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Fuzzy Logic-Based Control System to Maintain pH in Aquaponic

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***Abstract*—One of the important things in an aquaponic system is to keep the pH value of the water stable, so a system is needed to maintain the stability of the pH value. This paper describes the design of a pH control system in an aquaponic system based on fuzzy logic control. The system was developed using 2 pH sensors, a pH A sensor placed in the aquarium and a pH B sensor placed in hydroponics. The system also used 2 motor pumps, the first pump aimed to increase the pH value (pH up), and the second pump aimed to lower the pH value (pH down). In order to set the addition or reduction of pH to be more stable, a fuzzy logic algorithm was implemented to control the length of time the pump motor works. Testing the response system of the acid water to reach the set point took 11 seconds, the delay time t_d was 4 seconds, the rise time t_r was 3 seconds. However, in alkaline water, it reached the set-point for 11 seconds, the delay time t_d was 3 seconds, the rise time t_r was 2 seconds, and both occurred without overshoot.**

***Keywords*— pH control system, aquaponik, fuzzy logic, motor pump**

I. INTRODUCTION

Nowadays, aquaponics is one of the best ways of food production systems that combines aquaculture with hydroponics, the cultivation of nutrient-rich water is distributed to hydroponic plants by involving nitrification bacteria to convert ammonia into nitrates [1]. To make optimal aquaponics, an intelligence system is needed in aquaponics. Since technology is growing rapidly, many researchers are trying to develop smart urban farming, especially aquaponics using various methods and approaches [2][3][4].

Aquaponics consists of two important components, namely the hydroponic section where plants grow, and the aquaculture section where fish are raised [5]. To keep fish alive, we must maintain the pH of the water in a stable and controlled culture [6]. Along with a very busy urban lifestyle, manual monitoring systems may be difficult at this time, so an automatic control system is needed to control the pH of the water in the aquaponics system in order to regulate the production process as targeted [7].

Studies on monitoring and controlling water pH levels have been carried out by several researchers [8] [9] [10]. So many methods have been applied to control the pH level, one of them is fuzzy logic [11] [12] [13] [14]. Fuzzy logic model is one of methods that can be used to control several variables in order to obtain the output we need. In the process of utilizing fuzzy logic, there are several things that must be considered, one of them is how to process input into output through a fuzzy inference system [15]. Fuzzy logic can be used to determine the length of time or motor rotation speed by setting the duty cycle for each motor [16] [17] [18] [19] [20].

In this paper, it is proposed Mamdani fuzzy inference model embedded in Arduino Uno to control pH in an aquaponics system. The system is expected to be able to control the pH value according to the set value with a stable and fast response.

II. THE PROPOSED SYSTEM DESIGN

A. Schematic Design

The control system used in this study was a closed loop control system. The system was developed using Arduino Uno microcontrollers, two pH sensors, namely pH A sensors placed in the aquarium and pH B sensors placed in hydroponics. The system also used 2 pump motors, the first pump motor served as an enhancer of pH value (pH up) if the pH was below the limit and the second pump motor was used to lower the pH value (pH down) if the pH value exceeded the limit. The control uses Mamdani fuzzy logic which produces output in the form of values in the fuzzy set domain, which are categorized into linguistic components and used to regulate the time of the motor works in increasing or decreasing pH.

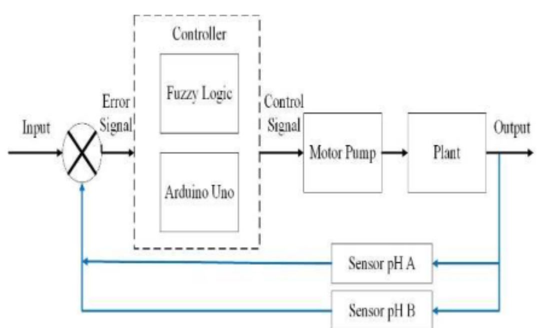

Fig. 1. Control system diagram.

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The length of time of the motor works is conducted by adjusting the amount of duty cycle on each motor. The system scheme developed can be seen in Fig. 1.

If the desired pH value has not been achieved, the process will continue to repeat until the sensor detects that its output has matched the reference value. Aquaponics systems are designed for all aquaponics sizes using the DFT (Deep Flow Technique) system.

B. Controller Design Based on Fuzzy Logic

1) Membership function

The output data of this system is the value of the pH A sensor and the pH B sensor, while the control output is the motor variable pH up (to raise the pH) and the motor variable pH down (to lower the pH). After determining the value of the controller output, inputting linguistic terms are written as listed in Table I and the output is in Table II.

