

PH monitoring system, temperature automation and clown fish feeding in aquarium using fuzzy logic method based on internet of things

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Abstract. Clown fish are marine ornamental fish that are in great demand because they have unique beauty and economical prices. Aquariums are used as a medium for keeping clown fish. However, clown fish are difficult to find on the market because clown fish care must pay attention to all aspects, including the condition of the fish. Fish food, water pH and water temperature. Overcoming this problem is by creating a pH monitoring system, temperature automation and fish feed in aquariums based on the Internet of Things (IoT). Implementation of this system can be controlled and monitored remotely via the website. Monitoring water pH uses a pH-4502C sensor connected to the Node MCU and DS18B20 sensor to control water temperature. Water temperature automation uses the fuzzy logic method. When the water temperature is below 25°C the heater will turn on to increase the water temperature to normal and after the temperature becomes normal the heater will turn off, while at temperatures above 28°C the fan cooler will turn on and after the temperature becomes normal the fan cooler will turn off. Black box testing is used to test the monitoring system that has been designed and the test results show that this system has worked well, and usability testing has been carried out by 18 respondents, 87% agree with the system.

1 Introduction

As a maritime country, Indonesia has enormous marine natural potential. One of the potentials that is much sought after is marine ornamental fish, because marine ornamental fish are one of the pets that are in great demand by various groups, both children and the elderly [1]. One of the marine ornamental fish that is in great demand is the clown fish, because clown fish have a unique beauty and are economical. However, even though clown fish are in great demand, clown fish are difficult to find on the market because care in raising clown fish must be very careful, this applies to all aspects, be it fish feed, water pH, sanitation, phosphate, nitrate, trace elements, and temperature water [2].

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One of the main aspects that greatly influences the condition of clownfish is the water temperature in the aquarium. A good aquarium water temperature for clownfish ranges from 25°C to 28°C. The clownfish's appetite will decrease and the clownfish's body will become moldy if the water temperature is below 25°C. Meanwhile, if the water temperature is above 28°C, the fish will breathe faster, so the oxygen needed increases and causes the amount of oxygen in the aquarium to decrease [3]. Apart from that, water pH is also an aspect that must be handled carefully. A pH range of 7.8 to 8.6 is ideal for keeping clownfish in an aquarium [4].

Apart from that, fish food is also one of the main aspects in raising clownfish to improve the color quality [5], usually fish food is given by hand so its effectiveness is not optimal. For example, when the keeper is not at home the fish are not given food, and the temperature and pH of the water is not controlled so that the condition of the fish becomes bad and the fish can even die. Therefore, to overcome this problem is with a new system. Technological developments have been applied in various fields, one of the technologies that is currently widely used is the use of Internet of Things technology. In contrast to other technologies that still do things manually, the Internet of Things uses intelligent and automatic work processes that can help complete tasks more easily [6].

Therefore, in this research, researchers created a system based on the Internet of Things so that it can help clown ornamental fish keepers in maintaining them. This system is a pH monitoring system, temperature automation and fish feed in the aquarium. Based on the Internet of Things, the implementation of this system can be controlled and monitored remotely via the website [3]. To monitor water pH, a pH-4502C sensor is used which is connected to Node MCU and DS18B20 sensor for water temperature control [7]. Water temperature automation uses the Sugeno fuzzy logic method, because the Sugeno fuzzy logic method has the ability to group data based on input that has been set as rules so that the resulting output is appropriate [8]. When the water temperature is below 25°C, the heater it will turn on to increase the water temperature to normal and after the temperature becomes normal the heater will then turn off, whereas at a temperature above 30°C the fan cooler will turn on and after the temperature becomes normal the fan cooler will then turn off [9].

In this system, fish feeding automation in the aquarium uses RTC as a time sensor, servo motor, and ultrasonic sensor connected to the NodeMCU [10]. The system will operate according to the menu that has been selected via the website, the LCD which functions as an output will show fish food, water pH and water temperature directly [11]. Apart from that, an alarm will sound and a notification will appear on the website as a notification when the feed has been given. Other notifications will also appear on the website after the menu is selected.

Based on the background above, the researchers created the title "PH Monitoring System, Temperature Automation and Clown Fish Feeding in Aquariums Using Fuzzy Logic Methods Based on the Internet of Things".

2 Material and Methods

2.1 Research Method

The method used in this research is a mixed method. Mixed method is a combination of qualitative research and quantitative research. This combined research method combines qualitative and quantitative research methods which are used together in research activities to obtain more comprehensive, valid, reliable and objective data [12]. The qualitative method is carried out descriptively in order to ascertain and also describe the characteristics of

important variables in a situation. Meanwhile, the quantitative method uses statistical data analysis [13].

In this research, to build a pH monitoring system, temperature automation and clownfish feeding in an aquarium using the Internet of Things-based fuzzy logic method, several stages were carried out, these stages are shown in Fig.1

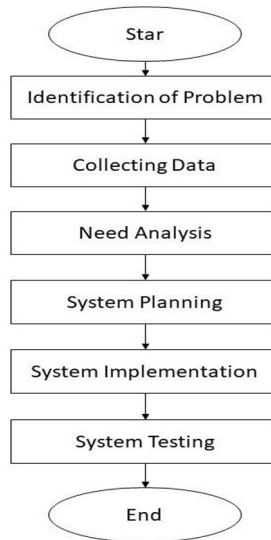


Fig. 1. Research Flow

Figure 1 shows the research flow which is structured as follows: Identification of problems, Data collection, Needs Analysis, System planning, System Implementation and System Testing.

