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Implementation of Fuzzy Logic Controller for Oxygen Control System in Aquaculture Pond

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Abstract

The objective of this research is to implementation of fuzzy logic controller system for monitoring the water quality of aquaculture ponds by monitoring the temperature and dissolved oxygen. The measured water quality level decides when to turn the pump ON/OFF. The proposed system is straightforward to use for aquaculture farmers. Experimental results show that fuzzy logic controllers used to control water oxygen systems can reduce the electricity consumption of the pumps ON/OFF and reduce the risk of mortality in aquaculture effectively.

Keywords—fuzzy logic, controller, oxygen, aquaculture, pond

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Abstract— **The objective of this research is to implementation of fuzzy logic controller system for monitoring the water quality of aquaculture ponds by monitoring the temperature and dissolved oxygen. The measured water quality level decides when to turn the pump ON/OFF. The proposed system is straightforward to use for aquaculture farmers. Experimental results show that fuzzy logic controllers used to control water oxygen systems can reduce the electricity consumption of the pumps ON/OFF and reduce the risk of mortality in aquaculture effectively.**

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I. INTRODUCTION

Water matters in aquaculture, whether it is temperature, acidic or alkaline, turbidity or light transmittance in water, dissolved oxygen, total alkalinity, and hardness. These all influence aquaculture together [1]. Therefore, oxygen in water is one of the relevant factors in the growth of aquatic animals. For example, when the water temperature and salinity are high, there is less dissolved oxygen. Therefore, the concentration of dissolved oxygen in water is equal to the oxygen in the atmosphere, so it is called the saturation level. Thus, aquatic animals are at risk of oxygen shortage. This results in the need to control and prevent the reduction of dissolved oxygen to protect aquatic animals from living normally [2].

Introducing automatic control systems for aquaculture will assist farmers in technically correct raising procedures and resolve problems more precisely, faster, and more accurately. A fuzzy logic controller (FLC) is a method used to control controllers to make decisions that are close to humans [3]. It can work together with multiple wells with pump control. It can save equipment costs and is convenient for maintenance. Fuzzy controls have control rules that are used to deal with actual variables, such as water quality, to make rational decisions. Which the decision to control raising appropriately proper control of food intake Controlling various parameters of water quality to an appropriate value, etc., in order for the aquaculture animals to have better quality and increase productivity.

In this paper, the researchers applied FLC method to the aquaculture oxygen control system to control and prevent the dissolved oxygen content from decreasing and maintaining a stable temperature suitable for the growth of aquatic animals. This article presents "Implementation of a fuzzy logic controller for oxygen control system in aquaculture pond" provides two parameters, temperature and dissolved oxygen (DO) as inputs in crisp form and converts the variables into a single fuzzified output for control. The controller was then taken to experiment with oxygen control in the aquaculture pond.

II. MATERIALS AND METHODS

An oxygen control system in aquaculture pond uses the Mamdani of fuzzy logic to improve decision-making or estimation. The system architecture shown in Fig.1 comprises the dissolved oxygen sensor, temperature sensor, Arduino, LCD, relay, magnetic contactor, and motor pump. A sensor system is placed in the pond to collect real-time water quality values and collect dissolved oxygen and temperature data of water. Arduino will then decides the working style from the fuzzy rules to decide on the ON/OFF motor pump. Arduino processes the data from the measured sensors and signals the relay control. The working relay signals the magnetic contactor to control the motor pump.

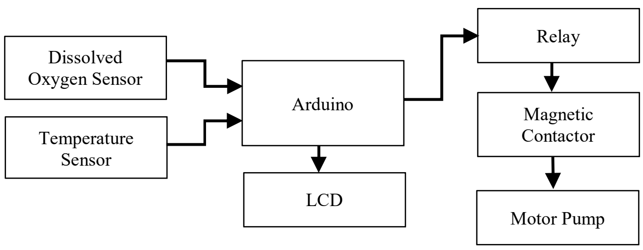

Fig.1 Block diagram of the system architecture

The water quality control system in the pond uses the main processor, Arduino Uno R3. It receives the input of temperature value and DO value sends it to the processor to judge the motor pump. The driver runs when the oxygen content in the water is >= 3 ppm and the water temperature is below 25ºC – 32 ºC. The processing part operates according to the fuzzy rules that are defined and signals the relay control. Then order the magnetic contactor to control the water pump and display the output data on the LCD screen.