The acidity variables are detected by sensors of both pH A and pH B that are divided into three categories, namely Acid, Neutral, and Alkaline. The membership function of the pH B sensor can be seen in Fig. 2 and Fig. 3. The membership function equation for the sensor variables pH A and pH B is presented as follows:

$$\mu_{Acid} = \begin{cases} 1, & x \leq 6 \\ \frac{6,5-x}{0,5}, & 6 \leq x \leq 6,5 \\ 0, & x \geq 6,5, \end{cases} \quad (1)$$

$$\mu_{Neutral} = \begin{cases} 1, & 6,5 \leq x \leq 7,5 \\ \frac{6-x}{-0,5}, & 6 \leq x \leq 6,5 \\ \frac{8-x}{0,5}, & 7,5 \leq x \leq 8 \\ 0, & other, \end{cases} \quad (2)$$

$$\mu_{Alkaline} = \begin{cases} \frac{8-x}{-0,5}, & 7,5 \leq x \leq 8 \\ 1, & 8 \leq x \leq 14 \\ 0, & other. \end{cases} \quad (3)$$

The process of increasing the pH value is conducted using a pH up motor, i.e., if the water is acidic. The variables formed consist of four categories, namely Stop, Short, Medium, and Long. The pH up motor membership function can be seen in Figure 4. The membership function equation for the pH up motor variable is presented as follows:

$$\mu_{Stop} = \begin{cases} 1, & 0 = 1 \\ 0, & other, \end{cases} \quad (4)$$

$$\mu_{Short} = \begin{cases} 1, & x \leq 1500 \\ \frac{2000-x}{500}, & 1500 \leq x \leq 2000 \\ 0, & x \geq 2000, \end{cases} \quad (5)$$

$$\mu_{Medium} = \begin{cases} 1, & 2000 \leq x \leq 3000 \\ \frac{1500-x}{-500}, & 1500 \leq x \leq 2000 \\ \frac{3500-x}{500}, & 3000 \leq x \leq 3500 \\ 0, & other, \end{cases} \quad (6)$$

$$\mu_{Long} = \begin{cases} \frac{3500-x}{-500}, & 3000 \leq x \leq 3500 \\ 1, & 3500 \leq x \leq 5000 \\ 0, & other, \end{cases} \quad (7)$$

On the other hand, lowering the pH value is carried out using a pH down motor. This occurs when water is alkaline. The variable is formed into four setting values, namely Stop, Short, Medium, and Long. The membership function of the pH down motor can be seen in Fig. 4. The equation for the membership function of the pH down motor variable is stated as follows:

$$\mu_{Stop} = \begin{cases} 1, & 0 = 1 \\ 0, & other \end{cases} \quad (8)$$

$$\mu_{Short} = \begin{cases} 1, & x \leq 1500 \\ \frac{2000-x}{500}, & 1500 \leq x \leq 2000 \\ 0, & x \geq 2000 \end{cases} \quad (9)$$

$$\mu_{Medium} = \begin{cases} 1, & 2000 \leq x \leq 3000 \\ \frac{1500-x}{-500}, & 1500 \leq x \leq 2000 \\ \frac{3500-x}{500}, & 3000 \leq x \leq 3500 \\ 0, & other \end{cases} \quad (10)$$

$$\mu_{Long} = \begin{cases} \frac{3500-x}{-500}, & 3000 \leq x \leq 3500 \\ 1, & 3500 \leq x \leq 5000 \\ 0, & other \end{cases} \quad (11)$$

TABLE I. LINGUISTIC TERM OF INPUT

pH Value	Linguistic Term Input	
	pH-A Sensor	***TDS-B Sensor***
[0 0 6 6.5]	Acid	[0 0 6 6.5]
[6 6.5 7.5 8]	Neutral	[6 6.5 7.5 8]
[7.5 8 14 14]	Alkaline	[7.5 8 14 14]

TABLE II. LINGUISTIC TERM OF OUTPUT

Motor Time (ms)	Linguistik Term Output	
	pH Up	***pH Down***
[0 0 0 0]	Stop	Stop
[0 0 1500 2000]	Short	Short
[1500 2000 3000 3500]	Medium	Medium
[3000 3500 5000 5000]	Long	Long

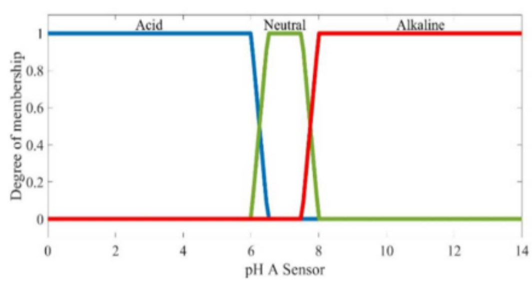

Fig. 2. Membership function of pH-A sensor.

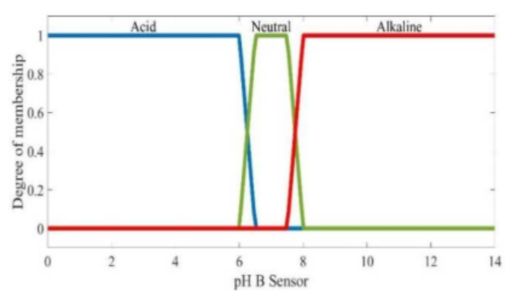

Fig. 3. Membership function of pH B sensor.