- Identification of Problems
The researcher has explained the problem identification in this research in the background section, namely regarding the maintenance of clown fish which is still done manually, so its effectiveness is not yet optimal
- Data collection
Data collection carried out in this research was literature study, observation and questionnaires.
- Needs Analysis
At this stage the researcher analyzes the need for equipment and materials used in this research.
- System planning
System design in research uses prototype methods, use case diagrams, flowcharts, and schematic diagrams.
- System Implementation
The system implementation in this research consists of 2, namely software implementation on a website for monitoring pH, automation of temperature and clownfish feed in the aquarium remotely and directly, and hardware implementation of tools that will be placed in the aquarium.
- System Testing
After the system has been implemented, to determine the functional accuracy of the system, testing is carried out using black box testing and usability testing

2.2 Data Collection

Data collection carried out in this research was literature study, observation and questionnaires:

- Literature review
The literature study that researchers carry out is by studying references related to this research, whether from articles, journals, e-books, scientific works, or books
- Observation
The data source in this research is primary data obtained from researchers' observations by measuring the temperature and pH of the water in the aquarium using a thermometer and pH meter for 3 days at 07.00, 13.00 and 19.00. The data from these observations is shown in Table 1.

Table 1. Observation Data

No	Observation Data			
	<i>Observation</i>	<i>Time</i>	<i>Temperature</i>	<i>pH</i>
1	Day 1	07.00	31°	8
2	Day 1	13.00	28°	7.9
3	Day 1	19.00	29°	8.5
4	Day 2	07.00	30°	8.2
5	Day 2	13.00	28°	7.8
6	Day 2	19.00	31°	8.6
7	Day 3	07.00	29°	8.4
8	Day 3	13.00	30°	8.1
9	Day 3	19.00	28°	8.3

From Table 1. it can be concluded that for 3 days the water temperature and water pH were unstable, where on the 1st day at 07.00 the temperature was 31° and pH 8, at 13.00 the temperature was 28° and pH 7.9 and 19.00 the temperature was 29° and pH 8.5. On the 2nd day, 1 hour 07.00 the temperature was 30° and pH 8.2, at 13.00 the temperature was 28° and pH 7.8 and 19.00 the temperature was 31° and pH 8.6. And on the 3rd day, 1 hour 07.00 the temperature was 29° and pH 8.4, at 13.00 the temperature was 30° and pH 8.1 and 19.00 the temperature was 28° and pH 8.3. Thus, a pH monitoring system and temperature automation are needed in the aquarium so that the pH and temperature become stable.

- Questionnaires
Researches conducted survey on system testing with 18 respondents.

2.3 System Development Method

2.3.1 Prototype Method

Prototypes a temporary design of the system that will be created before it is finalized in program form [14]. Prototyping starting with requirements gathering, involving system developers and users to determine the goals, functions and operational needs of the system [15]. The steps in prototyping are as follows:

- Requirements Collection

In this research, the devices used are hardware and software. The hardware required for this research consists of the equipment and materials needed for this research which are shown in Table 2 and Table 3.

Table 2. Equipment

No	Equipment		
	Tool	Specification	Amount
1	Laptop/PC	Coresi3	1
2	Aquarium	Acrylic size 50x30x40cm	1
3	Soldering tools	Works fine	1

Table 3. Material

No	Material		
	Testing Scenarios	Test Cases	Expected results
1	NodeMCU	ESP8266	2 pieces
2	LCD	20x4	1 piece
3	Jumper Cables	20cm	1 role
4	PCB board	20x10cm	1 piece
5	Male header pins	2.54mm	2 pieces
6	Female header pins	2.54mm	2 pieces
7	Power supply module	12V	1 piece
8	Temperature sensor	DS18B20	1 piece
9	Adapter	12V DC	1 piece
10	Resistors	4.7 k ohms	1 piece
11	Buzzers	3V	1 piece
12	Servos	4.8-6V DC	1 piece
13	Relays	5V	1 piece
14	Soldering tin	0.8mm	1 role
15	pH sensors	pH-4502C	1 piece
16	Heaters	100W	1 piece
17	Fan cooler	12V	1 piece

Table 4. Software Requirement

No	Application
1	VsCode
2	Arduino IDE

- Design Process

The design process in this research is to create a schematic diagram. The schematic diagram in this research is shown in Figure 2.

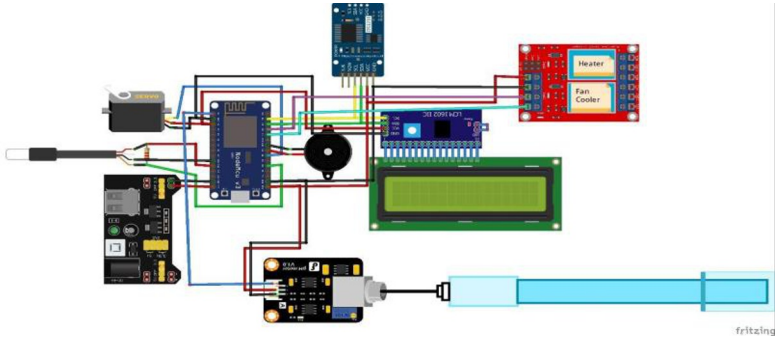


Fig. 2 Schematic Diagram

In Figure 2, the Node MCU is connected to several sensors via the pins shown in Table 5 below:

Table 5. Node MCU Pins and Additional Device

No	Node MCU Pins and Additional Device		
	<i>Node MCU Pins</i>	<i>Sensor Pins</i>	<i>Sensor Name</i>
1	D1	SCL	RTC
2	D2	SDA	RTC
3	3.3V	VCC	RTC
4	G	G	RTC
5	D1	SCL	LCD 20 X 4
6	D2	SDA	LCD 20 X 4
7	VU	VCC	LCD 20 X 4
8	G	GND	LCD 20 X 4
9	D5	VCC	Buzzers
10	G	G	Buzzers
11	D6	Pin data	Servo
12	VU	VCC	Servo
13	G	G	Servo
14	D8	Pin data	DS18B20
15	3.3V	VCC	DS18B20
16	G	G	DS18B20
17	G	G	pH sensor
18	3,3V	3.3V	pH sensor
19	A0	A	pH sensor
20	VCC	VCC	Relay
21	G	G	Relay
22	D3	D1	Relay
23	D4	D2	Relay

- Building Prototypes
The prototype design in this research is shown in Fig.3:

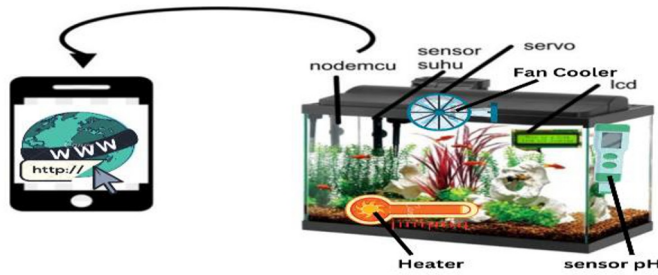


Fig. 3 System Prototype

Fig.3 shows the prototype design from this research, which consists of a NodeMCU, temperature sensor, servo, pH sensor, heater, fan cooler and LCD connected to the website. NodeMCU is an electronic device that uses the ESP8266 chip and is designed to operate with a microcontroller and be connected to the internet [16]. LCD (Liquid Crystal Display) is a display media with a dot matrix system as its operation and a main display with liquid crystals. The use of LCDs has been widely used in various fields, for example computer screens [17].

- Evaluation and improvement
After being evaluated, the prototype above is already good so it can be implemented immediately:

2.3.2 System Planning

- Use Case Diagram
Use Case Diagrams is a depiction of how users interact with an application and perform various tasks to meet their needs [18]. There are actors who will carry out the flow in this use case diagram. Use case diagrams in this research, Figure 4.

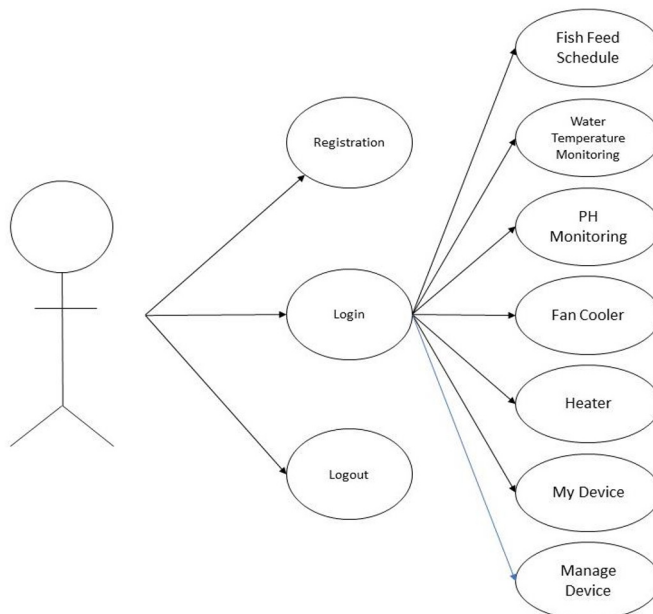


Fig. 4 Use Case Diagram

Figure 4 shows the use case diagram from this research which starts from the user opening the website address, then displays a landing page containing registration and login. If you don't have a user account, you must register first. After successful registration, even if you already have a user account, you must log in and then the user is directed to a menu display consisting of fish feed schedule, water temperature monitoring, pH monitoring, heater, fan cooler, manage device, and log out.

- Flow Chart

Figure 5 shows the flowchart of this research starting from the RTC, The RTC consists of a crystal and a battery, where the crystal functions as a precise time counter and the battery functions as a power source so that the crystal can continue to do so [19], and the website menu which consists of a menu of fish feeding schedules, water temperature monitoring, pH monitoring, heater, fan cooler as input and servo, LCD, heater, fan cooler, website notifications as output.

