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Article

Water Quality Control System In Goldfish Aquarium Using Fuzzy Method

Rizky Rizwansyach [1], Isa Hafidz[2*], and Chaironi Latif [3]

[1,2,3] Electrical Engineering, Telkom University, Surabaya, Indonesia

[*] Correspondence: isahafidz@telkom.university.ac.id

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Abstract: Considering the beauty and unique characteristics of goldfish as ornamental fish, keeping goldfish in an aquarium is a popular hobby among the community. However, some people face challenges in maintaining goldfish that must be controlled manually. In this work, the author proposes to create a water quality control system for goldfish aquariums using fuzzy logic. This system uses the E-201-C pH sensor to measure the water's pH level, the SEN-0189 turbidity sensor to detect water turbidity, an ultrasonic sensor to maintain water height, and the ESP32 as the microcontroller. In the pH control, a mini pump is used, which activates when the pH level is >9 to lower the water's pH to the set point. Meanwhile, for controlling water turbidity, two 12V DC pumps are used, where one pump functions to discharge turbid water and the other to fill with clean water. The data read by the sensor can be monitored through the OLED screen. Based on the test results, the water quality control system for the goldfish aquarium using the fuzzy method can function well. Meanwhile, the water draining process takes 5 minutes and 20 seconds, and the clean water filling takes about 15 minutes and 24 seconds.

Keywords: Fuzzy Logic; Goldfish; pH water; Turbidity; Water Pump.

1. Introduction

Keeping fish is one of the hobbies of most people, one of which is keeping goldfish. Goldfish are known as one of the ornamental fish that possess beauty and unique characteristics. According to data held by the Ministry of Maritime Affairs and Fisheries of the Republic of Indonesia, the freshwater ornamental fish sector contributes significantly to the Indonesian economy. Freshwater ornamental fish exports will be USD 111 million by 2020. Furthermore, the ornamental fish farming business can be considered one of the most cost-effective. This is inversely related to market conditions that drive the freshwater ornamental fish sector's strong demand. However, cultivators continue to face challenges such as the difficulty of performing regular coaching and supervising all of the monastery sites, which are many [1].

One of the common problems encountered when keeping fish in an aquarium is water quality. Non-tuberculous mycobacteria (NTM) are important diseases in wild, captive, marine, and freshwater fish, posing an infection risk to both aquarium fish and people. This study looked at the prevalence of NTM in ornamental fish from Ilam, western Iran. A total of 50 contaminated fish samples were collected and processed, with sediments added to Lowenstein-Jensen and Herrold egg medium. Positive colonies were assessed for growth rate, pigmentation, colony morphology, and biochemical activity, and molecular identification was accomplished using heat shock protein 65 kD gene (hsp65) sequencing. NTM were detected in 13 samples (26%), with 6 (46.2%) rapid-growing strains and 7 (53.8%) slow-growing strains. Mycobacterium marinum was the most usually isolated species, posing a concern to both fish and people. The results emphasize ornamental fish as an important source of NTM[2]. Poor water quality can negatively impact the health and growth of goldfish, and can even lead to death. In an effort to maintain aquarium water quality, managing parameters such as water pH and turbidity levels is crucial for ensuring the well-being of goldfish. The pH level required for goldfish aquarium water is in the range of 7 – 8 [3], but many goldfish keepers do not pay attention to the pH level, resulting in suboptimal fish growth and even death.

To determine the pH level in a goldfish aquarium is something that ornamental fish keepers do not think about. Aquarium keepers must manually check the water's pH level using a pH meter. In addition, water turbidity also greatly affects the decline in the health of goldfish. If the water in the aquarium has become cloudy, the owner should start changing the water to keep the goldfish healthy. However, if the water does not appear cloudy but the pH level is below the parameter, there is no need to change the water; it is sufficient to raise the pH level in the aquarium[4].

In a Closed-Loop System, the use of feedback from sensors can optimize the dynamic measurement and correction of motor performance according to actual conditions[5]. By using sensors such as encoders, closed-loop control can continuously monitor parameters such as speed, torque, and motor position to quickly respond to changes in load or operational conditions[6]. This ensures that the motor operates according to the desired setpoint, improving precision and performance stability, whereas in an open loop system, commands are given without considering direct feedback from the system's conditions.

In this work, the author proposed to create a water quality control system for goldfish aquariums using fuzzy logic. The open-loop system responds to commands that have been predetermined, without the ability to adjust its operations according to changes in load or working conditions. The open-loop system tends to be less responsive and less able to respond to unexpected changes in the operational environment.

