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GOLDFISH AQUARIUM WATER QUALITY CONTROL AND MONITORING SYSTEM USING FUZZY LOGIC CONTROLLER (FLC)

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Abstract

Goldfish is a unique type of carp. Its interesting shape makes it popularly kept by people as a hobby or business. In goldfish farming, it is necessary to manage water quality properly to meet the required water quality criteria to support their life. In this study, a water quality monitoring and control system was developed so that breeders can observe water quality conditions online, and the water quality control process can be carried out automatically. The system utilizes two sensors, namely turbidity sensor and pH sensor, to detect turbidity and pH levels in the aquarium water. The method employed in this study utilizes fuzzy logic to control the filter and pump in the aquarium. The results of the trial showed that turbidity decreased by 21.84%, from an initial value of 16.66 NTU to 13.02 NTU, and pH decreased by 15.26%, from an initial value of 7.86 to 6.66.

Keyword: Goldfish, Water Quality Control, Monitoring System, Fuzzy Logic.

INTRODUCTION

Keeping ornamental fish is a hobby that many people encounter, either as a side business or just to enjoy the beauty of these fish [1]. Goldfish are a type of ornamental freshwater fish that is in great demand by the public (Figures 1). These fish have varying sizes and shapes, and have various colors ranging from white, yellow, red, black and silvery [2].

Figure 1. Oranda Goldfish

Good water quality management is very important in keeping goldfish, with the aim of adjusting water quality criteria that support their habitat. Water problems in ornamental fish cultivation can be caused by the absence of water filters, food waste and fish feces. This results in poor water quality, such as turbidity, non-neutral pH, ammonia and DO [3]. However, most people only observe water quality in terms of turbidity. If the aquarium looks cloudy, clean it and replace the water with clean water. One

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effort to make it easier to keep goldfish so they can grow optimally is to control the turbidity and pH of the water. Fuzzy logic was chosen as the control method because it has a simpler method and has a fast response compared to the PID method [4].

Based on this background, this research designs and implements an Arduino-based aquarium water quality control and monitoring system for goldfish using the Fuzzy logic method. Control in the aquarium is expected to produce good water replacement times based on readings from the turbidity sensor and pH sensor, so that it can make it easier to maintain goldfish without having to supervise them directly.

There are various types of goldfish available, but there are only 15 types of goldfish which are quite popular and much liked by the public [5]. The type of Oranda goldfish as in Figure 1 is one of them, which has an attractiveness that makes it very popular among ornamental fish lovers. The length of the Oranda goldfish is around 20-23 cm. With proper care and living conditions, Oranda goldfish have a potential lifespan of up to 15 years [6].

Figure 2. Turbidity sensor module

The turbidity sensor used in the system as in Figure 2 uses a turbidity probe module which has a working principle similar to a proximity sensor. There is a photo diode as a receiver and an LED photodiode as a transmitter in it. This sensor uses light from the transmitter, then the reflected light is read by the receiver. Thus, the level of water turbidity detected will be proportional to the level of reflected light received, and vice versa [7].

This sensor has a working voltage specification of 5 Volt DC, max working current. 40mA, response time < 500ms, operating temperature 5°C to 90°C, has 2 output modes: analog s 0 to 4.5v and digital adjustable with potentiometer threshold value.

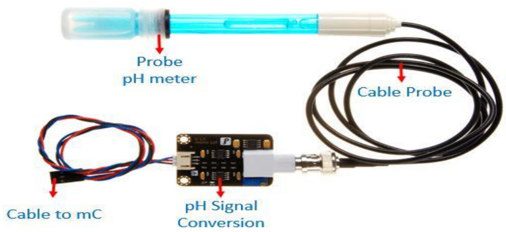

Figure 3. Water pH sensor

The pH sensor is used to measure the level of acidity or base (alkalinity) in a solution. This sensor module detects the pH level of water with an analog voltage output. The water pH sensor as in Figure 3, has specifications [8]: detection range: 0 – 14, working temperature 5 – 60 °C, response time < 2 minutes, working voltage 3.3 – 5.5 VDC, and analog output 0 – 3 V.

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As the main controller of the system, an Arduino Mega 2560 is used as in Figure 4. A microcontroller board with an ATmega2560 chip has 54 digital I/O pins, 15 of which can function for PWM output, 16 analog inputs, 4 UART (hardware serial ports), oscillator 16 MHz crystal, ICSP header, USB connection, and reset button [9]. Arduino Mega 2560 is compatible with most I/O modules and has complete features so it was chosen for this research.