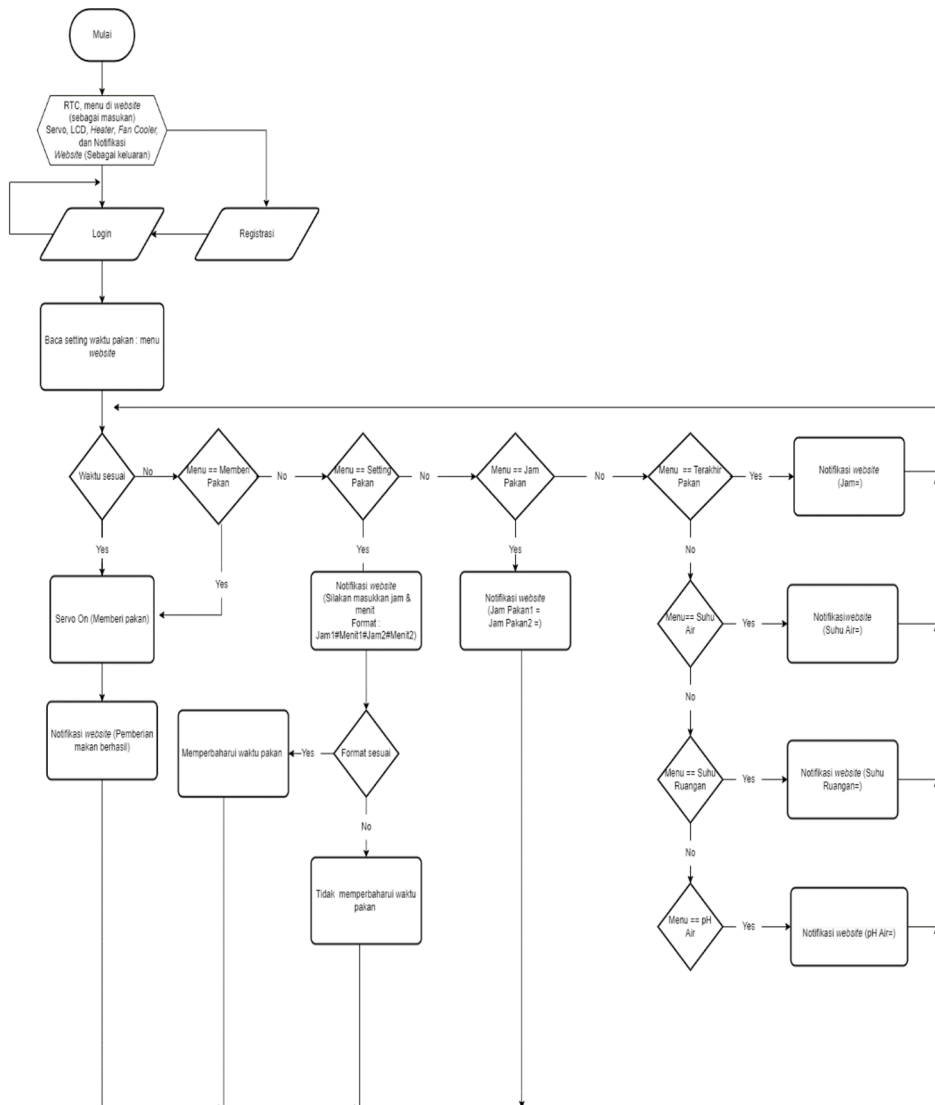


Fig.5. Flow Chart

- User interface dashboard page as show in Figure 6.

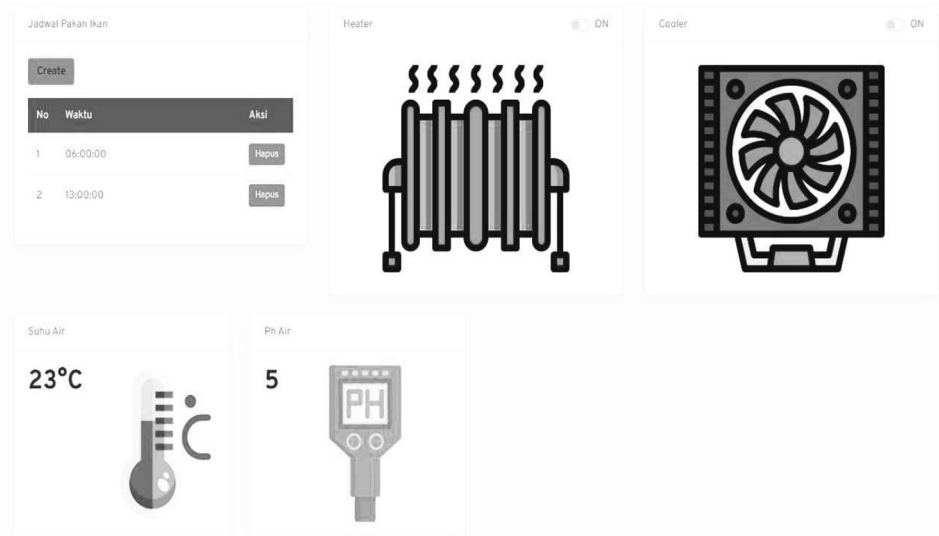


Fig.6. User Interface Dashboard Page

2.3.3 Sugeno's Fuzzy Logic Method

Apart from the prototype method, the Sugeno fuzzy logic method is a system development method used in this research. The Sugeno fuzzy logic method is a fuzzy rule inference method for rules presented in the form of IF-THEN statements, where the system output is in the form of constants or linear equations [22],[23]. The Sugeno model uses a Singleton membership function which has a membership degree of 1 for a single crisp value and 0 for other crisp values[24]. The Sugeno fuzzy logic model in this research is shown in Figure 7.