2. Materials and Methods

In this research, a system is needed that can maintain the quality of pH levels and water clarity in a goldfish aquarium. Thus, this system uses a water pump controlled by a fuzzy logic controller to drain and fill the water as needed. Since goldfish aquariums rarely experience acidic conditions (pH < 6.5), the control focus in this system is limited to pH > 9. However, two-way control will be a part of future developments. The mechanical specifications for this aquarium include dimensions of 40 x 20 x 30 cm made of acrylic glass. Meanwhile, the electronic specifications include a 220 VAC power supply, ESP32 processor, OLED display, output voltage of 0 – 12 VDC, and output current up to 60 A, as illustrated in Figure 1.

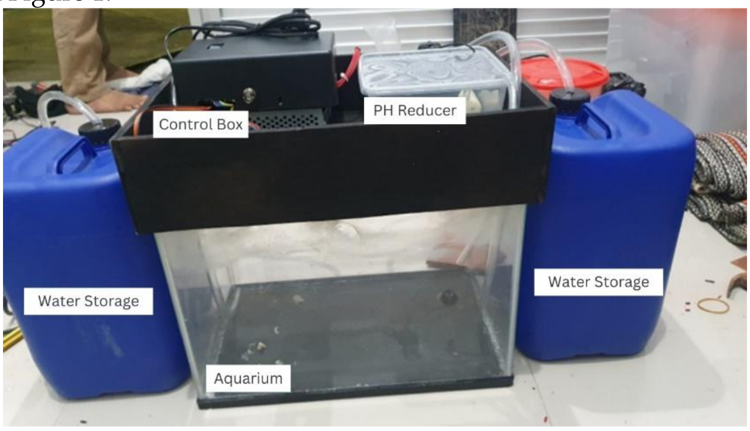

Figure 1. Water Quality Control System in Goldfish Aquarium Design.

2.1 Research Diagram

The purpose of a block diagram is to make it easier to depict the workflow of the system that will be constructed. The input to the general requirements of the intended system operation is where this procedure begins. The block diagram is made up of various parts. The system's block diagram, which includes input devices, processes, and outputs, is shown below. Murky water is drained by Pump 1 (DC 12V Pump 1), clean water is filled by Pump 2 (DC 12V Pump 2), and pH is neutralized by Pump 3 (micro pump).