Figure 4. Arduino Mega 2650

METHODS

The system that will be built in the research will adjust the aquarium water quality conditions by carrying out automatic controls such as water filters and water draining. The results of the turbidity and pH sensors obtained will then be processed by fuzzy logic control using the fuzzy mamdani method, with the output results being the action of draining and refilling the water.

System Block Diagram

Overall, the system can be described in a block diagram [10]. In Figure 5 you can see a block diagram including taking input, processing on the Fuzzy Logic Controller, output action, and monitoring via the website. With a website, the system can be monitored and its behavior observed remotely [11].

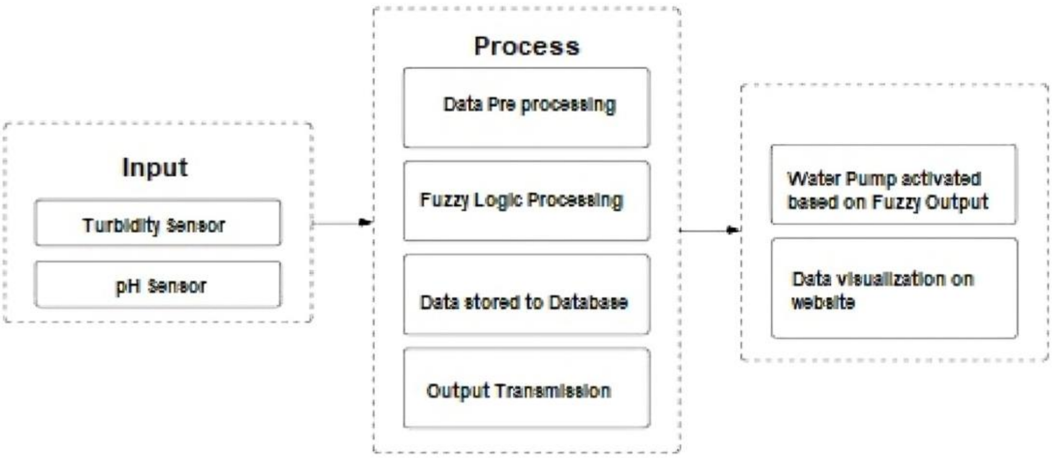

Figure 5. Block diagram of the water quality control and monitoring system

The turbidity sensor and water pH sensor are located in the input block. Meanwhile, in the process block there is an Arduino Mega board which functions to read the values obtained by the sensors and a NodeMCU which functions to process sensor data. In the output block there is a water pump and a website as a monitoring medium.

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Meanwhile, a clear picture of the physical relationships between parts of the system can be seen in the system architecture in Figure 6. This system architecture provides a detailed picture of the signal direction in the system along with the physical components used to process signals at each stage.

An explanation of the process flow in the system is as follows:

1. Data input: this stage reads the water turbidity value by the turbidity sensor, then reads the water pH value by the pH sensor which will be sent to the Arduino Mega.
2. Data processing: Arduino Mega receives data from the turbidity sensor and water pH sensor which are still in the form of analog values, then a calculation process will be carried out to obtain the turbidity value in NTU units and the pH value in pH units. After that, NodeMCU will retrieve the data using serial communication, in addition to processing it using the fuzzy mamdani method.
3. Data output: The output that will be issued will be the turbidity value and pH value of the water and the output results of the fuzzy logic method which will make the pump turn on for the same duration as the fuzzy output value that has been obtained. Sensor values are sent to the server and stored in a database so that they can later be observed on the monitoring website.