In this research, there are using 2 types of sensors are used to check water quality comprising temperature sensor No. DS18b20 is a digital measuring IC with a measurement range of -55 - 125ºC, accuracy +- 0.5ºC, is wrapped in plastic, making it convenient to measure the water temperature in the pond. DO sensor uses a replaceable head-type oxygen sensor. It has a feature that measures the resistance variable with the oxygen level in the water. When the oxygen value in the water is low, it means that the sensor head resistance is high. And the higher the oxygen in the water, the less the sensor head resistance.

A. Design of Fuzzy Logic Controller

Fuzzy inference system (FIS) is a computational science that has played an important role in research and has been used in various fields. Fuzzy logic is a flexible decision-making tool that employs logic that mimics human thinking.

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Fuzzy logic operates under a knowledge base built from a database and the expertise of the system's creators tuned in to provide a relatively stable output response. It is stable based on past behavior and the level of knowledge base used. FIS is accordingly a control scheme that allows the water quality to reach the optimum range precisely, as shown in Table 1. The optimum quality range of dissolved oxygen in water and temperature will make the pond suitable for living propagation and conservation of aquatic animals.

The control system receives parameters, including DO value and temperature value and sends them to fuzzification. By interpreting degree of membership, then inferring to find the system output fuzzy set using "if-then" fuzzy rule base and defuzzification using center of maximum method to get output. Where the output is the percentage of the measured water quality to control the on-off of the pump, shown in Fig.2.

TABLE I. THE PARAMETERS FOR FRESHWATER AQUACULTURE

Parameters	Desirable Range	Acceptable Ranges
Dissolved oxygen	5-8 ppm	5-12.12 ppm
Temperature	20^0C – 35^0C	2^0C – 35^0C

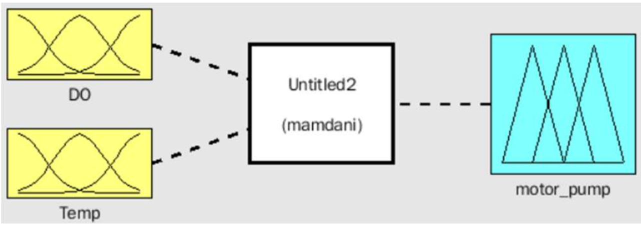
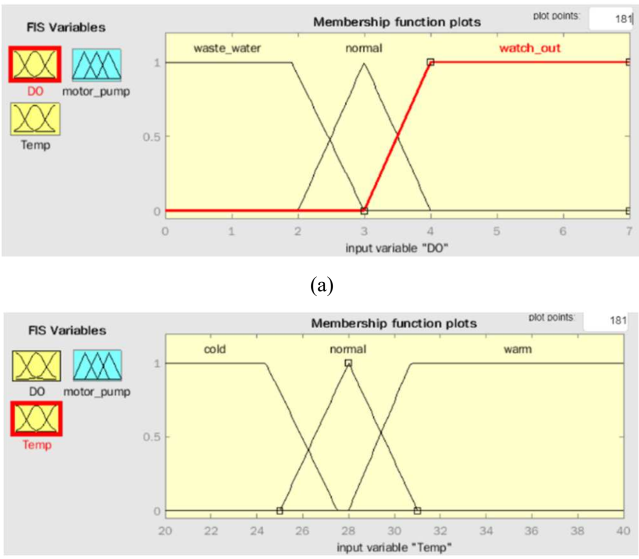


Fig. 2 Fuzzy logic model of oxygen control system



(a)

(b)

Fig. 3 Membership function for parameters: (a) Dissolved Oxygen, (b) Temperature

TABLE II. LINGGUISTIC RULE OF INPUTS MEMBERSHIP FUNCTIONS

DO / Temp	Waste water	Normal	Watch out
Cold	ON	ON	ON
Normal	OFF	OFF	OFF
Warm	ON	ON	ON

Fig.3 FIS variables have two parameters that use trapezoidal and triangular functions as the primary function for calculating membership: Do variables define set as wastewater, normal, and watch out. Temp variables define set as cold, normal, and warm. For set output set to ON and OFF. When the output is obtained from the process defuzzification to find the fuzzy set output by using the 9 fuzzy rule with the inference when the system has a fuzzy set output, as shown in Table II.

