Design and Implementation of Filter Pump Control in a Freshwater Fish Aquarium based on Fuzzy Logic

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Abstract. One of the essential factors in the cultivation of freshwater ornamental fish in the aquarium is the water quality. Quality aquarium water is clear water with appropriate temperature and pH. In this study, the design and implementation of the control system based on fuzzy logic for filter pump work cycle were reported. The fuzzy logic in the controller will provide the strength of filter pump work based on the information on the turbidity level of water obtained from the photodiode sensor and the acidity of the water collected from the pH sensor. The results of the fuzzy logic controller design are implemented in Arduino UNO R3 microcontroller to control filter pump strength. The experimental results show that the controller can improve the water clarity level at the desired level in a reasonably short time. In addition, it was also demonstrated that the system performance was still good even in the existence of disturbance.

1. Introduction

Indonesia is a country with a tremendous diversity of ornamental fish. At present, there are more than 400 species of freshwater ornamental fish and more than 650 species of marine ornamental fish that have been cultivated in Indonesia. Market potential and trends in ornamental fish production in Indonesia have excellent economic prospects [1]. According to the ministry of marine affairs and fisheries of the Republic of Indonesia, currently, Indonesia is the third largest exporter of seawater ornamental fish in the world and the fifth largest exporter of freshwater ornamental fish [2]. With better management and proper technology, Indonesian ornamental fish production will be increased.

One technology that needs to be developed in ornamental fish cultivation is aquarium technology. The technology used in seawater fish aquariums has a difference from that used in freshwater fish aquariums. In this paper, the type of aquarium that will be discussed is only for freshwater fish. In general, the technology developed in aquariums is to maintain the quality of water to be in the best condition for fish, Parameters including water hardness, acidity, temperature and aeration [3]–[6]. Water hardness is due to the presence of various ions of calcium, magnesium, barium, and strontium. Water hardness also influences water acidity or alkalinity. Generally, an aquarium system comprises of filter, pump, aerator and heater. In a tropical country like Indonesia, the heater is rare to use since the temperature is nearly constant all year. That is why the aquarium system mainly a mechanism of controlling filter-pump-aerator to maintain the quality of water. There are many types of filters, i.e. physical filter, chemical filter and biological filter [7]. This paper will discuss the controlling filter pump in maintaining water quality. Only physical filter is being considered here while the aerator works at the same time with the filter pump.
Since first proposed by Lofti Zadeh in 1965, fuzzy logic has attracted extensive attention [8]. The most important implementation of Fuzzy logic is in control field [9]. It radically changes control paradigm which is based on precise modelling, estimation and decision into the approximate one based on imprecise, or vague information. Using a fuzzy logic controller, a complex or ill-defined system can simply be approximated by natural language. The aquarium is a combination of physical (i.e. filter-pump-aerator) and biological system, hence modelling and control such a complex system could be a very laborious task. In this paper, we proposed to use the fuzzy logic controller to control the strength of the filter pump in a freshwater fish aquarium.

2. Design and Implementation of Control System

2.1. Description of Controlled System

Figure 1 is a schematic diagram of the aquarium system. This aquarium is a medium size one with the dimensions of 100 cm x 40 cm x 40 cm containing about 130 liters of fresh water. A pump placed outside the aquarium box sucks the water flowing to the filter via a hose. Strength of water suction is controlled by the fuzzy logic controller embedded in an Arduino Uno microcontroller according to water condition. There are two sensors used in this system, photodiode sensor and acidity (pH) sensor. From photodiode information, the turbidity of the water is sensed. Turbidity and pH value provides the control system information to maintain water quality (i.e. water hardness, acidity and aeration) in the aquarium.

![Figure 1. Prototype of Aquarium System](image)

Block diagram of the control system is depicted in Figure 2. The desired output is a certain level of turbidity. This information, combined with current turbidity level and pH value will be processed by a fuzzy logic controller to determine voltage applied to the filter pump. Fish excretion as well as uneaten food will become disturbance of the system since they are affecting both turbidity and pH of the system.

