ensure stability and adaptability. This study explores the application of fuzzy logic in designing a temperature and humidity control system for infant rooms, aiming to maintain an optimal environment for infant care. Fuzzy logic offers a robust approach for handling variability, enabling precise adjustments based on a set of predefined rules and inputs. The system operates by processing real-time input values of temperature and humidity and producing adaptive responses through control outputs, such as cooler, heater, and blower settings. These adjustments are determined by a series of if-then rules that interpret the input conditions to produce the necessary responses. Experimental testing and evaluation confirm that the fuzzy logic-based control system effectively maintains room temperature and humidity within the desired range. The results indicate that this approach can successfully sustain a stable and comfortable environment, underscoring its potential application in enhancing infant health and comfort through controlled indoor climate conditions.*

Keywords – *Baby Room; Temperature Control; Humidity Control; Fuzzy Logic; Infant Comfort.*

I. INTRODUCTION

NEWBORN babies have a tendency to be sensitive to any changes in the surrounding environment, especially to changes in temperature and humidity. This is because babies do not yet have enough fatty tissue in their bodies, which results in babies easily feeling cold.

An ideal and well-ventilated room can help babies feel comfortable and sleep well and can reduce the risk of SIDS (Sudden Infant Death Syndrome) or commonly defined as sudden infant death syndrome. However, a room that is too cold can reduce the baby's body temperature and cause the baby to shiver [1, 2].

Changes in the hot weather outside and high humidity affect the room temperature, so that it has an impact on the baby, namely feeling uncomfortable. Maintaining appropriate temperature and humidity in infant care environments is crucial for newborn comfort and survival, particularly for premature infants [3, 4]. Research has shown that controlling these factors can significantly improve survival rates, especially for smaller infants [4]. Various systems have been developed to regulate temperature and humidity in incubators and rooms, including microcontroller-based designs [3, 5] and embedded systems [6]. These systems typically aim to maintain temperatures between 33–35°C and humidity levels between 40–60% [7]. Recent advancements include the use of fuzzy-PID hybrid controllers for improved performance [5] and android-based applications for remote monitoring [8]. While proper temperature and humidity control is essential, it is important to avoid extremes that could lead to hyperthermia or uncontrolled heat loss [9, 10]. Recommendations according to the Indonesian Ministry of Health Regulations, which are required and must be met for baby rooms at home, include room temperature between 18°C and 30°C, humidity 40–60%RH, and a ventilation rate of 0.15–0.25 m/s [11].

To maintain the stability of temperature and humidity in the baby room, a control system is needed

The manuscript was received on August 21, 2024, revised on November 1, 2024, and published online on November 29, 2024. Emitor is a Journal of Electrical Engineering at Universitas Muhammadiyah Surakarta with ISSN (Print) 1411 – 8890 and ISSN (Online) 2541 – 4518, holding Sinta 3 accreditation. It is accessible at https://journals2.ums.ac.id/index.php/emitor/index.

that can regulate the room's temperature. The technique for controlling the temperature and humidity of the baby room uses the fuzzy logic method, where this control technique is expected to manage the room conditions more effectively than the traditional on-off system [12]. Fuzzy logic control systems have been widely studied for regulating temperature and humidity in baby incubators and other environments. These systems have shown effectiveness in maintaining stable conditions, with some studies reporting error rates below 5% [13, 14]. Fuzzy-PID hybrid controllers have demonstrated improved performance compared to traditional PID controllers [5]. While fuzzy logic systems can effectively manage temperature, humidity control remains challenging in some cases [15]. Implementation of fuzzy logic control in various applications, including greenhouses and egg incubators, has shown promising results in terms of energy efficiency and system response [16, 17]. However, some research indicates that fuzzy logic control may require more battery power and take longer to reach desired temperatures compared to PID control in certain scenarios [18]. Overall, fuzzy logic control systems offer a viable solution for maintaining stable environmental conditions in various applications.

