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Portable Baby Incubator Based On Fuzzy Logic

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ABSTRACT

The Global Action Report on Preterm Birth (2012) The United Nations Agency says, 15 million babies are born prematurely every year worldwide. Among them, more than one million babies die from complications due to premature birth. In 2010, Indonesia ranked fifth in the world with the highest number of premature babies in the world. The high birth rate for premature babies and the limited ability of parents to access health facilities to care for premature babies. The baby incubator serves to maintain a stable internal temperature and humidity so that it can help babies born prematurely to survive. This study aims to design and implement portable baby incubator control using fuzzy logic which consists of two fuzzy modules: based on Temperature and humidity. This baby incubator control uses fuzzy logic designed so that the system can display information on the baby's incubator temperature and humidity conditions, the baby's weight and the baby's heart rate without opening the incubator. The temperature in the system to be designed ranges between 36 ℃-37 ℃, and the humidity is between 40% RH-60% RH. This incubator has a measurement and regulation system using temperature and humidity, namely the DHT22 sensor, the AC Dimmer Module to control PWM (Pulse Width Modulation), the acuator in the form of AC 220V incandescent lamps with a power of 60W and Arduino uno as a controlling microcontroller and an artificial fuzzy logic system Sugeno control method with a setting point value of 37 ℃ to maintain the stability of the temperature in the incubator in accordance with what is needed by premature babies. With the setting point at 37 ℃ the temperature in the baby incubator will survive in the range 37 ℃-38 ℃.

*Keywords: Incubator**,** Temperature**,** Humidity**,** Fuzzy Logic Control**,** Microcontroller**,*** DHT22

1. INTRODUCTION

Premature labor is labor that lasts between 20 and 37 weeks' gestation and is marked by the appearance of uterine contractions of sufficient intensity and frequency to cause thinning and cervix [1]. According to WHO (2013), preterm labor is labor that occurs before 37 weeks' gestation. If the gestational age is not known with certainty, then the benchmark is the weight of the baby at birth which is only around 1,000 - 2,500 grams [2].

Based on data from the 2016 statistical bureau, the infant mortality rate (IMR) reaches 25 deaths per 1000 babies born. This is certainly a concern of various parties because IMR is an indicator of the health level of a country. The cause of premature birth is sometimes unknown, but early rupture of membranes is one of the main causes of premature birth. Some factors that trigger premature birth such as multiple pregnancy, genitalia infection, premature rupture of membranes, stress on the mother, smoking habits in the baby's mother [3].

Premature births have a series of effects on babies, so it's no wonder that premature babies have to get special care. According to Dr. Hari Martono, SpA., Said that babies born not yet months old have very low adaptability to the outside world. As a result, there are clearly a range of effects that may occur following untimely births, such as respiratory failure (asphyxia), the digestive tract is not fully functional, liver function is not maximal (yellow), and is susceptible to infection.

As a result of regulating the temperature in the body of a premature baby is not perfect, the temperature can rise or fall dramatically. This condition can certainly endanger his health condition. Besides the muscles are also relatively weak. While the fat reserves are also less than normal babies born. Therefore, babies need an incubator that functions to maintain the baby's temperature to remain stable. Thus the baby is expected to remain at the appropriate temperature as in the mother's womb. The importance of this incubator in handling premature infants requires a temperature regulation system that has good measurement and regulation quality in the temperature range of 36 ℃ - 38 ℃. So the research was made with the title "Portable Baby Incubator Based on Fuzzy Logic Methods".

2. RESEARCH METHOD

According to the National Standardization Board (DSN) a baby incubator is a tool used to treat premature babies or babies with low birth weight (LBW) by providing a stable temperature and humidity in accordance with conditions in the mother's womb. The development of science and technology makes incubator technology more sophisticated. This development can be seen in terms of shape, energy sources, temperature and humidity control which are already close to the conditions in the mother's womb.

The baby incubator control system actually has previous research on the application and several methods. The research that is relevant to this research is in the baby incubator control system in using PID control [4], Temperature Stability Control System on Arduino Uno Brbasis Baby Incubators with Matlab / Simulink [5], Design and Manufacture of Incubators Based on Temperature Distribution [6], Analysis temperature distribution and air flow in baby incubators with variations in wall types and overhead screens [7], and subsequent development by wireless memoitoring [8].

