International Journal of Artificial Intelligence & Robotics (IJAIR)
Vol.6, No.1, 2024, pp.1-7
E - ISSN : 2686-6269

Prototype of pH and Water Temperature Control System in Discus Fish Farming Using IoT-based Sugeno Fuzzy

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ABSTRACT

Challenges in cultivating discus fish often arise from abrupt pH and temperature fluctuations attributed to manual and sluggish intervention. An IoT-based prototype for automatic pH and water temperature regulation was developed to address this. The study aimed to evaluate the efficacy of the prototype in controlling pH levels and water temperature and to explore the application of IoT-based fuzzy logic in discus fish cultivation. Test data from the implemented tools and sensors revealed an error comparison value of 0.0132% and an accuracy level of 99.986% for pH measurement. In comparison, temperature sensing yielded an error value of 0% with 100% accuracy. The IoT-based fuzzy Sugeno system demonstrated regular and effective operation in regulating pH and water temperature in discus fish cultivation, showcasing superiority over manual handling systems in mitigating sudden environmental changes.

Keywords: Discus Fish Farming, pH, Water Temperature, Fuzzy Logic, Microcontroller.

Article History		
Received : Dec 12th 2023	Accepted : May, 25th 2024	Published : May, 31st 2024

I. INTRODUCTION

Indonesia has abundant natural resources, from land to sea, which are valuable [1]. Indonesian waters have many types of fish, such as freshwater fish and seawater fish, with different growth rates, including Discus fish. Discus fish are freshwater ornamental fish with a round, flat shape like a disc. This fish comes from the waters of the Amazon River, where the water is slightly calm and shallow, with a depth of around 60cm. Discus fish are ornamental fish known for their beauty and color, but they require serious care because they are sensitive [2]. Drawing from the issue, the researchers developed a device capable of autonomously adjusting pH levels and water temperature. This tool will be accessible through an Android app to simplify the task of maintaining optimal water conditions for fish farmers, promoting consistent water quality, and facilitating better fish growth.

Researchers created a pH and water temperature control system for discus fish cultivation using IoT-based fuzzy Sugeno applying a NodeMCU ESP8266 microcontroller, which acts as a data processing center. Microcontrollers are ICs with very high density; all the necessary parts are packaged in one chip. The microcontroller consists of CPU, RAM, EEPROM/EPROM/PROM/ROM, /I/O, serial and parallel, timer, and interrupt controller. A microcontroller is an example of a simple computer system included in the embedded computer category. The microcontroller also contains a processor, memory, I/O, clock, and other things [3]. In the tool that will be made, sensors such as a pH sensor and temperature sensor and other tools such as a DC 5v water pump for acid and base liquids, a chiller, and a heater to reduce or increase the water temperature are used all controlled by a four-channel relay which functions as an automatic switch which is controlled on the NodeMCU. The relay is used as an electrical switch and, in the design, connects and disconnects the water pump and aerator [4]. The system used for this tool is the Internet of Things (IoT). IoT is a system for sending data or information with embedded devices, so a computer/laptop is unnecessary. This system is connected to sensors to monitor information from the environment, which are connected to actuators that can respond to monitoring conditions [5].

Controlling pH and water temperature in discus fish cultivation will involve a fuzzy logic method, namely Fuzzy Sugeno. One method in the fuzzy system that can be used to predict is the Sugeno method; this method is almost the same as the Mamdani method, and the output (consequence) is not a fuzzy set but a constant or linear Equation. Takagi, Sugeno, and Kang proposed the Fuzzy Sugeno Model to build a systematic approach to generating fuzzy rules from a given input-output data set. The fuzzy inference system using the Sugeno method has the characteristic that the consequent is not a fuzzy set. Still, it is a linear Equation

DOI: http://dx.doi.org/10.25139/ijair.v6i1.7524

with variables according to the input variables [6]. The Fuzzy Sugeno Method is a fuzzy inference method for rules represented IF – THEN. The advantage of Sugeno fuzzy is that it is a method that assumes a system with several inputs and one output [7].