Controlling the temperature of the baby's room using fuzzy logic involves determining the fan conditions (cooling), heater conditions (heating), and air circulation based on the temperature and humidity parameters in the room. The design of a fuzzy logic-based control system simulation is conducted to evaluate the performance of the baby room control system, with a particular focus on the Mamdani fuzzy logic method [19, 20].

II. Research Methods

The research methodology adopted in this study is designed to systematically gather, analyze, and interpret data with the specific aim of solving problems related to maintaining optimal temperature and humidity levels in a baby room environment. This research applies both theoretical analysis and practical implementation to evaluate the effectiveness of fuzzy logic-based control systems. Several critical steps are included in this methodology to ensure accurate data collection and effective control system performance. These steps include designing a system block diagram, defining fuzzy logic rules using Matlab, configuring membership functions, and creating a comprehensive system flowchart to map out the entire control process.

i. System Block Diagram

The block diagram serves as a foundational step in understanding how each system component interacts within the control environment. It provides a visual representation of how signals are processed and transmitted among various devices within the system. The system block diagram for the baby room temperature control prototype, as shown in Figure 1, outlines the flow of information from input (temperature and humidity sensors) to the output (cooler, heater, and blower), highlighting the interactions facilitated by the fuzzy logic controller.

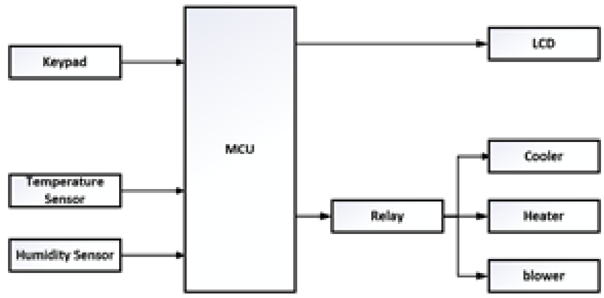


Figure 1: Diagram Block System

As depicted in Figure 1, the temperature and humidity sensors are critical components for real-time monitoring of environmental conditions within the designated baby room. These sensors are strategically placed to provide accurate readings, enabling precise control adjustments. The keypad allows users to set the desired temperature and humidity values, which serve as setpoints in the fuzzy logic control system. This control system, based on the Mamdani fuzzy logic method, then compares actual sensor readings with these setpoints to generate control actions that stabilize the environment [21, 22]. An LCD display is integrated to present real-time temperature and humidity readings, providing feedback to the user. Additionally, if the room temperature exceeds the setpoint, a cooler is activated to reduce the temperature. Conversely, a heater is used to increase the room temperature if it falls below the desired level. A blower is also included to remove hot air, ensuring a balanced and comfortable environment for the baby.

ii. Fuzzy Membership Functions with Matlab

The core of this control system is built around fuzzy logic principles, particularly the Mamdani fuzzy inference method, which is commonly known as the min-max method. The fuzzy logic controller is implemented in Matlab, where fuzzy membership functions are defined for both input and output variables. This includes setting membership functions for temperature and humidity inputs, as well as for outputs like cooling, heating, and airflow adjustment. The choice of Mamdani fuzzy logic in this study is driven by its proven effectiveness in managing temperature-sensitive environments [23]. The fuzzy control approach helps in smoothing erratic changes detected by sensors, leading to stable and responsive control actions that maintain desired conditions with minimal fluctuations.

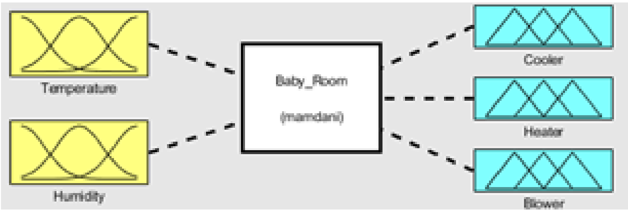


Figure 2: Membership Function

In Figure 2, the defined fuzzy membership functions show two input variables—temperature and humidity within the baby room—and three output variables: cooler, heater, and blower. These membership functions are carefully constructed using Matlab's Fuzzy Logic Toolbox to provide an appropriate range of linguistic variables such as "Cold," "Cool," "Normal," "Warm," and "Hot" for temperature, and "Dry," "Ideal," and "Moist" for humidity. Each membership function uses a combination of triangular and trapezoidal shapes to represent various degrees of membership. This configuration allows the system to interpret sensor input with greater granularity, enabling more nuanced control responses.