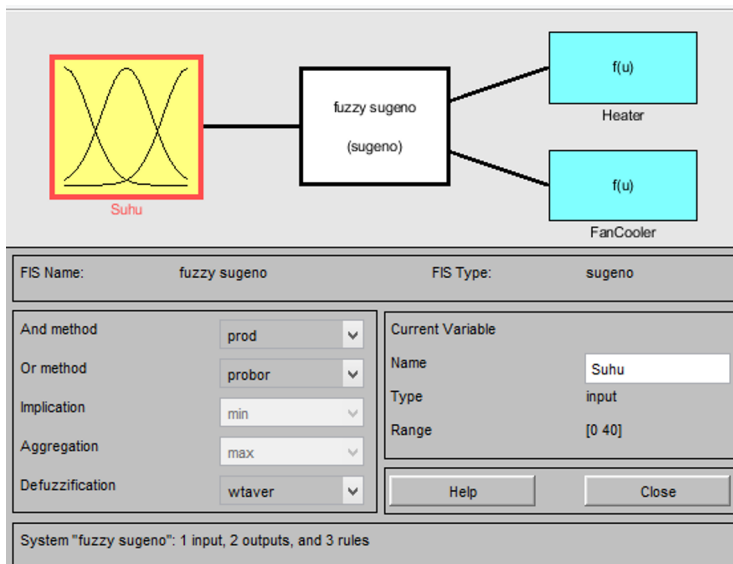


Fig. 7. Sugeno's Fuzzy Logic Model

2.3.4 System Testing Method

- **Functional Testing**
The system testing method used in this research is functional testing. Functional testing is used to determine whether a system that has been built is running well or not. Black box testing is a functional test that researchers carried out in this research. Black box testing is testing the appearance of a system that has been built [20,21].
- **Usability Testing**
Usability testing is a test to explore user experience regarding quality level information in the research created [22]. In this test, researchers conducted a survey by asking questions to respondents. To produce a good evaluation, the researcher asks specific questions to find accurate results. Therefore, researchers created several questions in the form of a questionnaire using a Likert scale [23]

3 Results and Discussion

In this chapter the researcher will discuss data collection, needs analysis, system design, implementation and testing of the pH Monitoring System, Temperature Automation and Clown Fish Feeding in Aquariums Using the Fuzzy Logic Sugeno Method Based on the Internet of Things.

3.1 Implementation

3.1.1 Tool Implementation

Figure 8 shows the implementation of the tool in this research, namely the tool is placed in the aquarium, where this tool functions for pH monitoring, temperature automation and automatic fish feed which will be displayed on the LCD and website.

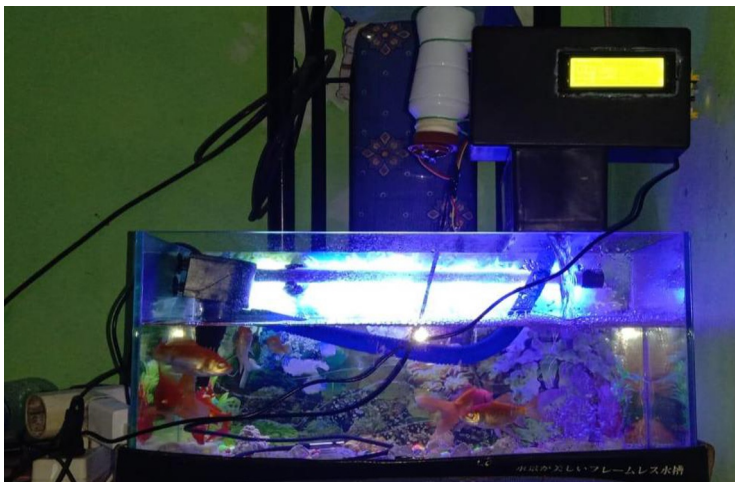


Fig. 8. Tool Implementation

3.1.2 System Implementation

The image of this dashboard page is shown in Figure 9.

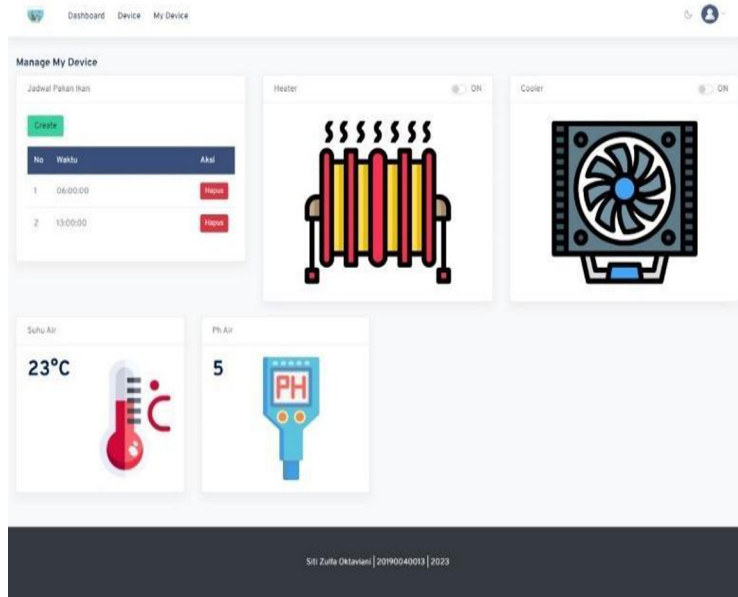


Fig. 9. Dashboard Pages

Figure 9 shows the dashboard page of the website for the pH monitoring system, temperature automation and aquarium fish feed, where this page is the first page you will see after successfully logging in:

- Fuzzy Logic Implementation
 - Model Implementation Fuzzy Logic Sugeno

Figure 10 shows the implementation of the Sugeno fuzzy logic model with temperature input and heater and fan cooler output.