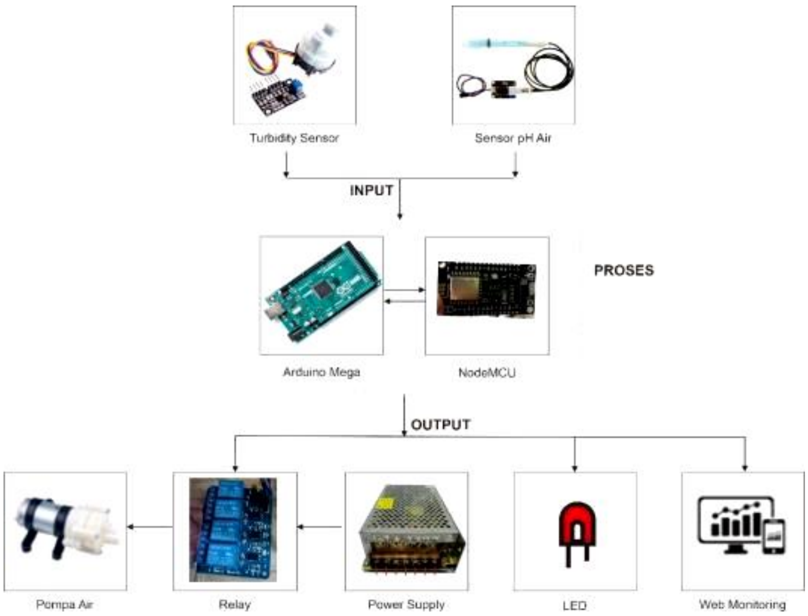

Figure 6. System architecture

Flowchart Diagram

The entire system process is controlled by a program embedded in the Arduino Mega 2560 with an algorithm in the form of a flowchart in Figure 7.

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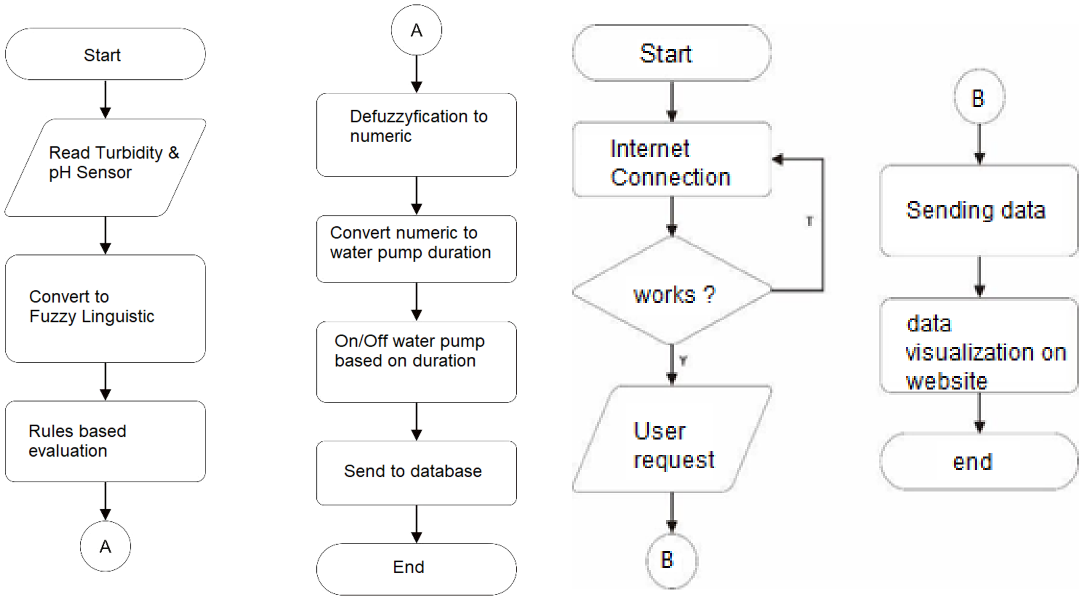
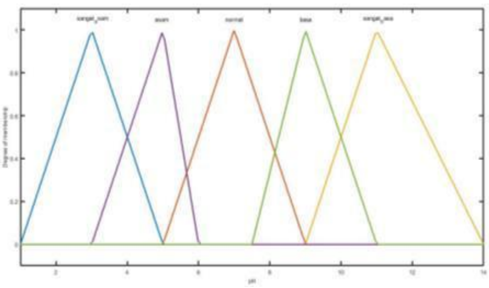


(a) (b)

Figure 7. (a) Flowchart of the FLC process and (b) data monitoring process

Fuzzification and Membership Function Design

The method used in the system is fuzzy mamdani, which is used to obtain duration values which will later be used to determine the movement of the actuator. In this fuzzification process, a decision-making process occurs to transform crisp inputs (definite forms) into fuzzy (linguistic variables). The determination of crisp inputs and crisp outputs in the form of a membership function can be seen in Figure 8:



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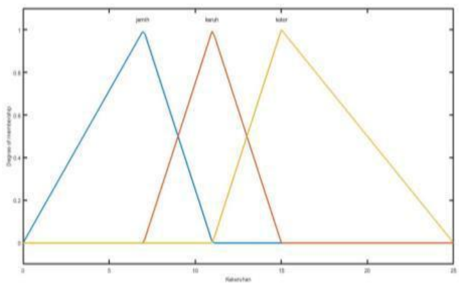