The Matlab environment facilitates the construction and simulation of the fuzzy control system, enabling adjustments to membership functions and testing various control scenarios. The fuzzy rules for the system are developed based on expert knowledge and empirical data, defining how the system should respond under different environmental conditions. For example, if the room temperature is classified as "Hot" and the humidity level is "Ideal," the system may prioritize activating the blower over the cooler to efficiently dissipate heat while maintaining energy efficiency. Such configurations are tested in Matlab to ensure that the control system remains robust under varying conditions.

This methodical approach ensures that the fuzzy logic control system is capable of maintaining a stable, comfortable environment in the baby room while minimizing energy usage. The comprehensive testing and adjustment of fuzzy membership functions and rules in Matlab allow for optimization, ensuring the control system performs effectively across a range of conditions.

III. Results and Discussion

The results and discussion section is designed to observe and analyze each part of the block diagram that is tested, including the performance of temperature and humidity sensors as well as the output control.

i. Testing Temperature Sensor and Humidity (Sensor SHT-11)

Testing of the SHT-11 temperature sensor was conducted to determine its performance and accuracy in measuring temperature [24]. In this test, temperature readings from the sensor were compared with those from a thermometer, and the results are displayed in Table 1.

Table 1: Result Sensor SHT-11 (Temperature)

No	Sensor Temperature	Thermometer Temperature	Error
1	20.2	20	0.2
2	24.5	25	0.5
3	28.8	29	0.2
4	30.3	30	0.3
5	32.4	32	0.4
6	34.3	34	0.3
7	35.7	36	0.3
Total Error			0.31

Table 1 illustrates the comparison between the SHT-11 temperature sensor readings and the thermometer readings. The results show a very low total error of 0.31%, indicating that the SHT-11 sensor provides reliable temperature readings within an acceptable accuracy range.

Similarly, the performance of the humidity sensor was evaluated by comparing sensor readings with those from a hygrometer. Table 2 summarizes the findings.

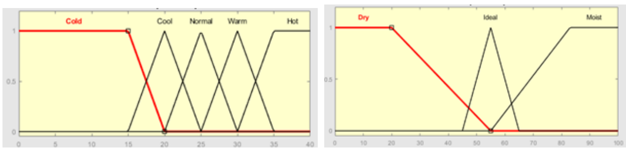
Table 2: Result Sensor SHT-11 (Humidity)

No	Humidity Sensor	Humidity Hygrometer	Error
1	62.70	62	0.7
2	66.57	66	0.5
3	63.37	63	0.3
4	58.77	58	0.7
5	56.66	56	0.6
6	55.92	56	0.1
7	55.22	55	0.2
Total Error			0.44

As seen in Table 2, the humidity sensor also performed with a low error rate of 0.44%, confirming that it can accurately measure humidity within the specified range. This level of accuracy is crucial for maintaining a stable environment in the baby room.

ii. Fuzzy Logic Test

The fuzzy logic testing aims to establish fuzzy variables and membership functions. The degree of membership for temperature is shown in Figure 3(a), which represents the categorization of temperature based on a combination of trapezoidal and triangular models.



(a) **(b)**

Figure 3: Membership degrees (a) temperature (b) humidity

Figure 3(a) illustrates how the temperature degrees are categorized into distinct fuzzy sets. The variables for temperature degrees are provided in Table 3 for better understanding of the temperature classifications.