2.1. Fuzzy Logic Control

Fuzzy logic control is also called Fuzzy Inference System / FIS is a control system that uses the concept of fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning. Basically, FIS input can be in the form of fuzzy input or crisp input, but the output produced is almost always in the form of fuzzy sets. When FIS is used as a controller, crisp (firm) output is needed [9] [10]. To change fuzzy set to crisp value, defuzification method can be used. Fuzzy logic control consists of fuzzification (fuzzification), database (membership function of the fuzzy set used in fuzzy rules), rule base (rule base), decision-making unit (operation of inference on fuzzy rules), and defuzzification (defuzzification). The basic structure of the fuzzy logic control is shown in Figure 1.

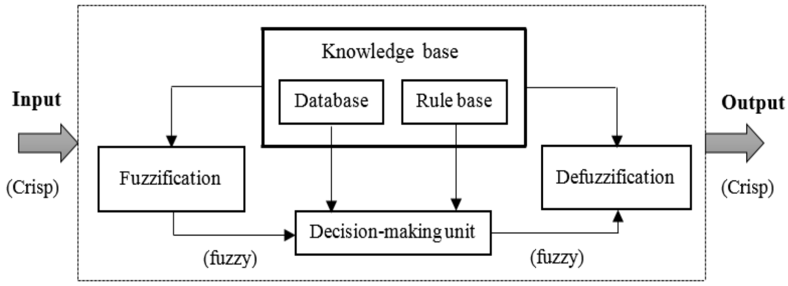

Figure 1. The basic structure of fuzzy logic control

2.1.1 Fuzzyfication

Fuzzyfication is the process of mapping crisp values into a fuzzy set and determining the degree of membership within the fuzzy set [11]. The principle of the fuzzification process is shown in Figure 2.

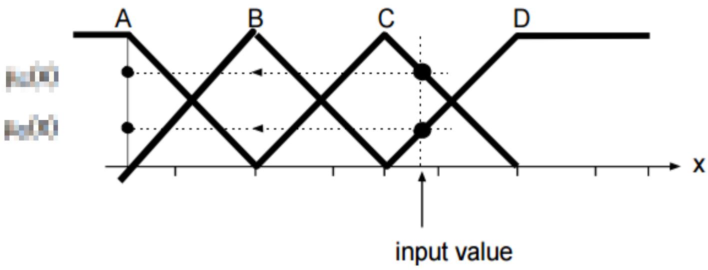

Figure 2. Principles of the fuzzification process

In Figure 2 it can be seen that through the fuzzification process, one firm input value that is in the membership functions C and D is converted to a fuzzy value that has two degrees of membership μ_C (x) and μ_D (x).

2.1.2 Rule of Basis

The rule base contains empirical knowledge relating to the operation of the process to be controlled. The rule base consists of a number of If-Then fuzzy rules, which can be applied easily by condition statements in fuzzy logic. The basic structure of the basis of the rules of disguised logic is as follows:

$$\begin{array}{lllll} Rule_1: & if & condition\ P_1 & then & Conclusion\ C_1 \\ Rule_2: & if & condition\ P_2 & then & Conclusion\ C_2 \\ Rule_3: & if & condition\ P_3 & then & Conclusion\ C_3 \\ \ldots & & & & \\ Rule_n: & if & condition\ P_n & then & Conclusion\ C_n \end{array}$$

If there are two input variables and one output variable, and the two input variables are combined with one "And" operator, then the rule base can be written in matrix form, where the value of the input variable is expressed in the form of columns and rows, and the contents of the matrix are the values of output variables such as found in picture 3.

Input Variable X_1 (columns); Input Variable X_2 (rows)

	NB	NS	Z	PS	PB
NB	NB	NS	Z	PS	PS
NS	NS	NS	PS	PS	PB
Z	Z	Z	PS	PB	PB
PS	Z	Z	PS	PB	PB
PB	Z	NS	PB	PB	PB

NB = Negative Big NS = Negative Small Z = Zero
PB = Positive Big PS = Positive Small

Figure 3. The form of the rule base matrix with two input variables

2.1.3 Defuzzification

The result of inference is the set of fuzzy logic or fuzzy logic membership functions. Information in fuzzy logic must be converted into explicit values so that it can be used to control a process. The firm value must reflect the information contained in the fuzzy logic set. The process used to convert the results of fuzzy inference into firm value output is called defuzzification. Defuzzification methods that can be used include: CoG (Center of Gravity), BoA (bisector of Area), MoM (Mean of Maximum), and CoGS (Center of Gravity Method for Singleton).
In this part of the defuzzification method, the CoGS (Center of Gravity Method for Singleton) method will be discussed because this method is used on the system to be designed. The CoGS equation is as follows

$$U(t_k) = \frac{\sum_{i=1}^{p}[U_i * a_i(t_k)]}{\sum_{i=1}^{p}[a_i(t_k)]} \quad ......(1)$$

where a is the singleton value of each rule. The CoGS method is shown in figure 4.