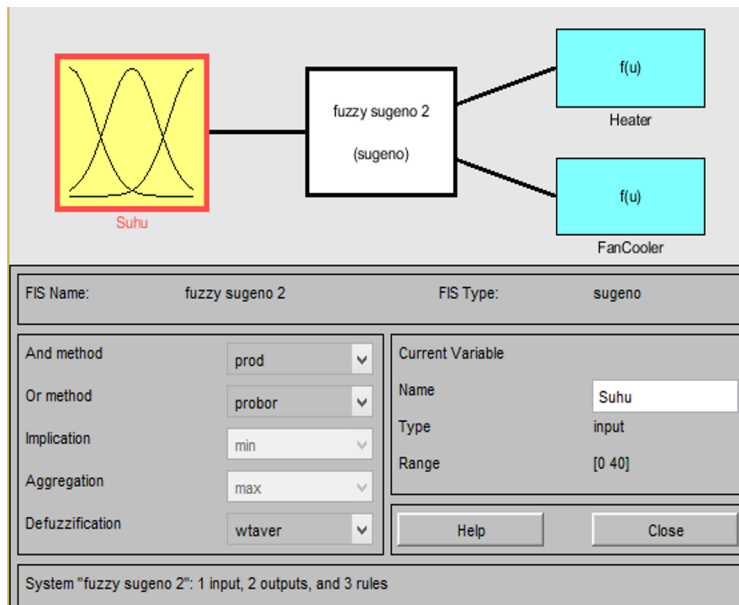


Fig.10. Model Implementation Fuzzy Logic Sugeno

- Sugeno's Fuzzy Logic Rules

Figure 11 shows the Sugeno fuzzy logic rules where there are 3 rules, namely if the temperature is cold the heater will turn on while the fan cooler will turn off, if the temperature is normal the heater and fan cooler will turn off, and if the temperature is hot the heater will turn off while the fan cooler will turn on.

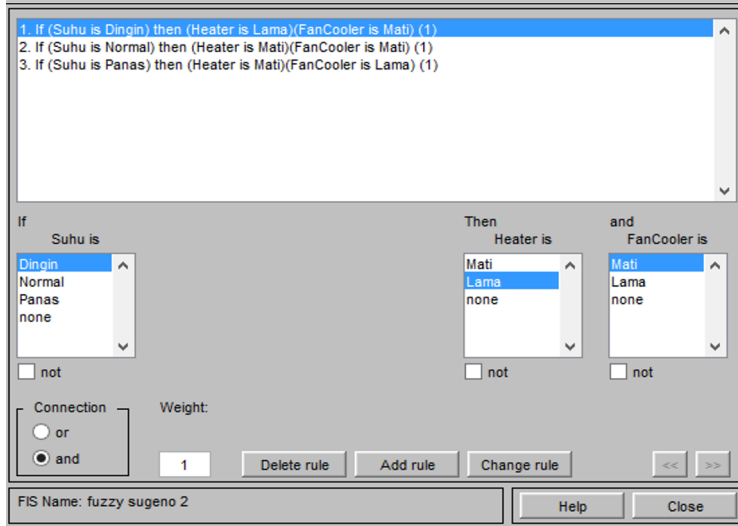


Fig. 11. Model Implementation Fuzzy Logic Sugeno

- Sugeno's Fuzzy Logic Rules Graph.

Figure 12 shows the Sugeno fuzzy logic rules graph with 3 temperature conditions, namely cold temperature ($0^{\circ}\text{C} < x < 25^{\circ}\text{C}$), normal temperature ($25^{\circ}\text{C} \leq x \leq 28^{\circ}\text{C}$), and hot temperature ($28^{\circ}\text{C} > x$).

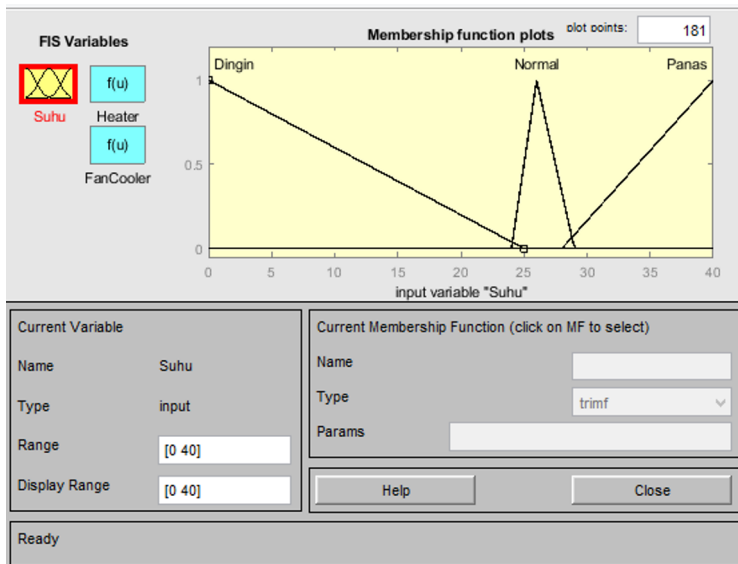


Fig.12. Sugeno's Fuzzy Logic Rules Graph

- Implementation of Sugeno's Fuzzy Logic Rules
 Figure 13 shows the implementation of Sugeno fuzzy logic rules with normal temperatures, namely the heater and fan cooler are off.

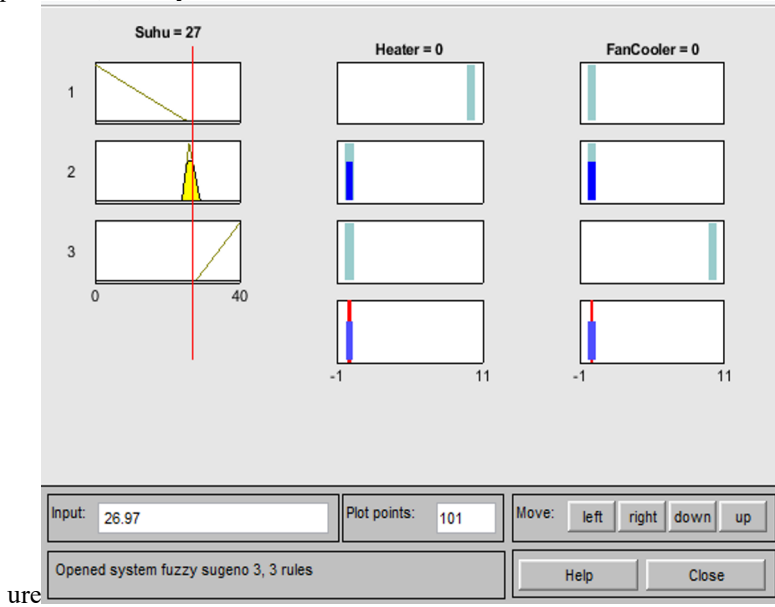


Fig. 13. Normal Temperature Rules

Figure 14 shows the implementation of Sugeno fuzzy logic rules with cold temperatures, namely the heater will be on while the fan cooler is off.