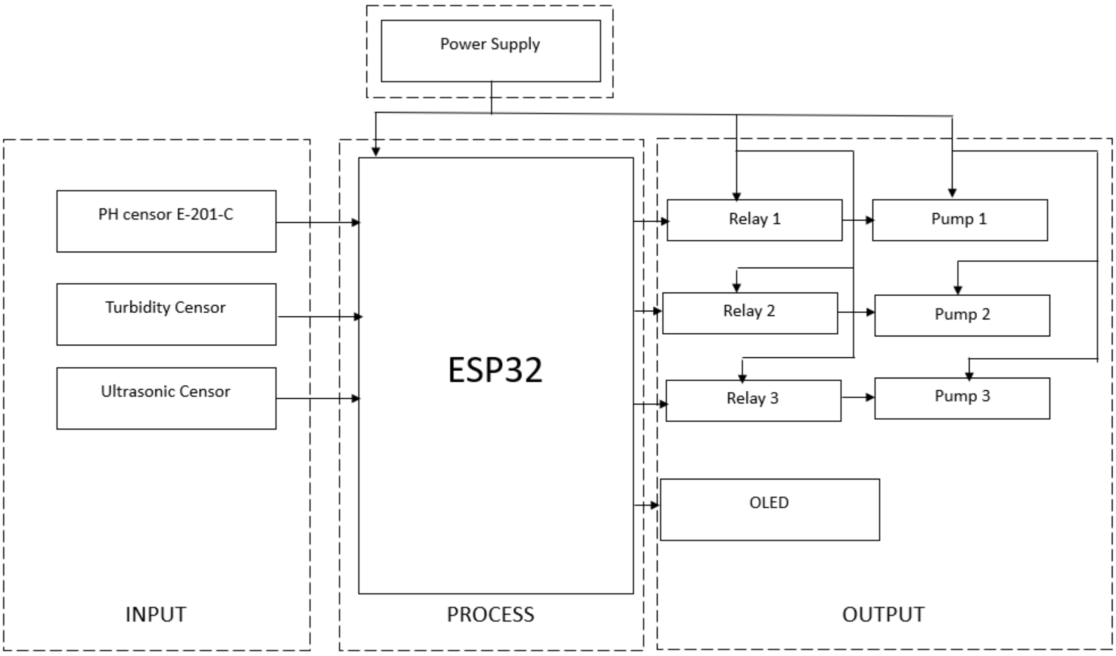

Figure 2. Block Diagram

2.2 Software Design

In Figure 2, there are fuzzy membership variables that will be used. The use of Fuzzy Logic in this tool is only as a pH controller for the goldfish aquarium using the mamdani method. The design of the Fuzzy logic in the system uses membership functions for water pH and turbidity. For acidic, neutral, basic categories on the pH scale are determined based on aquarium water quality standards. and clear water in aquarium terms generally has turbidity below 50 NTU. Water with turbidity above 100 NTU can stress sensitive tropical fish according to Encyclopedia of Aquarium Fish by Axelrod, H. R[7]

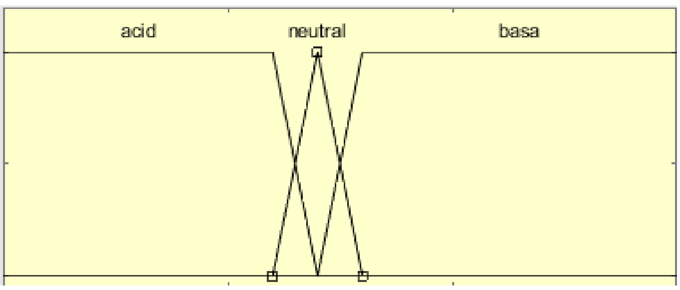

Figure 3. Fuzzy Membership Variables of Water pH

$$Acid = \begin{cases} 1\ ;\ x \le 6 \\ \dfrac{(7-x)}{(7-6)};6 < x < 7 \\ 0\ ;\ x \ge 7 \end{cases}$$

$$Neutral = \begin{cases} 0\ ;\ x \le 6\ atau\ c \ge 8 \\ \dfrac{(x-6)}{(7-6)};6 < x < 7 \\ \dfrac{(8-x)}{(8-7)}\ ;\ x \ge 7 \end{cases}$$

$$Basa = \begin{cases} 1\ ;\ x \ge 8 \\ \dfrac{(8-x)}{(8-7)};7 < x < 8 \\ 0\ ;\ x \le 7 \end{cases}$$

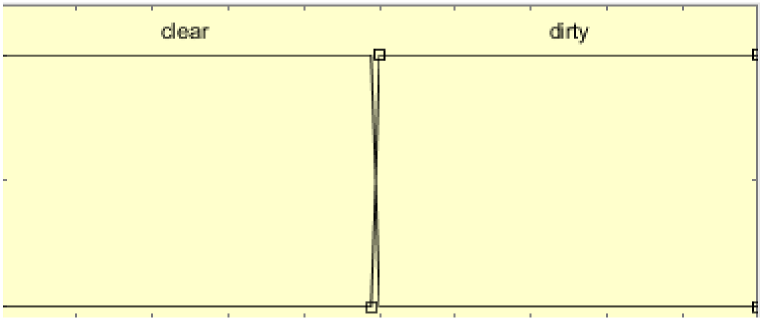

Figure 4. Fuzzy Membership Variables of Turbidity.

$$clear = \begin{cases} 1\ ;\ x \le 49 \\ \dfrac{(49-x)}{(50-49)};49 < x < 50 \\ 0\ ;\ x \ge 7 \end{cases}$$

$$dirty = \begin{cases} 1\ ;\ x \ge 49 \\ \dfrac{(x-49)}{(50-49)};49 < x < 50 \\ 0\ ;\ x \le 50 \end{cases}$$

After setting the fuzzy variable parameters for pH and water turbidity, the next step is to set the output membership variable parameters and provide the rulebase for the fuzzy system.

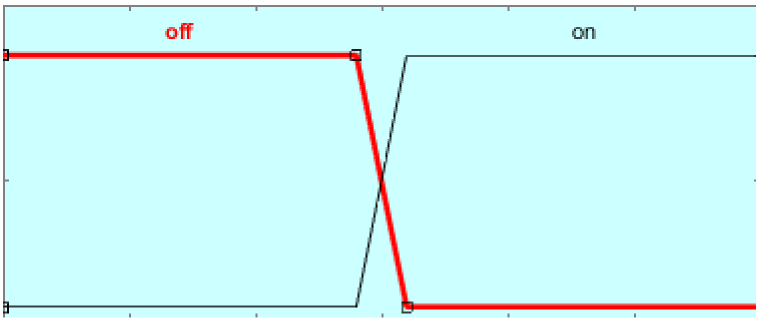

Figure 5. Output Membership Variables in Fuzzy

$$off = \begin{cases} 1\ ;\ x \le 14 \\ \dfrac{(15-x)}{(15-14)};14 < x < 15 \\ 0\ ;\ x \ge 15 \end{cases}$$

$$on = \begin{cases} 1\,;\ x \geq 15 \\ \dfrac{(16-x)}{(16-15)}\,;15 < x < 16 \\ 0\,;\ x \leq 15 \end{cases}$$