Table 3: Temperature Degrees Variables

Temperature Degrees	Temperature (°C)
Cold	< 20
Cool	15 - 25
Normal	20 - 30
Warm	25 - 35
Hot	> 30

As shown in Table 3, the temperature degrees are divided into five categories: Cold, Cool, Normal, Warm, and Hot. These classifications provide an effective way to apply fuzzy logic rules to manage the temperature in the baby room.

In a similar manner, the humidity membership degrees are depicted in Figure 3(b). The variable definitions for humidity degrees are listed in Table 4.

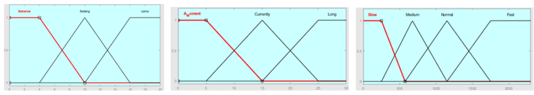
Table 4: Humidity Degrees Variables

Humidity Degrees	Humidity (%)
Dry	< 55
Ideal	45 - 65
Moist	> 55

As displayed in Table 4, the humidity is divided into three categories: Dry, Ideal, and Moist. This classification is essential for determining the fuzzy logic outputs related to humidity control in the room.

Figure 4(a) shows the cooler membership degrees, which define how the cooler operates based on fuzzy logic rules. The specifics are outlined in Table 5.

The cooler's operation times, shown in Table 5, are categorized into three levels—A Moment, Currently,



(a) **(b)** **(c)**

Figure 4: Membership degrees () cooler (b) heater (c) blower

Table 5: Cooler Degrees Variables

Cooler Degrees	Time (Second)
A Moment	< 10
Currently	4 - 16
Long	> 10

and Long. This allows precise control of cooling duration in the room.

In Figure 4(b), the heater membership degrees are defined. These membership degrees are explained further in Table 6.

Table 6: Heater Membership Degrees Variables

Heater Degrees	Time (Second)
A Moment	< 15
Currently	5 - 25
Long	> 15

Table 6 categorizes the heater duration into A Moment, Currently, and Long, enabling effective temperature control adjustments.

Figure 4(c) depicts the blower membership degrees. The corresponding variables are outlined in Table 7.

Table 7 divides blower speeds into Slow, Medium, Normal, and Fast, allowing precise airflow control in the baby room environment.

Figure 5 provides a visual representation of fuzzy logic rules, demonstrating how various input variables interact to determine the outputs.

The following figures illustrate the fuzzy system responses:

Figure 6 shows the response of the fuzzy system to temperature and humidity changes affecting the cooler output.

Figure 7 shows the system response for the heater, where the output varies with ideal humidity and low temperature.

In Figure 8, the response of the blower is shown, with increased speed in response to high temperature and humidity.

Table 7: Blower Degrees Variables

Blower Degrees	Blower Speed (RPM)
Slow	< 575
Medium	250 - 1150
Normal	575 - 1750
Fast	> 1150

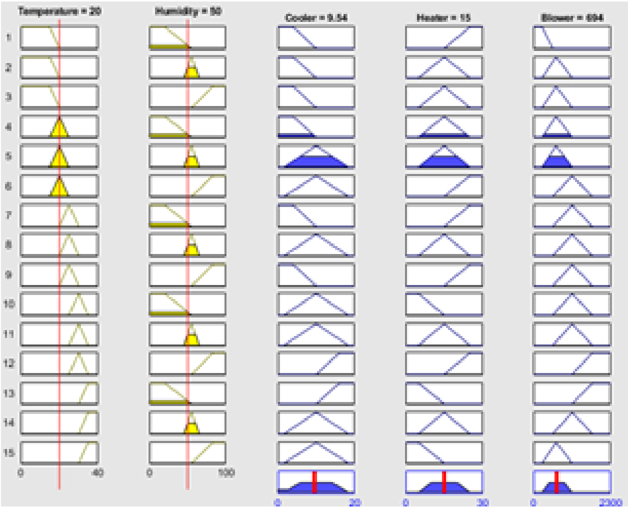


Figure 5: Fuzzy Logic Rules Visualization

IV. Conclusion

This fuzzy logic control system for the baby room provides an effective and adaptive approach to maintaining optimal room conditions. It allows real-time adjustment of temperature and humidity control based on changing room conditions. The fuzzy rule modeling and membership functions are well-defined and can model the optimal response to changes in input values. This solution offers a significant improvement in maintaining stable temperature and humidity in a special baby room when compared to conventional control methods.