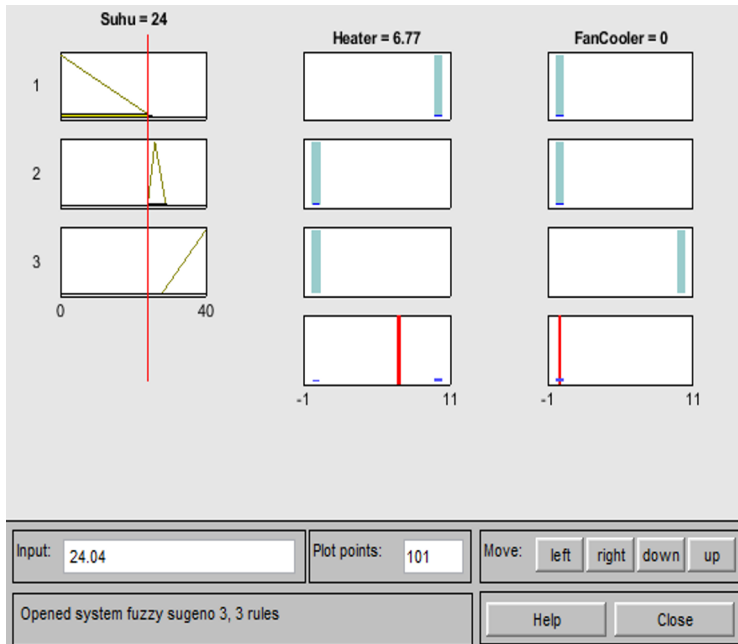


Fig. 14. Cold Temperature Roles

Figure 15 shows the implementation of Sugeno fuzzy logic rules with hot temperatures, namely the heater is off while the fan cooler is on.

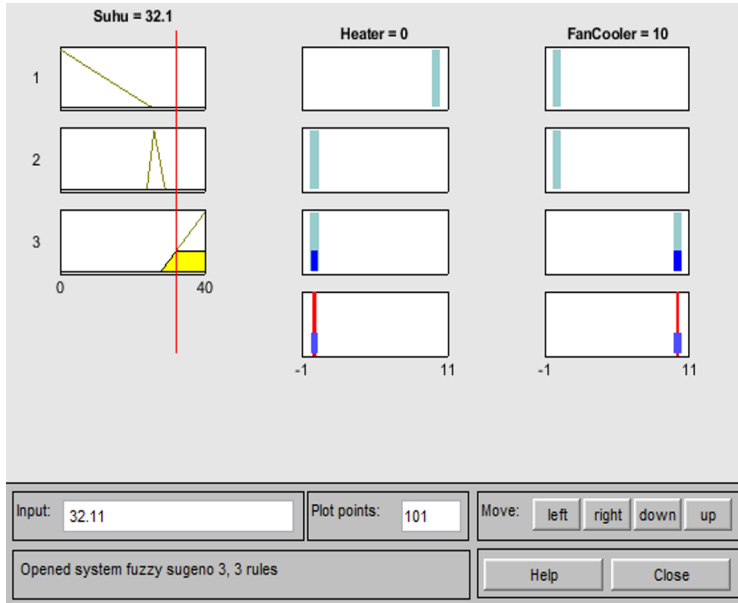


Fig. 15. Hot Temperature Roles

3.2 Tool and System Testing

3.2.1 Black Box Testing

After the system has been implemented, to determine the functional accuracy of the system, testing is carried out using black box testing. The first test is regarding the predetermined time settings. When the time setting is reached, the servo motor will turn on. Then the tool will dispense the feed. In this experiment, two feeding times were arranged, namely 07.00 and 16.00 in the afternoon. The results of this test are shown in Table 6 and Table 7 below :

Table 6. Test Result 1 Feeding Setting

No	Result			
	<i>Feeding Time</i>	<i>Servo Motor</i>	<i>In accordance</i>	<i>Feed Output</i>
1	07.00	Move	V	1 gram
2	16.00	Move	V	1 gram

Table 7. Test Result 2 Feeding Setting

No	Result			
	<i>Feeding Time</i>	<i>Servo Motor</i>	<i>In accordance</i>	<i>Feed Output</i>
1	06.00	Move	V	1 gram
2	13.00	Move	V	1 gram

The next test is a comparison of system temperature monitoring with temperature monitoring using a thermometer. The results of this test are shown in Table 8.

Table 8. Temperature Sensor Test Result

System Temperature sensor	Thermometer	Differentt
27.2°C	27.2°C	0°C
25.5°C	25.8°C	0.3°C
30°C	29.9°C	0.1°C
29.1°C	29.3°C	0.2°C
23.2°C	22.9°C	0.3°C
24.2°C	24.2°C	0°C

The next test is a comparison of system pH monitoring with pH monitoring using a pH meter. The results of this test are shown in Table 9.