Next, add the rulebase using the "IF-THEN" rule that produces the following results:

1. If (pH is acidic) and (turbidity is clear) then (pump1 is off) (pump3 is off)
2. If (pH is acidic) and (turbidity is dirty) then (pump1 is on) (pump3 is off)
3. If (pH is neutral) and (turbidity is clear) then (pump1 is off) (pump3 is off)
4. If (pH is neutral) and (turbidity is dirty) then (pump1 is on) (pump3 is off)
5. If (pH is basic) and (turbidity is clear) then (pump1 is off) (pump3 is on)
6. If (pH is basic) and (turbidity is dirty) then (pump1 is on) (pump3 is on)

This reasoning is based on the fact that turbid water and high pH levels require both water replacement and pH neutralization. With the Mamdani method, using two inputs and two outputs. Then what will be obtained are six rules in the designed fuzzy system.

3. Experiments and Results

3.1 pH System Testing

pH system test aims to ensure that the water quality control system in the goldfish aquarium can operate optimally. In this test, a water quality control system with fuzzy control is used. The testing steps include the preparation of the necessary equipment, followed by testing the overall pH level of the water in the aquarium, and concluding with observation and recording of the test results to assess the overall performance of the system. A thorough system test was conducted to determine whether the pH control system in the goldfish aquarium is functioning properly, with the test results shown in the table 1.

Table 1. Testing the System Response Without Fuzzy Control

Time (Minute)	pH censor	Pump 3 (pH reducer)
00.00	10.70	Active
03.00	9.96	Active
05.00	7.64	Inactive
05.00	7.25(Neutral)	Inactive
08.00	9.20	Active
10.30	12.67	Active
11.02	14.58	Active
12.19	10.53	Active

Time (Minute)	pH censor	Pump 3 (pH reducer)
13.10	8.45	Active
13.30	7.24(Neutral)	Inactive
14.09	9.10	Active
14.50	11.75	Active
15.10	12.25	Active
17.08	10.03	Active
18.24	8.89	Active
20.10	6.82	Inactive
21.15	7.92	Inactive
23.57	9.77	Active
24.50	10.71	Active
26.01	11.84	Active
27.05	10.11	Active
29.07	7.10(Neutral)	Inactive
30.55	8.96	Active
31.49	9.74	Active
32.50	10.72	Active
33.10	11.85	Active
34.06	10.36	Active
36.57	7.97(Neutral)	Inactive

Based on the results of testing the system without controlling the aquarium's water quality, specifically pH, and using baking soda to boost the pH, which produced real-time data, it can be said that the pH levels' decline indicates variations. This happens because the micro pump's fluid production is controlled by an on-off mechanism rather than being precisely controlled, making it impossible to precisely adjust the volume of fluid delivered to lower the aquarium's pH.

Table 2. Results of System Response Testing to High pH Disturbances.

Time (Minute)	pH censor	Pump 3 (pH reducer)	Fuzzy
00.00	6.50	Inactive	7.68
02.55	7.10	Inactive	8.95
03.27	7.90	Inactive	21.1
05.01	9.20	Active	22.6
07.20	12.67	Active	22.6
09.30	14.58	Active	22.6
11.12	10.53	Active	22.6
12.15	8.45	Active	22.6
13.16	7.24(Neutral)	Inactive	11.1
14.09	9.10	Active	22.6
15.13	11.75	Active	22.6
15.58	12.25	Active	22.6
15.10	10.03	Active	22.6
16.07	8.89	Active	22.6
18.21	6.82	Inactive	7.52
20.11	7.92	Inactive	21.4
21.19	9.77	Active	22.6
23.43	10.71	Active	22.6
24.39	11.84	Active	22.6
26.01	10.11	Active	22.6
27.25	8.86	Active	22.6
28.30	7.10(Neutral)	Inactive	8.95
29.34	8.96	Active	22.6
30.25	9.74	Active	22.6
31.49	10.72	Active	22.6

Time (Minute)	pH censor	Pump 3 (pH reducer)	Fuzzy
32.47	11.85	Active	22.6
33.18	10.36	Active	22.6
34.25	9.24	Active	22.6
36.38	7.97	Inactive	21.1

Table 2 describe the experiment testing the system's response to disturbances in the form of pH levels higher than the setpoint. It takes approximately 8 minutes for the water's pH to return to the setpoint marked with an orange color table.