Prof. Lotfi A. Zadeh first introduced Fuzzy Logic. The basis of Fuzzy logic is Fuzzy set theory. In fuzzy set theory, the role of membership degree as a determinant of the existence of elements in a set is vital. Membership value or degree of membership is the main characteristic of Fuzzy logic reasoning [8]. The implementation of this tool controls the water pH and temperature in Discus fish. When the pH sensor and temperature sensor detect that the water pH and temperature values are inappropriate, this tool automatically adjusts the water quality and water temperature. This tool can send sensor data, both pH and temperature sensors, to the user's smartphone device in real-time and can be controlled manually [9].

The part of fuzzification used for mapping is the membership function. Membership functions map elements of a set to membership values in the interval between 0 and 1. Membership functions differentiate fuzzy sets from firm sets. Membership functions can be represented in various ways, but the most common and widely used in systems based on fuzzy logic is analytical representation [10]. The membership function is a range of values representing the system input or output form and is used to map the input to fuzzy membership degrees. Members Gaussian is the same as a triangular curve; this curve is defined by two parameters, namely the value in the domain, which indicates the center of the curve (γ) and half the width of the curve (β) [11].

II. METHOD

A. Planning

Planning is a systematic process of preparing activities carried out to achieve specific goals. The planning function is a systematic preparation of activities carried out to achieve goals. The research planning process is carried out in several stages, namely the preparation, design, testing, and implementation stages [12].

1) Preparation Phase: The preparation stage is a series of activities before data collection and processing to assist in the process of completing the research, a thorough work guide was created so that the time to complete the research report can be planned well and the writing target can be achieved [13]. In the preparation stage, the aim is to prepare all the tools and materials needed to research a prototype system for controlling pH and water temperature in discus fish farming.

2) Design: At the design stage, a block diagram explains how the prototype of the pH and Water Temperature Control System in Discus Fish Farming Using the IoT-Based Sugeno Fuzzy Method works. This can be seen in Fig.1 block diagram design above, where several stages consist of Input - Process - Output. The block diagram shows several processes used in the pH and Water Temperature Control System in Discus Fish Farming. The explanation of the stages of Input - Process - Output is as follows:

- *a) Inputs:* A pH and water temperature control system in discus fish cultivation requires input from a pH sensor and a temperature sensor. The temperature and values obtained from the two sensors will be processed in NodeMCU.
- *b) Process:* In the process section, the pH value of the water obtained from the pH sensor and temperature sensor will be fuzzy-fused and processed in the NodeMCU to run the output of the DC water pump and chiller.
- *c) Outputs*: After processing, the DC water pump output will flow the acid and base solution, and then the chiller output cools the water temperature, and the heater warms the water temperature. Then, all data is sent to NodeMCU to be displayed in the Android application [14].

3) Testing: The testing stage is carried out by comparing the results based on manual tools with the sensors used and ensuring that the tools and systems usually function.

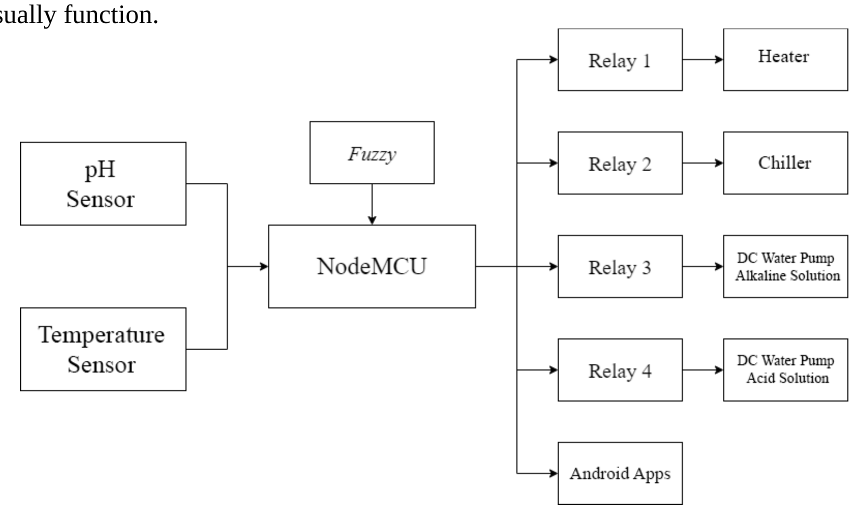

Fig.1. Block Diagram Design

B. Needs Analysis

At this stage, an analysis will be carried out of the system and hardware requirements for creating a pH and temperature control system for discus fish cultivation. The system analyzed contains information about everything related to pH and water temperature control devices in discus fish cultivation. The analysis stage used is the input and output requirements; in the analysis stage, the