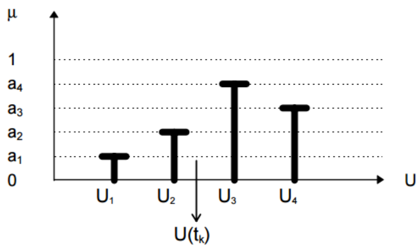

Figure 4 : CoGS Method (*Center of Gravity Method for Singleton*)

2.2 Fuzzy Logic Design

The incubator's temperature control system is controlled using fuzzy logic. The output of this fuzzy logic control in the form of a PWM (Pulse Width Modulation) control signal is then used to control the plant heater and blower. So the light intensity and blower rotational speed are controlled by the control signal of the fuzzy logic controller. Block control diagram in general can be seen in general can be in Figure 5.

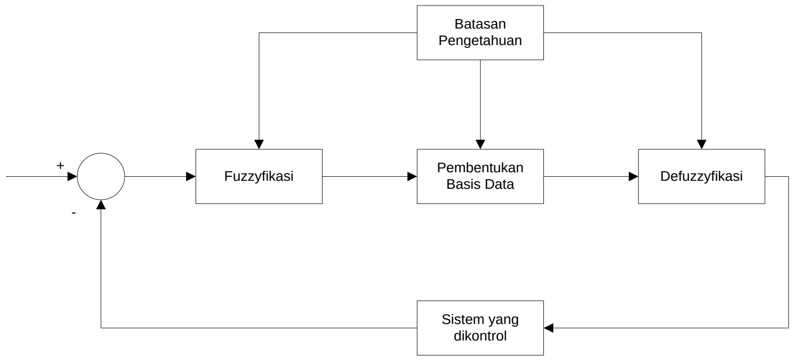

Figure 5. Block Control System Flow Chart

Can be seen from Figure 5 block diagram of the fuzzy logic control system, the input value is taken from the DHT11 sensor reading value which reads the temperature and humidity entering the first process of fuzzy logic controller which is the formation of fuzzyfication which will be formed to some degree of fuzzy membership. After that it will be made fuzzy logic database formation or often called rule formation. In the last stage, the fuzzy value will be defuzzyfied again, that is, to change the fuzzy value to an explicit value as output. From this output value will be used as control on the system to be controlled. The block diagram of the design of a baby incubator temperature control system using the DHT11 sensor can be seen in Figure 6.

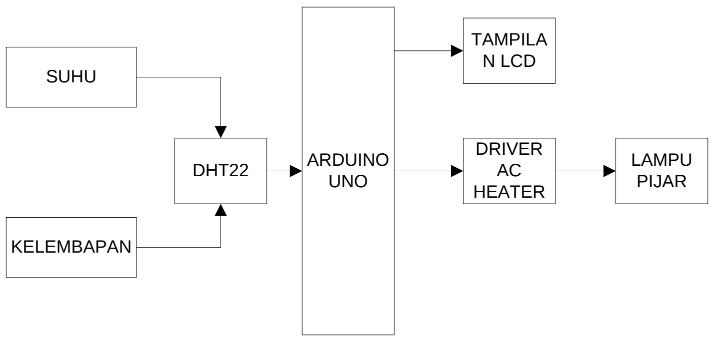

Figure 6. Block Diagram of Control System Design

From Figure 6, the initial process of this system is the process of measuring temperature and humidity, whether the temperature and slowness in normal conditions are around 36 ℃ - 38 ℃. The entire system performance is controlled by a controller in the form of an arduino uno microcontroller that works in accordance with the commands set in the software. Output temperature and humidity measurements will be displayed on the LCD while Output in the form of an AC driver is used to control the heater which is a lamp and in accordance with the PWM output fuzzy logic. Fan or fan will function as a safety system. Where when the temperature exceeds the set point, the fan will turn on. The voltage source on the tool uses a power source from PLN.