Table 9. pH Sensor Test Result

System pH sensor	pH meter	Differentt
7.8	7.9	0.1
8.7	8.5	0.2
8.2	8.2	0
7.6	7.8	0.2
8.6	8.6	0
7.6	7.7	0.1

The next test is regarding the functions or features of the website that has been created. When you enter the website address, a login page will appear. If you log in successfully, the user will be directed to a menu display consisting of fish feed schedule, water temperature monitoring, pH monitoring, heater, fan cooler, manage device, and logout. The results of this test are shown in Table 10 below :

Table 10. Result of Feature on the Website

Result			
<i>Website Menu</i>	<i>Website Notification</i>	<i>Tool Output</i>	<i>In Accordance</i>
Fish Feeding Schedule	Time	Update time	√
Water Temperature Monitoring	Temperature=	-	√
pH Monitoring	Hour pH=	-	√
heaters	ON/OFF	-	√
Fan Cooler	ON/OFF	-	√
Manage Device	Create/Edit	-	√

The next test is the implementation of the Sugeno fuzzy logic method on the system. The results of this test are shown in Table 11:

Table 11. Fuzzy Logic Implementation Test Result

Test Nomor	Temperature	Tool Output	In Accordance
1	27.2°C	Normal	Fan cooler and the heater turns off
2	25.5°C	Normal	Fan cooler and the heater turns off
3	30°C	Hot	Fan cooler live until the temperature is at 28°C and the heater turns off
4	29.1°C	Hot	Fan cooler live until the temperature is at 28°C and the heater turns off
5	23.2°C	Cold	Fan cooler turns off and the heater turns on until the temperature is 25°C
6	24.2°C	Cold	Fan cooler turns off and the heater turns on until the temperature is 25°C

3.2.2 Usability Testing

Usability testing is a test to explore user experience regarding quality level information in the research carried out this time. In this test the researcher made several questions in the form of a questionnaire using a Likert scale [24]. To produce a good evaluation, the author provides specific questions that are useful for seeking feedback in this research. The researcher carried out validity and reliability tests [25]. The list of questions that researchers created is as follows :

- Do you think that a pH monitoring system, temperature automation and clownfish feeding in aquariums using the Internet of Things-based Sugeno fuzzy logic method is needed?
- Can using a website in a pH monitoring system, temperature automation and clownfish feeding in an aquarium using the Internet of Things-based Sugeno fuzzy logic method make things easier for you?
- Is the existence of a pH monitoring system, temperature automation and clownfish feeding in aquariums using the Internet of Things-based Sugeno fuzzy logic method useful in keeping fish?
- Can a system for monitoring pH, temperature automation and feeding clown fish in an aquarium using the fuzzy logic Sugeno method based on the Internet of Things solve the problem of keeping fish in an aquarium?
- Is the system for monitoring pH, temperature automation and feeding clown fish in aquariums using the Sugeno fuzzy logic method based on the Internet of Things easy to understand and use?

After conducting the questionnaire, the author received answers from 18 respondents. Answer data from respondents will be processed using a data validity process and a data reliability process. The number of answers to the questionnaire results is shown in Figure 16.

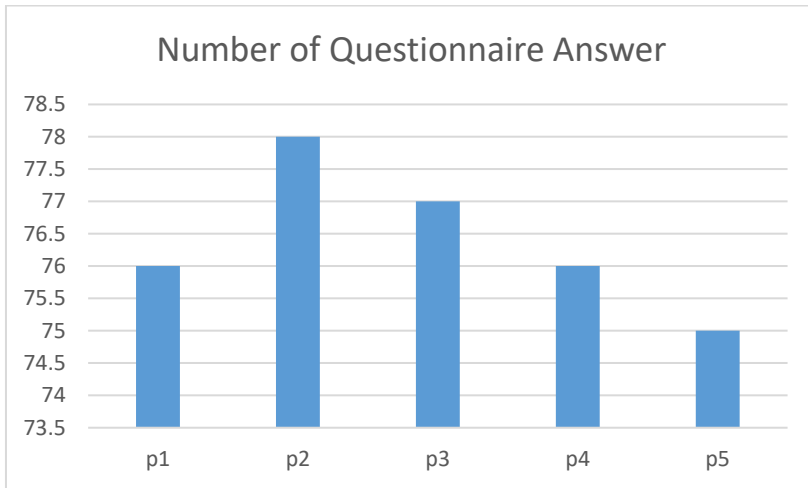


Fig. 16. Number of Questionnaire Answer

The data validity formula for finding the calculated R is shown in equation (1):

$$r_{xy} = \frac{n \sum x_i y_i - \sum x_i \sum y_i}{\sqrt{(\sum x_i^2 - (\sum x_i)^2) (n \sum y_i^2 - (\sum y_i)^2)}} \tag{1}$$

Information :

r_{xy} = person correlation

n = number of respondents

x_i = score of each item on the first trial

y_i = score for each item on the next trial or total test

4 Conclusion

Based on tests carried out by researchers entitled "PH Monitoring System, Temperature Automation and Clown Fish Feeding in Aquariums Using Fuzzy Logic Methods Based on the Internet of Things" it can be concluded that. The implementation of Sugeno fuzzy logic in this research has been running with 3 rules, namely if the temperature is cold ($0^{\circ}\text{C} < x < 25^{\circ}\text{C}$) the heater will turn on until the temperature is at 25°C while the cooler fan is off, if the temperature is normal the temperature is normal ($25^{\circ}\text{C} \leq x \leq 28^{\circ}\text{C}$) the heater and the fan cooler turns off, and if the temperature is hot ($28^{\circ}\text{C} > x$) the heater turns off while the fan cooler will turn on until the temperature is at 28°C . In the comparison test of the system temperature sensor with a thermometer there was a maximum difference of 0.3, while in the comparison test of the system pH sensor with a pH meter there was a maximum difference of 0.2°C

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