DOI: http://dx.doi.org/10.25139/ijair.v6i1.7524

 E - ISSN : 2686-6269

input entered is the pH level and water temperature, which are read by the pH sensor and the water temperature sensor. In the analysis, the output specified is the pH sensor data and the water temperature sensor [15].

C. Flow chart

In this system flowchart, so that the program is made by hardware and software, it is necessary to do a hardware work program flow and software design program flow so that the program algorithm can be appropriately structured and clearly. The program will be written using the C programming language in the desktop application, the Arduino IDE. Fig.2 is an overview of the flowchart of the programming system.

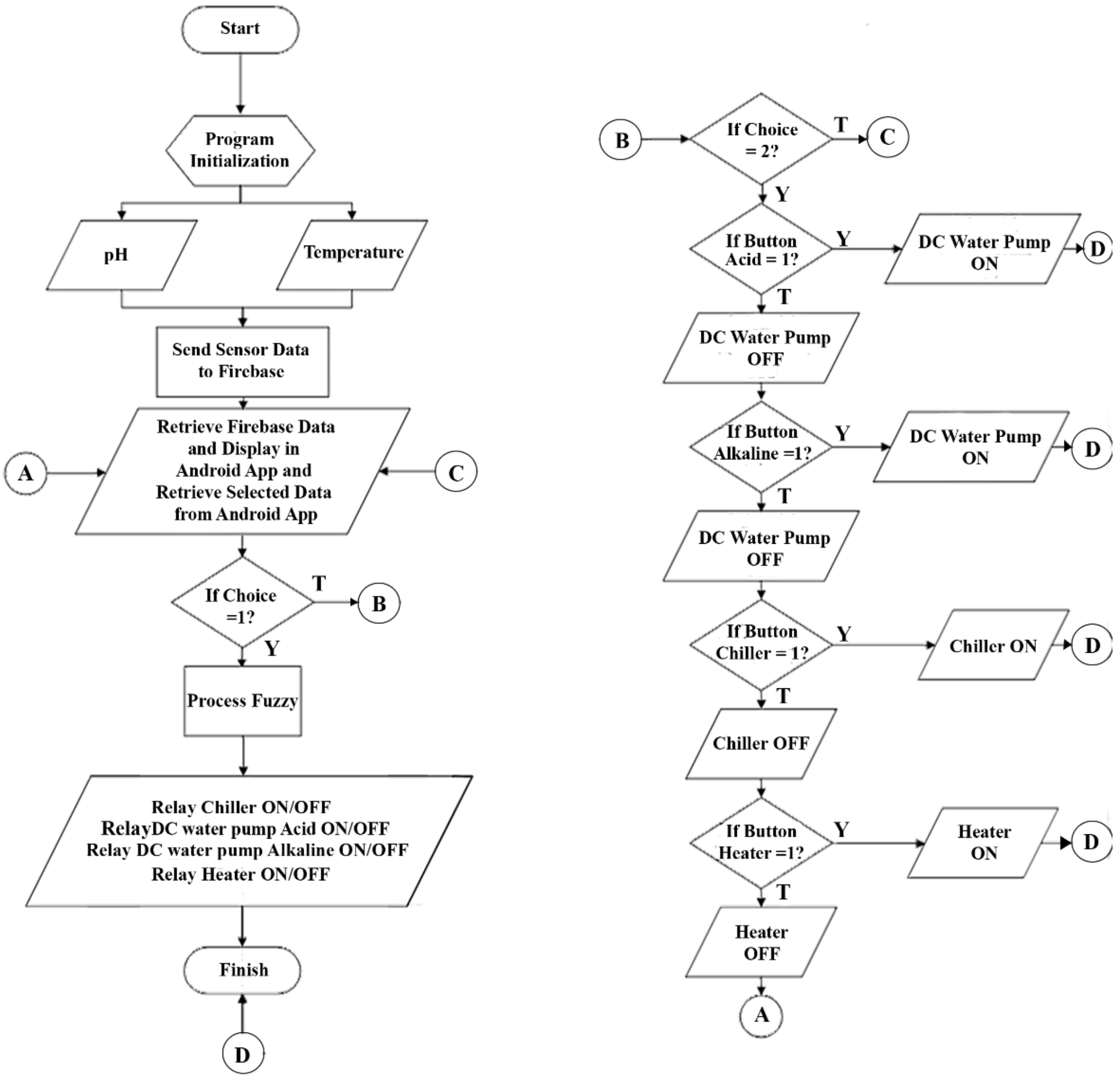

Fig. 2. System Flowchart

III. RESULTS AND DISCUSSION

A. Data Representation

This section describes the stages used to represent data, including fuzzification, formation of fuzzy rules, rule composition, and defuzzification.

1) Fuzzification: At this fuzzification stage, the crisp input value is taken from the pH and temperature sensors. In the trial, an aquarium was used as a cultivation container with a capacity