The Fuzzy portable baby incubator flow chart is shown in Figure 7.

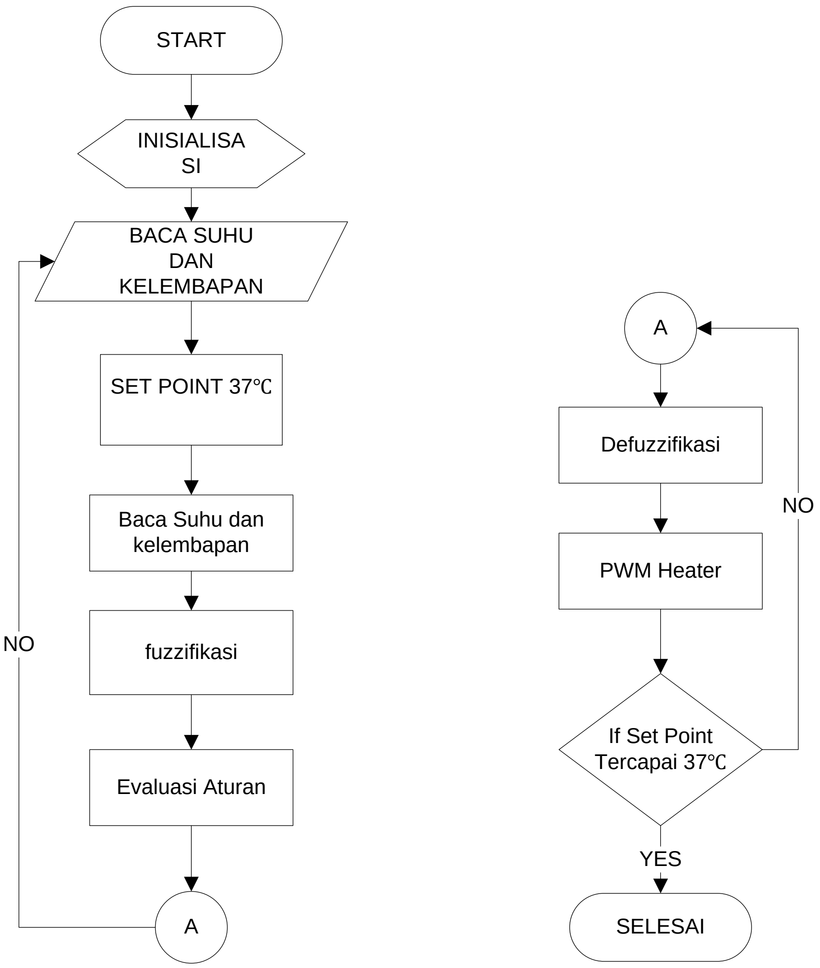

Figure 7. Fuzzy System Flow Diagram

From the flowchart in Figure 7 can be clarified as follows:

1. Start by turning the On / Off switch.
2. Determine the set point at 37 ℃.
3. The DHT11 sensor detects temperature and humidity.
4. After the temperature is obtained, the next step is fuzzyfication, which is changing the exact value into the form of fuzzy input and forming fuzzy membership.
5. The next step is rule evaluation, which is the process by which the establishment of fuzzy base rules uses (IF ... THEN)
6. Defuzzyfication, in using the sugeno method, the defuzzyfication is done by finding the average value (Average).
7. The output of defuzzyfication in this study is the value of PWM on the heater.

2.3 Fuzzyfication

The formation of membership functions must be adjusted to the conditions that will be needed. Judging from the configuration of the tool and the need for the tool, a number of membership functions will be determined. For the values of each membership function must also be adjusted to what is needed by the system to run well. The temperature error membership function can be seen in Figure 8.

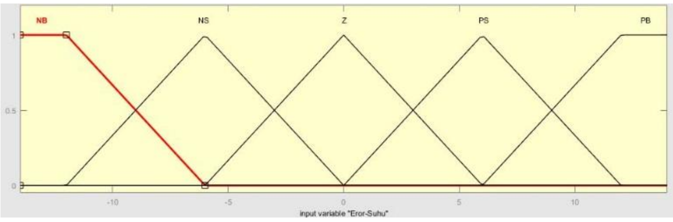

Figure 8 Temperature membership functions

It can be seen from the membership function picture above that there are 5 linguistic variables at temperature which consist of Negative Big, Negative small, Z, Positive Small and Positive Big. The error value is obtained from the setpoint minus the detected temperature (37 ℃ - Sensor value). In general, this research measures the temperature around 25 ℃ in the room so that the temperature error range from -12 to 12 based on the setpoint minus the measured temperature (37-25 = 12). The humidity membership function can be seen in Figure 9.