2.2. Design of Fuzzy Logic Controller

A fuzzy logic controller in this paper is a Mamdani type fuzzy system with two inputs, namely turbidity and pH level. Turbidity is designed in percentage which is determined according to the capability of the photodiode sensor to sense light in the aquarium. To realize this turbidity leveling, a certain amount of fish food (pellet) is added to the clean fresh water. Accordingly, 0% means clearest water level (with no pellet pour to the water), while 100% means the darkest water level (with 100 grams pellet pour to the water). Table 1 is selected data of the relation among amount of pellet (in grams), voltage of the photodiode (in Volts), intensity of measured light in the aquarium (in Lux) and given percentage value.
of turbidity. For pH, since the water condition is "Normal" to "Most Alkali" level, the lowest fuzzy set is with pH starting from 0 to 7, while the highest fuzzy set represents the most alkali condition (pH 14). Figure 3 and Figure 4 provide a fuzzy set of water turbidity and water acidity. The output of the fuzzy logic controller is the voltage applied to filter pump in term of Pulse Width Modulation (PWM) signal. A fuzzy singleton depicted in Figure 5 is employed for this purpose.

![Figure 2. Block Diagram of Filter Pump Control System](image)

| Amount of Pellet (gram) | Voltage of Photodiode (volt) | Light Intensity (lux) | Turbidity (%) |
|-------------------------|-----------------------------|----------------------|---------------|
| 0                       | 3.8                         | 131                  | 0             |
| 10                      | 3.7                         | 123                  | 7.4           |
| 20                      | 3.6                         | 112                  | 17.5          |
| 30                      | 3.48                        | 101                  | 27.7          |
| 40                      | 3.38                        | 91                   | 37            |
| 50                      | 3.2                         | 80                   | 47.2          |
| 60                      | 3.12                        | 70                   | 56.4          |
| 70                      | 2.96                        | 58                   | 67.5          |
| 80                      | 2.88                        | 45                   | 79.6          |
| 90                      | 2.77                        | 34                   | 89.8          |
| 100                     | 2.7                         | 23                   | 100           |
The main part of a fuzzy logic controller is the fuzzy rule, which is in the form of IF-THEN rule. Table 2 summarised fuzzy rules employed in this work. For example, when the turbidity is “Mid Clear” and the acidity is “Low Alkali” then the following rule will be used:

\[ \text{IF Turbidity is MC and Acidity is LA THEN PWM length is LSP} \]

Firing fuzzy rules were aggregated and then de-fuzzified using Weighted Average method to get the final control action signal. Fuzzy sets definitions, fuzzy rule, as well as the whole inference processes were embedded in an Arduino Uno R3 microcontroller.
Table 2. Fuzzy Rule

| Turbidity | Acidity |  \( N \) |  \( L \) |  \( A \) |  \( M \) |  \( H \) |  \( VH \) |
|-----------|---------|---------|---------|---------|---------|---------|---------|
| C         | \( SP \) | \( SP \) | \( SP \) | \( SP \) | \( SP \) | \( SP \) |
| MC        | \( SP \) | \( LSP \) | \( LLP \) | \( LP \) | \( LLP \) |
| M         | \( LSP \) | \( LSP \) | \( LLP \) | \( LLP \) | \( LLP \) |
| MT        | \( LLP \) | \( LLP \) | \( LSP \) | \( LSP \) | \( LSP \) |
| T         | \( LP \) | \( LP \) | \( LP \) | \( LP \) | \( LP \) |

3. Experimental Results and Discussion

Two types of experiments were conducted, namely, experiment without disturbance and with disturbance. In the first experiment (depicted in Figure 6), the proposed filter pump system was performed water treatment to reach the desired turbidity rate at 40%. The initial value of turbidity was 70%. After 155 minutes, the turbidity reaches its desired value and remain in steady state condition.

![Figure 6. Experimental Result without Disturbance](image)

In the second experiment, the aquarium was initially at clear and good condition (turbidity rate less than 30%). Then fish food was given into the aquarium so that the turbidity increased rapidly to 75%. Then the filter pump was activated to recover the condition. After 215 minutes the turbidity rate reached the desired value of 40% and remain at the value as the system reach its steady-state level.
4. Conclusions
This paper shows a fuzzy logic controller to provide the strength of filter pump based on the information on the turbidity level of water obtained from the photodiode sensor and the acidity of the water obtained from the pH sensor. The results of the fuzzy logic controller design are implemented in Arduino UNO R3 microcontroller to control filter pump strength. The experimental results show that the controller can improve the water clarity level at the desired level in a reasonably short time. In addition, it was also demonstrated that the system performance was still good even in the existence of disturbance.

5. References
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