of 20 liters of water. The two sensors will send data values to the microcontroller. After being received by the NodeMCU microcontroller, the data values obtained will be processed in the fuzzification stage to get the value of the membership degree [16]. To get the value of the membership degree, first determine the fuzzy set, which can be seen in Table I.

DOI: http://dx.doi.org/10.25139/ijair.v6i1.7524

TABLE I
SET TABLE

Function	Variable	Fuzzy Sets	Domain
Inputs	Power of Hydrogen(pH)	Acid	[0 - 4.5]
		Slightly Acid	[4.6 - 5.9]
		Neutral	[6 - 6.5]
		A Little Basic	[6.6 - 8.5]
		Alkaline	[8.6 - 14]
Inputs	Temperature°Cds18b20	Cold	[0°C- 22°C]
		Slightly Cold	[23°C- 26°C]
		Stable	[27°C- 30°C]
		A little bit hot	[31°C- 37°C]
		Hot	[38°C- 45°C]

Furthermore, to get the membership degree value, a membership function is also needed. In this prototype research, membership functions were used, namely triangular curves, rising curves, falling curves, and trapezoidal curves [17]. It can be seen in Fig.3, which is a curved image of the pH sensor membership function.

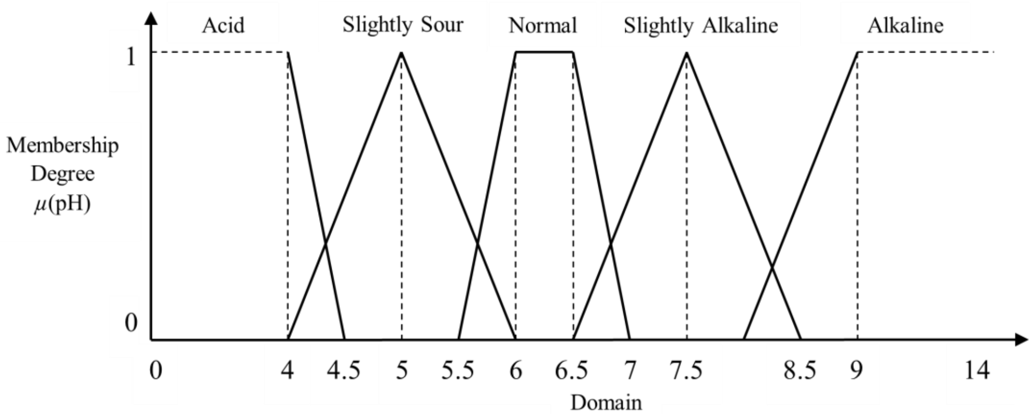

Fig.3. Sensor Membership Function Power of Hydrogen (pH)