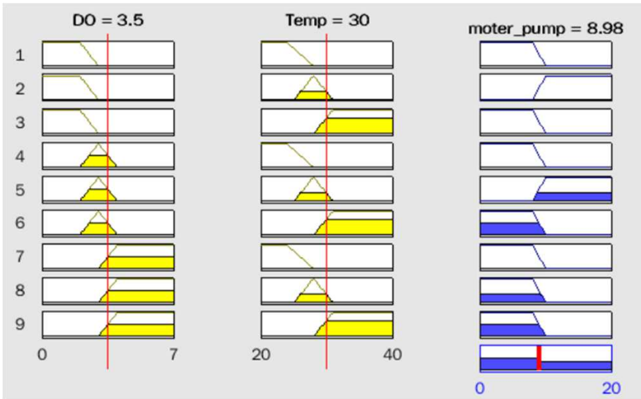


Fig. 4 Rule viewer

Fig. 4 Motor working results under fuzzy rule, when taking DO value and Temp value, interpret degree of membership into fuzzification system under 9 fuzzy rule defined and do defuzzification. Show the results to order the motor to work.

B. *Relative Error Formula*

The relative error formula (1) is used as a measure of precision when compared to the total measurement that is aiming for expected values. To calculate relative error, subtract the measured value (V_M) by the expected value (V_E) and then divide the absolute of that number by the V_E to get the relative error [5]. V_M is derived from the instrument used to measure parameters, whereas V_E results from measuring the implemented parameter. For this study is uses fuzzy logic.

$$\%\,error = \left[\frac{V_M - V_E}{V_E}\right] x100 \quad (1)$$

III. RESULTS AND DISCUSSION

The aquaculture pond has been equipped with equipment and test the operation of 2 components with Arduino working system and the motor pump system. The motor is used to spin the air pump to work with the belt system by placing the air release point in the middle of the pond to increase the efficiency. The amount of oxygen in the water and the temperature control of the aquaculture pond as shown in Figure 5.

Fig. 5 Aquaculture pond prototype and the sensors

A. *Testing of The sensors*

There are two sensors that will be tested, including a DO sensor and Temp sensor, which perform comparative testing of the measuring instrument and the sensor for accuracy in use. The experiments were measured every 2 hours from 5 a.m. to 11 p.m.

- DO sensor

TABLE III. DO SENSOR EXPERIMENT

Sample	DO Meter	DO Sensor	Error	Percentage
5 – 7 a.m.	4.35 ppm	4.43 ppm	0.0181	1.81%
7 – 9 a.m.	4.37 ppm	4.45 ppm	0.0180	1.80%
9 – 11 a.m.	4.42 ppm	4.52 ppm	0.0221	2.21%
11 – 13 p.m.	4.43 ppm	4.55 ppm	0.0264	2.64%
1 – 3 p.m.	4.47 ppm	4.58 ppm	0.0240	2.40%
3 – 5 p.m.	4.43 ppm	4.52 ppm	0.0199	1.99%
5 – 7 p.m.	4.45 ppm	4.57 ppm	0.0263	2.63%
7 – 9 p.m.	4.48 ppm	4.56 ppm	0.0175	1.75%
9 – 11 p.m.	4.49 ppm	4.59 ppm	0.0218	2.18%
Total			**0.1941**	**19.41%**
Average			**0.0216**	**2.16%**

Table III. the experiment of definable standard aqueous solutions tests was performed using a commercial laboratory DO meter as measured by reference values relative to the DO Sensor. It revealed that the calculated average relative error (1) is 2.16%. This shows that the accuracy of the dissolved oxygen detection of the sensor can be effective and applicable [7].

- Temperature Sensor

TABLE IV. TEMPERATURE SENSOR EXPERIMENT

Sample	Thermo meter	Temperature Sensor	Error	Percentage
5 – 7 a.m.	18.29^{0}C	18.32^{0}C	0.0016	0.16%
7 – 9 a.m.	22.42^{0}C	22.46^{0}C	0.0018	0.18%
9 – 11 a.m.	26.32^{0}C	26.39^{0}C	0.0027	0.27%
11 – 13 p.m.	26.46^{0}C	26.50^{0}C	0.0015	0.15%
1 – 3 p.m.	29.62^{0}C	29.69^{0}C	0.0024	0.24%
3 – 5 p.m.	29.92^{0}C	30.01^{0}C	0.0030	0.30%
5 – 7 p.m.	26.62^{0}C	26.69^{0}C	0.0026	0.26%
7 – 9 p.m.	25.69^{0}C	25.72^{0}C	0.0012	0.12%
9 – 11 p.m.	25.25^{0}C	25.28^{0}C	0.0012	0.12%
Total			**0.0179**	**1.79%**
Average			**0.0020**	**0.20%**

Table IV. the temperature sensor test was performed using a thermometer compared to the temp sensor. It was found that the calculated mean relative error (1) was 2.00%, showing that the temp sensor could detect the temperature effectively. This shows that the temp sensor can measure temperature effectively.