3.2 Overall Water Turbidity Testing

This test aims to assess whether the water quality control system in the goldfish aquarium is functioning optimally. The tool used in this test is the goldfish water quality control system. The procedure of the test includes equipment preparation, the complete execution of the test on the turbidity level of the aquarium water, as well as observation and recording of the overall system test results. With the test results, they can be seen in the table 3:

Table 3. Water Turbidity System Testing

NTU	Pump 1 (Discharging Water)	Pump 2 (Adding Water)	Ultrasonic sensor	Fuzzy
100	Active	Inactive	10	22.8
80	Active	Inactive	12	22.8
60	Active	Inactive	14	22.8
40	Active	Inactive	16	7.68
20	Active	Inactive	18	7.68
10	Active	Inactive	19	7.68
0	Inactive	Active	20	7.68
0	Inactive	Active	18	7.68
0	Inactive	Active	16	7.68
0	Inactive	Active	14	7.68
0	Inactive	Active	12	7.68
0	Inactive	Inactive	10	7.68

From the experiment, when the turbidity sensor detects water turbidity reaching more than 50 NTU, the system will automatically perform a drainage. The water drainage in this aquarium is carried out using a DC 12V 1 pump to remove the turbid water. This process will stop automatically when the ultrasonic sensor detects the water level reaching 20 cm, taking 5 minutes and 20 seconds. After that, the 12V DC pump 2 will turn on to fill with clean water, and will stop when the ultrasonic sensor detects a water height of 10 cm. At this point, the turbidity sensor will ensure that the water turbidity reaches 0 NTU, indicating that the water is clean. Filling the clean water takes 15 minutes and 24 seconds.

4. Conclusions

Based on the problem formulation, mechanical planning, and the design of the water quality control system in a goldfish aquarium with fuzzy control, several conclusions can be drawn. First, the water quality control system using the fuzzy method is capable of operating with a low error rate. Second, from the test results, this system can lower the water's pH level to the specified point. Third, the water turbidity control system will automatically drain the dirty water when the turbidity level reaches 50 NTU, with a drainage time of 5 minutes and 20 seconds using a 12V DC 1 pump. Finally, the pH and turbidity monitoring system is functioning well according to the readings on the OLED.

References

1. A. F. Nurzaman, M. Wildan, and N. Anisa, "Development of Internet of Things System for Smart Fishery in Ornamental Fish Farming," in *Proceedings of 2023 International Conference on Information Management and Technology, ICIMTech 2023*, 2023. doi: 10.1109/ICIMTech59029.2023.10277831.
2. M. Yazdanmanesh, K. Tadayon, D. Bagherian Koshkghazi, and N. Mosavari, "Isolation and identification of non-tuberculous mycobacteria from aquarium fish in Ilam, Iran," *J. Clin. Tuberc. Other Mycobact. Dis.*, vol. 37, 2024, doi: 10.1016/j.jctube.2024.100478.
3. M. Cleal, A. Gibbon, B. D. Fontana, and M. O. Parker, "The importance of pH: How aquarium water is affecting behavioural responses to drug exposure in larval zebrafish," *Pharmacol. Biochem. Behav.*, vol. 199, 2020, doi: 10.1016/j.pbb.2020.173066.
4. K. L. Onthank *et al.*, "The Open acidification Tank Controller: An open-source device for the control of pH and temperature in ocean acidification experiments," *HardwareX*, vol. 14, 2023, doi: 10.1016/j.ohx.2023.e00435.
5. N. L. Manuel, N. İnanç, and M. Lüy, "Control and performance analyses of a DC motor using optimized PIDs and fuzzy logic controller," *Results Control Optim.*, vol. 13, 2023, doi: 10.1016/j.rico.2023.100306.
6. L. Zhang, "A Deployment and Coverage Optimization Algorithm for Self-Powered Wireless Sensor Networks Based on Hybrid Swarm Intelligence," *IEEE Sens. J.*, vol. 23, no. 18, 2023, doi: 10.1109/JSEN.2022.3230955.
7. H. R. Axelrod, *Encyclopedia of Aquarium Fish*. Neptune City, New Jersey: TFH Publications, 2005.

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