The pH sensor membership function curve utilizes four types of curves: descending linear curves, triangular curves, trapezoidal curves, and ascending linear curves. In contrast, the temperature sensor membership function curve employs three types of curves: descending linear curves, trapezoidal curves, and ascending linear curves [18]. It can be seen in Fig.4, which is a curved image of the Temperatur sensor membership function.

a) Fuzzy Rule Formation: At this stage, the formation of fuzzy rules uses the Sugeno fuzzy method with a zero-order fuzzy rule formation model [19]. *If*(pH is Acid) and (Temperature is Cold), then (Heater is Old) (Chiller is Off) (pH Alkaline is Old) (pH Acid is Off).

b) Composition of Rules: At the rule composition stage in this research, the MIN implication function is used to find the α-predicate for each rule. Then the α-predicate value is used to calculate the output of the inference results firmly (crisp) on the rules (z1, z2, z3, ..., zn). In the example, the composition of the rules is as follows [20]. *If*(pH is Acid) and (Temperature is Cold), then (Heater is Old) (Chiller is Off) (pH Alkaline is Old) (pH Acid is Off)

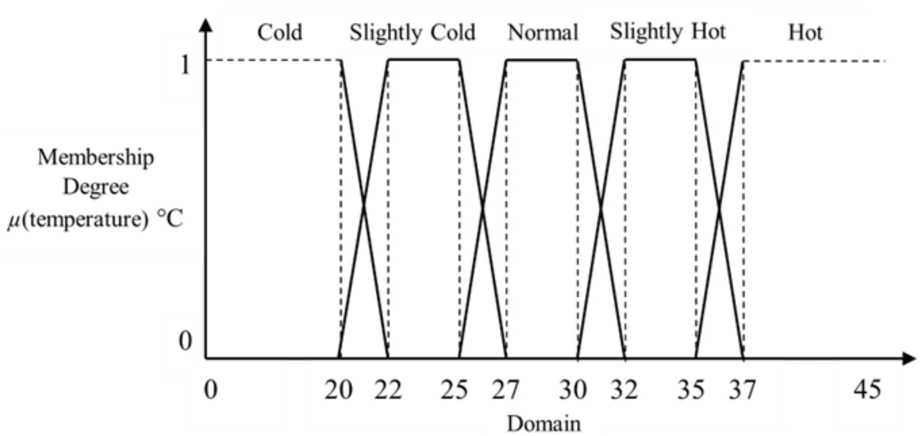

Fig.4. Temperature Sensor Membership Function

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2) Defuzzification: At this stage, the Sugeno fuzzy defuzzification process uses the average method. The defuzzification results are completed utilizing Equation (1) [21].

$$z = \frac{apred_1 * z_1 + apred_2 * z_2 + apred_3 * z_3 + \cdots + apred_n * z_n}{apred_1 + apred_2 + apred_3 + \cdots + apred_n} \tag{1}$$

B. Data Analysis Results

The results of the data analysis show that each component and factor influences each other. Based on the data, stages such as fuzzification, fuzzy rule formation, rule composition, and defuzzification are used to control each input and output of each fuzzy variable.

1) Planning: There are several stages to the design, namely tool design, software interface design, and fuzzy logic program design.

2) Tool Design: At the design stage of the tool for applying fuzzy logic to the prototype automatic pH and temperature control system in discus fish cultivation using two sensors as input, namely a pH sensor and a temperature sensor, as well as several hardware components such as NodeMCU, Chiller (consisting of 12V fan, Grill Fan Cover, Peltier 10 Ampere, water reservoir tube, Computer Heatsink), Relay, Heater, StepDown, 5v DC Pump, 41 Ampere PowerSupply, Aquarium container, Aquarium filter pump, aquarium filter, pH sensor and water hose. Fig.5 for the tool circuit from the front, back, and side directions.