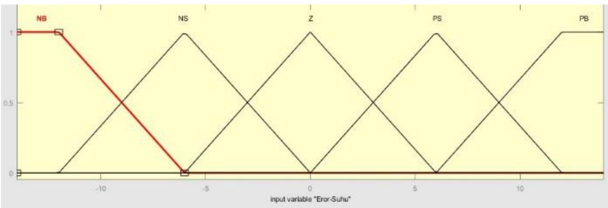

Figure 9. Humidity membership function

It can be seen from the membership function picture above that there are 5 linguistic variables on humidity that consist of No Moist, Less Moist, Rather Moist, Moist, Very Moist. With a value of humidity range between 0-100%.

2.4 Rule Evaluation

At this stage each of the outputs of this stage the outputs of the fuzzyfication stage in the form of degrees of membership and linguistic variables will be combined using the evaluation rule. From the rule evaluation, it will be known the variation of PWM on the heater. In rule evaluation there are linguistic rules to determine the control actions of the input values of defuzzyfication. In this step use the rules (IF ... AND ... THEN). The rule table can be seen in table 1:

Tabel 1 Tabel Rule

HUMIDITY		TEMPERATURE ERROR				
NO		NB	NS	Z	PS	PB
1	TL	O	O	O	R	S
2	KL	O	O	O	S	S
3	AL	O	O	O	S	S
4	L	O	O	R	S	T
5	SL	O	R	S	T	T

2.5 Defuzzyfication

Defuzzyfication is a step that has the purpose of converting or looking for real values or conversion steps for each result of the inference engine that is expressed in the form of fuzzy sets to a real number or real results. In the Sugeno fuzzy method the implication function used is MIN to get the α-predicate value for each rule. Then each α-predicate value is used to calculate the output of the results of the inference explicitly (crips) of each rule (Z1, Z2, ... Zn).

The membership function output in the form of PWM can be seen in Figure 10.

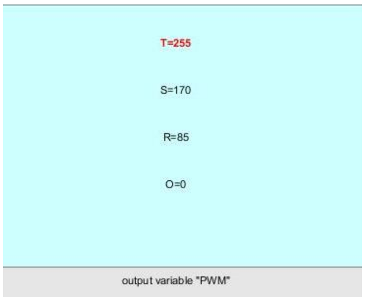

Figure 10. Output of PWM Membership Functions

It can be seen from the picture of the output membership function above that there are 4 linguistic variables in PWM consisting of Dead (0), Low (85), Medium (170), High (255). The determination of a constant value on membership output is based on the maker which is then also compared to previous research. In the Sugeno fuzzy method the defuzzyfication method used is to calculate the average value or Average.

3. RESULTS AND DISCUSSION

3.1 Testing Fuzzy Sugeno Logic

Fuzzy logic testing is done by comparing the output values generated in matlab with the output values in the arduino programming (Hardware). In this test, fuzzy rules that have been determined will be made, where the input value is obtained from the reading of the specified sensor program. These predetermined error-temperature and humidity input values will be displayed on the monitor serial in the arduino sketch. The input values entered in the matlab rule viewer are adjusted to the values in the Arduino programming. Figure 11. Fuzzy Output Results on Serial Monitor