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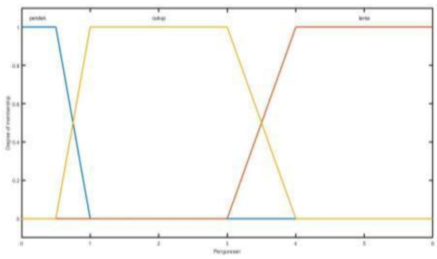
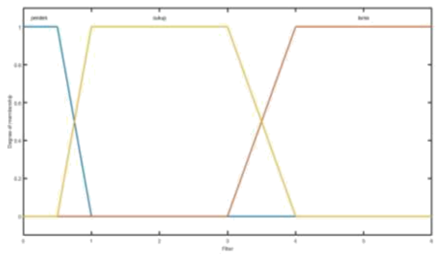


(c)



(d)

Figure 8. Membership functions for: (a) turbidity input, (b) pH input, (c) filter output, and (d) pump output

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a) The air turbidity variable is formed into three unitary functions, namely clear, turbid and dirty. The description of the values for each collection function is as follows: Clear = [0 7 11], Turbid = [7 11 15], Dirty = [11 15 25].
b) The air pH variable is formed into five collection functions, namely very acidic, acidic, normal, basic, and very basic. description of the values of each storage function as follows: Very Acid = [1, 3, 5], Acid = [3 5 6], Normal = [5 7 9], Basic = [7.5 9 11], Very Basic = [9, 11, 14].
c) The variable output filter has three group functions, namely short, sufficient and long. Description of the values of each membership function is as follows: Short = [0 0 0.5 1], Fair = [0.5 1 3 4], Long = [3, 4, 6, 6].
d) The drain output variable has three collection functions, namely short, sufficient and long. Description of the values of each membership function is as follows: Short = [0 0 0.5 1], Fair = [0.5 1 3 4], Long = [3 4 6 6].

Inference Systems

The inference mechanism is used as a reference to connect input and output variables where the processed and resulting variables are in fuzzy form. Explanation of the relationship between input and output usually uses "if-then". The fuzzy rules used by the system can be seen in table 1.

Table 1. Fuzzy Rules for Determining Pump Output

IF	Turbidity	pH	Filter	Drain
R1	clear	very sour	short	long
R2	clear	sour	short	medium
R3	clear	Normal	short	short
R4	clear	alkaline	short	medium
R5	clear	very alkaline	short	long
R6	turbid	very alkaline	medium	long
R7	turbid	sour	medium	medium
R8	turbid	Normal	medium	short
R9	turbid	alkaline	medium	medium
R10	turbid	very alkaline	medium	long
R11	dirty	very sour	long	long
R12	dirty	sour	long	medium
R13	dirty	Normal	long	short
R14	dirty	alkaline	long	medium
R15	dirty	very alkaline	long	long

Defuzzification

The defuzzification process is the final part of fuzzy mamdani, used to translate fuzzy membership values into decisions in numerical form. Or returning the fuzzy quantity value to a crisp value (exact number), and changing the fuzzy output to a crisp value based on the membership function, which was initially still in the form of a linguistic variable. The method used in this defuzzification process is the Centroid method (center point).

RESULTS AND DISCUSSION

Implementation of Website Monitoring

The first page that appears when the user runs the application is a display in the form of values from observations containing data such as water turbidity values, water pH, filter condition and pump condition. The appearance of the website can be seen in Figure 9.

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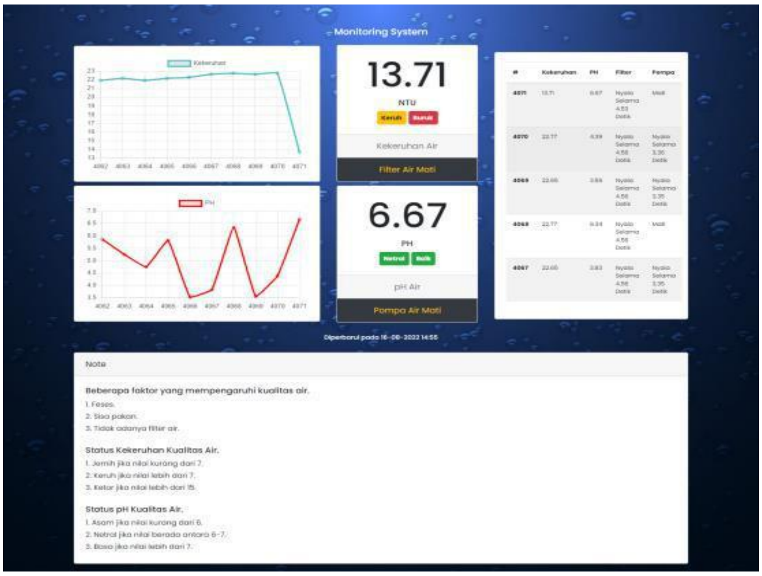

Figure 9. Monitoring website display

System Trial

The trial was carried out by comparing a system with a Fuzzy Logic Controller (FLC) and a system without using FLC. The resulting output results were taken through observations on the serial monitor. The data obtained can be seen in Table 2 for systems without using FLC and Table 3 for systems that use FLC.