Fig.5. Appearance of a series of tools

3) Software Design: At the design stage of this Android application, researchers used Kodular as a tool to help the process of making Android applications. Fig.6 for the appearance of the application design in this study.

a) *The initial interface display includes several displays*: The pH value display and temperature value display, as well as two menu buttons, the automatic and manual menu buttons. When the Automatically or Manually button is clicked, the next screen will appear.
b) *The system's automatic screen display:* The initial home interface screen, namely the display of pH and temperature values , the data of which is taken accurately via both sensors. The automatic system menu is declared active when the on/off switch button is turned on. Then, in the automatic system menu, there is a data display of the values of each output variable from Fuzzy Sugeno, which consists of the Chiller, Heater, base solution pump, and solution pump sour.
c) *The manual display menu:* The pH and temperature values , the initial interface, and the automatic menu. The manual menu is declared active when the on/off switch button is turned on. What makes the difference is that we can control all output variables manually in this manual menu. There are four variable output buttons for the base pump, acid pump, chiller, and heater.

(a) (b) (c)

Fig. 6. Android Application Display

4) Fuzzy Logic Design: At this fuzzy logic design stage, programming uses a desktop application called Arduino IDE. The program is written using the C programming language in the Arduino IDE application. The process in the fuzzy algorithm here consists of several stages, such as fuzzyfication and rule evaluation. [22]

DOI: http://dx.doi.org/10.25139/ijair.v6i1.7524

C. The calculation results

1) PH Sensor Testing: Testing is done by connecting the device to a power source so that the machine is on and the ESP8266 wifi sensor is connected to the internet network and the Firebase. In this trial, two ways of inputting data were carried out: from the internal pH sensor and external pH meter to test the accuracy of the two hardware devices and get a value comparison. Testing was carried out in a glass container using 250 ml of distilled water from a comparison of the two tools, which was carried out in 5 trials. The value comparison data from the two tools is sought for the average error value of the two tools using the formula Equation (2) below to calculate it. [23]

$$Error = \frac{pH\ Sensor\ Value - pH\ Meter\ Value}{pH\ Meter\ Value} \times 100\% \quad (2)$$

Manual calculations were carried out to test pH sensors and pH meters using acidic pH solutions 4.01 and alkaline 9.18, with a volume of 250ml of water and a measurement of two (2) tablespoons. Five trials were carried out to measure the percentage error. The result of the pH value of the percentage error is 0.066%, and the average error and accuracy of the pH value data are calculated using Equation (3) [24].

$$\text{Average error} = \frac{\sum Error}{\sum Uji\ Coba} \quad (3)$$
$$= \frac{0{,}066}{5}$$
$$= 0{,}0132\%$$

Overall precision (accuracy)$= 100\% - 0{,}0132\% = 99{,}986\%$

2) Temperature Sensor Testing: Temperature sensor testing was carried out using two data input methods, namely internal temperature sensor data input and external temperature thermometer, to test the accuracy of the two hardware devices and compare their values. Testing was carried out five times in a discus fish aquarium container with a water volume of 20 liters. Equation (4) calculates the average error value of the two devices. [25]

$$Error = \frac{Temperature\ Sensor\ Value - Digital\ Thermometer\ Values}{Digital\ Thermometer\ Values} \times 100\% \quad (4)$$

Another measurement of the temperature sensor and digital thermometer was carried out manually using a series of tools. PAM water was added to a 20-litre container along with ice cubes. Each experiment was repeated five times, and the final result obtained a percentage error value of 0.00%. Then, researchers calculated the average value of error and accuracy using Equation (5).

$$\textit{Average error} = \frac{\sum Error}{\sum Uji\ Coba} \quad (5)$$
$$= \frac{0{,}00}{5}$$
$$= 0\%$$

Overall precision (accuracy)$= 100\% - 0\% = 100\%$

IV. CONCLUSION

Based on the findings of evaluating fuzzy logic within the prototype design of the IoT-based automatic pH and temperature control system. The analysis of the tools and sensors employed in this study yielded a minimal error rate of 0.0132% with an exceptionally high accuracy level of 99.986% for pH measurement. Furthermore, the comparison between the temperature sensor and digital thermometer indicated an error rate of 0% with a remarkable accuracy of 100%. The comprehensive testing conducted in this research suggests that the automatic control system prototype for discus fish farming operates smoothly and reliably.

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DOI: http://dx.doi.org/10.25139/ijair.v6i1.7524