B. *Implementation Fuzzy Logic Controller of Oxygen Control System*

The system's fuzzy logic controller's ability to maintain dissolved oxygen and temperature were also tested. The test began testing from 7:00 a.m. to 7:00 p.m., which is a critical time because of the lack of sunlight for photosynthesis. The control system takes readings every 10 minutes for the aerator to respond sequentially to maintain a dissolved oxygen level of >= 3 ppm and maintain a water temperature of below 25^{0}C – 35^{0}C. If the specified value is reached, it sends a signal to the motor pump to work, as shown in Table V.

TABLE V. ABILITY OF THE MOTOR PUMP THROUGH THE OXYGEN CONTROL SYSTEM

Sample	Level		Moter Pump	Criterion Rule
	DO Sensor	Temperature Sensor	(ON/OFF)	
7.00 a.m.– 10.00 a.m.				
1	3.53 ppm	22.46^{0}C	OFF	ON
2	3.62 ppm	24.63^{0}C	ON	ON
3	3.56 ppm	24.69^{0}C	ON	ON
4	3.64 ppm	24.72^{0}C	ON	ON
5	3.69 ppm	24.73^{0}C	ON	ON
6	3.80 ppm	25.59^{0}C	OFF	OFF
7	3.86 ppm	25.96^{0}C	OFF	OFF
8	3.92 ppm	26.24^{0}C	OFF	OFF
9	4.45 ppm	26.61^{0}C	OFF	OFF
10	4.49 ppm	26.69^{0}C	OFF	OFF
11.00 a.m. – 2.00 p.m.				
11	4.52 ppm	26.72^{0}C	OFF	OFF
12	4.55 ppm	26.69^{0}C	OFF	OFF
13	4.58 ppm	26.70^{0}C	OFF	OFF
14	4.52 ppm	29.69^{0}C	ON	ON
15	4.57 ppm	30.01^{0}C	ON	ON
16	4.56 ppm	31.69^{0}C	ON	ON
17	4.59 ppm	31.72^{0}C	ON	ON
18	4.67 ppm	31.28^{0}C	ON	ON
19	4.62 ppm	31.13^{0}C	ON	ON
20	4.75 ppm	30.09^{0}C	ON	ON
4.00 p.m. – 7.00 p.m.				
21	5.24 ppm	29.46^{0}C	ON	ON
22	5.16 ppm	29.52^{0}C	ON	ON
23	5.25 ppm	28.45^{0}C	ON	ON
24	5.24 ppm	28.57^{0}C	ON	ON
25	5.20 ppm	28.53^{0}C	ON	ON
26	5.15 ppm	28.54^{0}C	ON	ON
27	5.04 ppm	28.14^{0}C	ON	ON
28	4.96 ppm	27.63^{0}C	OFF	ON
29	4.92 ppm	27.53^{0}C	OFF	ON
30	4.84 ppm	26.60^{0}C	OFF	OFF

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Table V. The Comparison of dissolved oxygen and temperature at different intervals. The system's response to the motor pump according to the set rules was accurate. As a result, the system can effectively prevent the reduction of dissolved oxygen and temperature. The system also prolongs the service life of the motor pump, as the motor pump is used only when needed. The implementation of fuzzy logic can also help the system make decisions similar to that of humans and with precision.

However, the results showed that the dissolved oxygen and temperature affect the operation of the motor pump with occasional changes from time to time that is commonly affected by the season. The unstable season affects the aquaculture pond. Therefore, when the dissolved oxygen and temperature in aquaculture pond change according to the operation using define fuzzy logic rules, it affects the operation of the motor pump.

IV. Conclusion

This study implementation of fuzzy logic controller for oxygen control system in aquaculture pond that can reduce damage due to water quality problems that result in the inability to complete the full cycle of culturing. The full cycle of cultivation will increase the yield. It also improves the quality of the produce. Whether it is the size or the price of the produce. The results found that the system can provide accurate water quality management that can measure water quality in real-time and help farmers to decide to turn ON/OFF the motor pump when necessary. This allows farmers to completely reduce the amount of electricity use of the motor pump when it is not needed. It also reduces the risk of loss of income caused by the mortality of aquatic animals by allowing water quality to be at critical levels without prior efforts to improve water quality.

The results of the test confirmed that implementing fuzzy logic controller for oxygen control system in aquaculture pond relying on real-time water quality data to decide is essential. If farmers want to increase the quality, productivity and reduce costs. It can be seen that the system can extend the number of days of raising cycles compared to other aquaculture ponds. The systems can reduce the electricity consumption of the pumps ON/OFF and reduce the risk of mortality in aquaculture effectively.

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