Table 2. Test Results Without FLC

Trial	Turbidity (NTU)	pH	Filter (secon)	Filter condition	Pump (secon)	Pump condition
1	17.49	7.62	3	ON	3	ON
2	17.25	6.77	3	ON	3	OFF
3	18.19	6.72	3	ON	3	OFF
4	17.25	5.98	3	ON	3	ON
5	17.6	4.69	3	ON	3	ON
6	16.66	5.58	3	ON	3	ON
7	16.9	5.37	3	ON	3	ON
8	15.14	5.89	3	ON	3	ON
9	14.43	5.39	3	ON	3	ON
10	14.32	4.79	3	ON	3	ON

Table 3. Test Results with FLC

Trial	Turbidity (NTU)	pH	Filter (secon)	Filter condition	Pump (secon)	Pump condition
1.	16.66	7.86	4.64	ON	1.6	ON
2.	17.84	7.33	4.67	ON	0.42	ON
3.	18.42	7.17	4.66	ON	0.42	ON
4.	17.02	5.77	4.59	ON	1.74	ON
5.	11.26	6.19	2.38	ON	0.43	OFF
6.	11.73	5.75	2.86	ON	1.79	ON
7.	12.56	6.43	3.04	ON	0.43	OFF
8.	12.56	6.85	3.04	ON	0.43	OFF
9.	12.56	5.92	3.2	ON	1.21	ON
10.	13.02	6.66	3.32	ON	0.44	OFF

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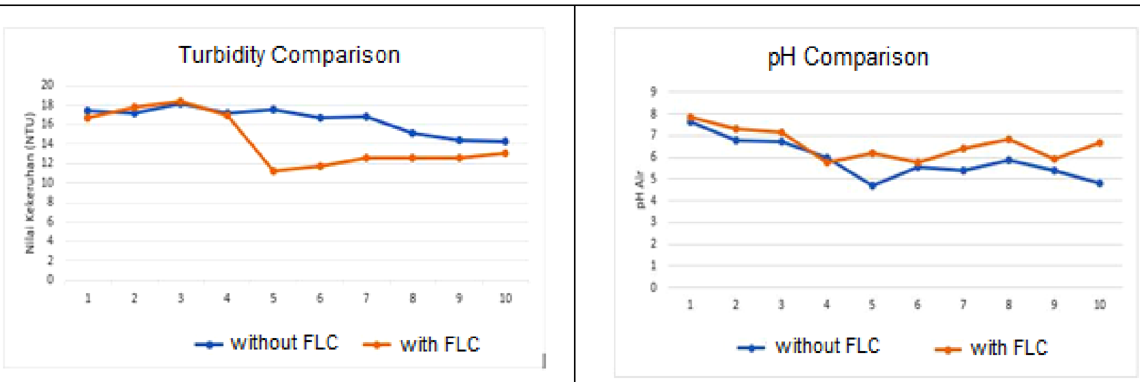
The results obtained from observations in table 2 and table 3 made a comparative graph of changes between the turbidity value and water pH which can be seen in figures 10 (a) and (b).



(a) (b)

Figure 10. Comparison graph of (a) changes in water turbidity, and (b) changes in water pH

From the results of comparison observations, for the system without FLC the turbidity value was reduced by 3.17 NTU, and for the system using FLC the turbidity value was reduced by 3.64 NTU. Meanwhile, for the comparative observation results of changes in pH values, for systems using FLC changes in pH values are more stable to be in the neutral pH range, namely 6-7 compared to systems without FLC.

CONCLUSION

Based on the research design and trials that have been carried out, it can be concluded that the implementation of an air quality control system using a Fuzzy Logic Controller makes it easier to control the quality of aquarium air that is very much needed by goldfish automatically and in real time. Tests that have been carried out by comparing the results of determining the duration of the pump against Turbidity and pH using FLC show a better tendency (decrease) compared to without FLC. Meanwhile, the existence of a monitoring website greatly helps the process of monitoring aquarium air quality. In addition, the system successfully controls the quality of aquarium water, with turbidity values decreasing by 21.84% from 16.66 NTU to 13.02 NTU, and pH values decreasing by 15.26% from 7.86 to 6.66.

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