Acknowledgment

The authors would like to thank the Electrical Engineering Study Program, Faculty of Engineering, Universitas Merdeka Malang for supporting this research, as well as LPPM Universitas Merdeka Malang for their invaluable support and assistance.

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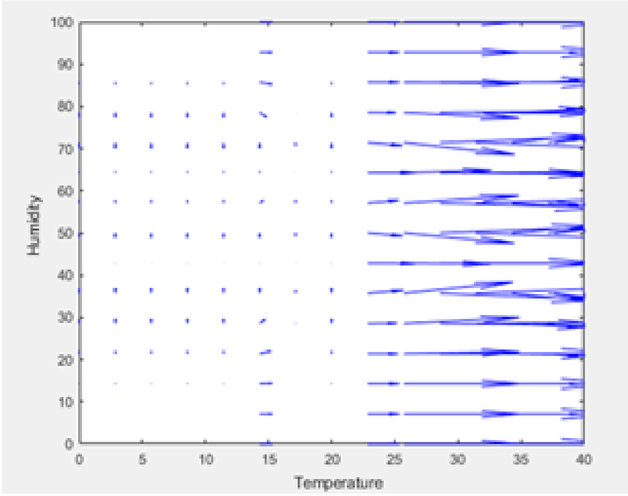

Figure 6: Temperature and Humidity Fuzzy System Response to Cooler

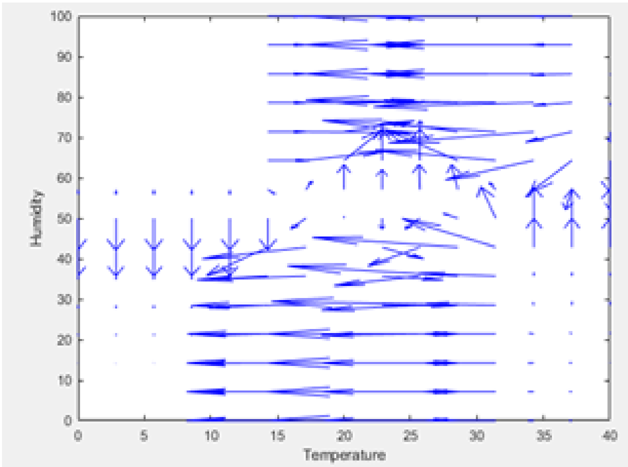

Figure 7: Temperature and Humidity Fuzzy System Response to Heater

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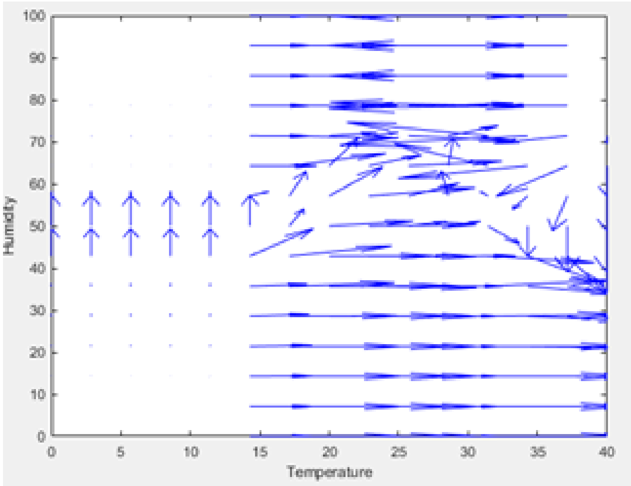

Figure 8: Temperature and Humidity Fuzzy System Response to Blower

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