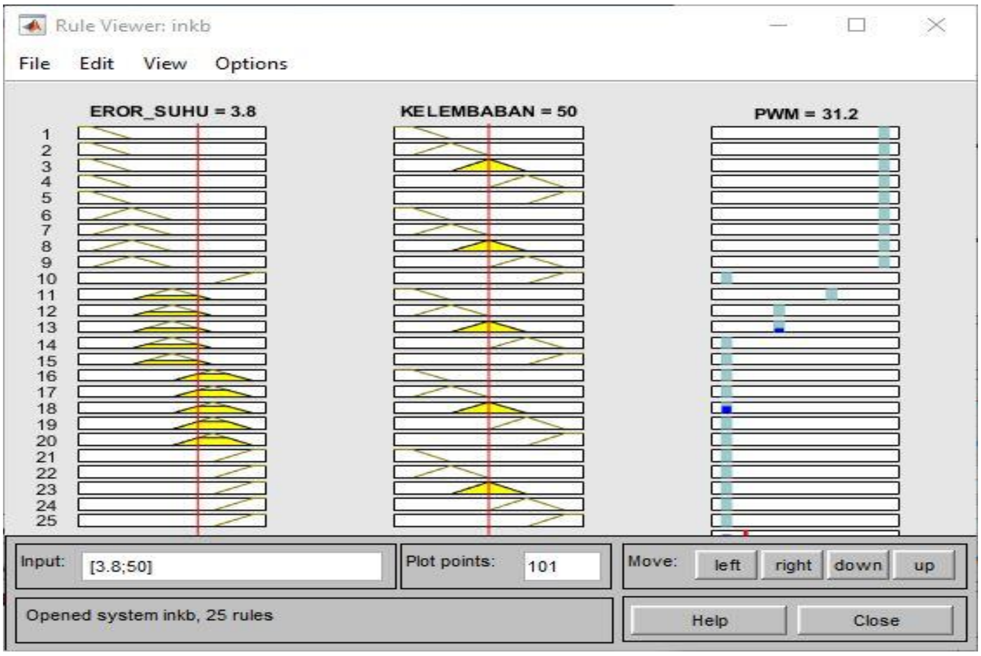

Figure 11. Fuzzy Output Results in Matlab

Fuzzy logic test results can be seen in table 2. The input read on the hardware must be the same as the input on matlab must have the same value to get accurate results. Matlab input values will be adjusted to the input values that exist in the arduino programming. In Figure 5.1, it can be seen the input conditions with an error-temperature value of 3.8 and humidity = 50 produce a fuzzy output value in the form of a PWM of 31.2 (bright lights conditions).

Tabel 2. Fuzzy Test Result

NO	INPUT		Fuzzy Output Testing Data(PWM)			
	ERROR-Temperature	Humidity	ARDUINO	MATLAB	DIFFERENCE	ERROR
1	-9	15	255	255	0	0.00%
2	-6.94	35	255	255	0	0.00%
3	-4.11	41	189.29	189	0.29	0.15%
4	-0.7	55	99.93	99.9	0.03	0.03%
5	2.6	59.5	23.91	23.9	0.01	0.04%
6	3.8	50	31.17	31.2	0.03	0.10%
7	4.3	55	16.06	16.1	0.04	0.25%
8	5.9	60	1.37	1.37	0	0.00%
9	7.9	65	0	0	0	0.00%
10	9.2	68	0	0	0	0.00%
ERROR AVERAGE					0.04	0.06%

Table 2 shows the results of fuzzy measurements in arduino programming (hardware) and measurements using the fuzzy matlab function calculation application, and it is evident from the system of using fuzzy calculations between matlab and hardware that is very good with error values below 1%. The error value is obtained from the formula as follows:

$$\boldsymbol{ERROR} = \frac{\boldsymbol{output\ Aduino - output\ Matlab}}{\boldsymbol{output\ Arduino}} \boldsymbol{x100} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\textbf{[2]}$$

Based on the test results above, it can be seen the average value of errors in measurements between Arduino (hardware) and measurements with errorny matlab is very small with an error of 0.06%.

3.2 Overall testing of infant incubators

The overall update is done to find out whether the system that has been made is working as planned or not. This test includes testing the DHT22 sensor, fuzzy method, LCD, and a series of other components. This test is done by looking at the display of the LCD and the output that occurs when the sensor reads the temperature conditions in the baby incubator and observes the temperature that can be maintained by the incubator at the setpoint and compares it with the baby incubator control system without the Fuzzy Logic Control method.

Tabel 3. Incubator temperature testing with *Fuzzy Logic Control*

Incubator temperature testing (Fuzzy Logic Control)		
Temperature ℃	Time (S)	Light
37	58	ON
37.2	70	ON
37.3	114	ON
37.4	157	ON
37.5	1886	ON

37.3	2327	ON

Tabel 4. Incubator temperature testing without Fuzzy Logic Control

Incubator temperature testing without *(Fuzzy Logic Control)*		
Temperature ℃	Time (S)	Light
37	39	Off
37.1	16	Off
37.2	28	Off
37.3	35	Off
37.4	40	Off
37.3	47	Off
36.9	16	Off
36.7	16	Off

As for the graph of the measurement chart table 3 Testing the stability of the temperature of the baby incubator with Fuzzy Logic Control and Figure 12 Testing the stability of the temperature of the baby incubator without Fuzzy Logic Control.

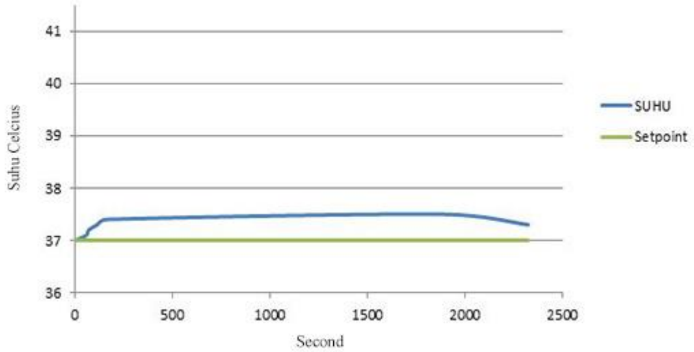

Figure 12. Graphic Testing of the temperature stability of a baby incubator with Fuzzy Logic Control

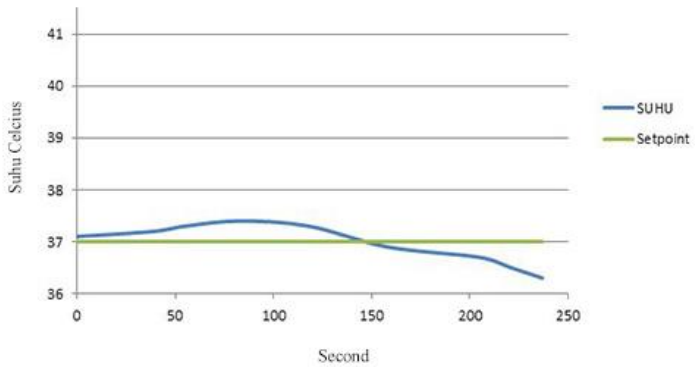

Figure 13. Graph of Testing the stability of the temperature of a baby incubator without Fuzzy Logic Control

Based on Figures 12 and 13, it can be seen that the difference between the baby's incubator temperature control system is using Fuzzy Logic Control and without using Fuzzy Logic Control.

Where in testing using Fuzzy Logic Control the temperature can be hot in a stable baby incubator in the temperature range of 37 ℃ - 37.5 ℃ and the lights remain on so that the temperature does not experience a decrease below the setpoint. Meanwhile, the incubator temperature stability test table without using Fuzzy Logic Control can be seen that the temperature of the incubator changes very quickly where when the temperature reaches setpoint 37 ℃, the heating lamp will turn off but the temperature in the baby incubator still rises to 37.4 ℃ and will return down until it reaches a temperature point of 36.5 with a fairly rapid temperature drop time of around less than 200 seconds. From the results of the raining above it can be concluded that artificial intelligence with the Sugeno Fuzzy Logic Control method can maintain a stable temperature in the setpoint range of 37 ℃ with an overshoot value of around 0.5 ℃.

Tabel 5. Temperature Stability Test

Pengujian ke stablian suhu Inkubator	
Suhu ℃	Waktu
37	58 Detik
37.2	1 menit 10 detik
37.3	1 menit 54 detik
37.4	2 menit 37 detik
37.5	31 menit 26 detik

Based on the measurement data in table 5. then, the stability of the temperature in the baby incubator can be seen that the system can maintain the value at the setpoint for 58 seconds and the temperature will rise above the setpoint with the highest difference value is 37.5 ℃ or the difference between 0.5 ℃.

4. CONCLUSION

Testing the value of the DHT22 sensor, there is an error of 0.29 ℃ or 1.03% in the temperature measurement and there is an error of 2.77 (RH%) or 4.52% in the reading of humidity, this error value is still within reasonable limits because it is in accordance with the DHT22 sensor datasheet which is 0.5 ℃ at temperature and 5% at humidity. Testing between the results of Sugeno fuzzy logic output on Arduino and Matlab there is an error value of 0.02%, the error value is still quite small and still within tolerance. The system can maintain a setpoint value of 37 ℃ for 58 seconds. Artificial intelligence with the Sugeno Fuzzy Logic Control method, can maintain a temperature in the setpoint range of 37 ℃ with an overshoot value of around 0.5 ℃.

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