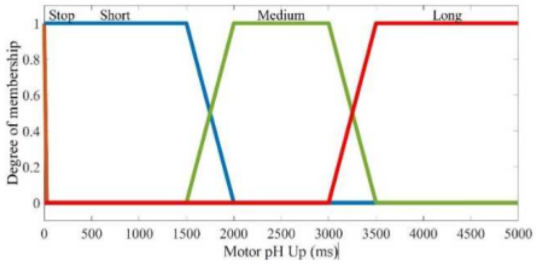

Fig. 4. Membership function of motor pH up.

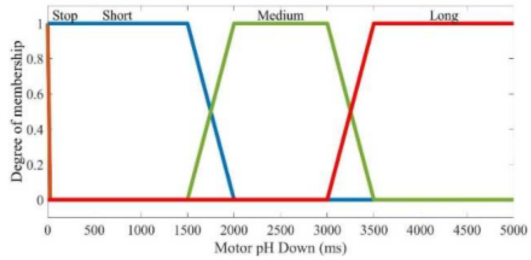

Fig. 5. Membership function of motor pH down.

2) *Fuzzy Logic Rules*

The step that proceeds after determining the membership function of each variable is to determine the fuzzy rules. There are 9 rules that generate 36 possibilities as shown in Table III. The realization of the developed aquaponics system can be seen in Fig. 6. The system consists of 2 pH sensors, 2 motor pumps, 36l aquarium, 3-inch pipe, 0.5-inch pipe, elbow pipe, and T pipe. Fig. 7 shows the pH sensor section connected to the Arduino Uno and the 1000 mAh Lippo battery as the power source. By using a fuzzy control system, the output value will be sought in the form of the length of the pH up motor and the pH down motor alternately in order to stabilize the acidity degree in the aquaponics system.

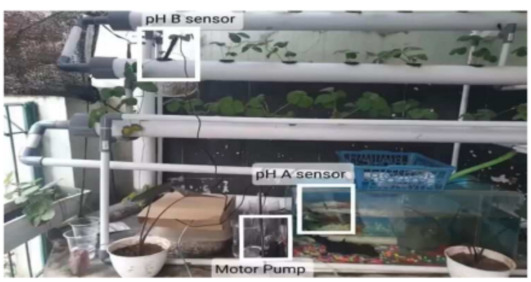

Fig. 6. Aquaponic System.

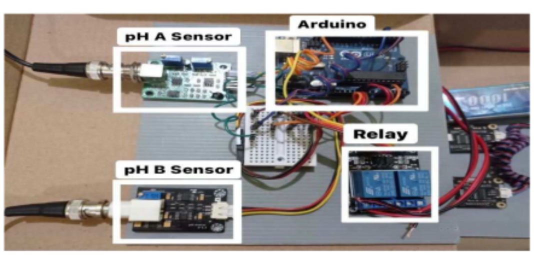

Fig. 7. Controller device

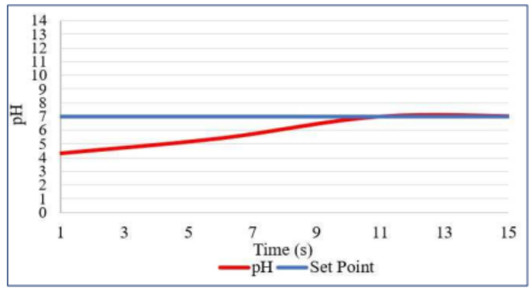

Fig. 8. Time for stabilize when acidic condition.

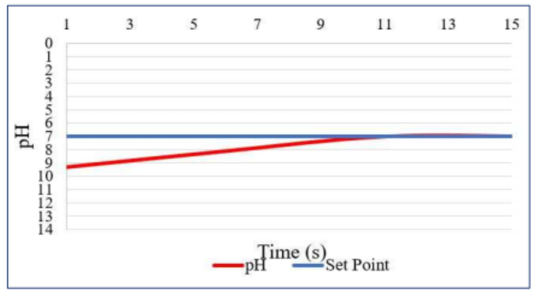

Fig. 9. Time for stabilize when alkaline condition.

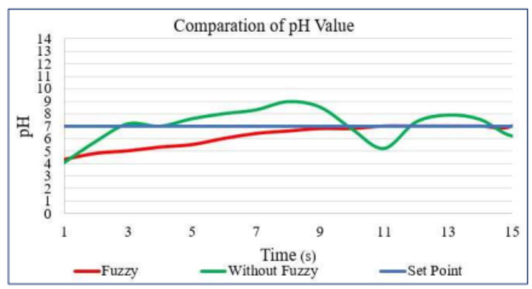

Fig. 10. Comparation of pH when acidic condition.

III. Result And Analysis

In this study, we made fuzzy logic modeling in the pH control systems in aquaponics. Testing the response of the pH stability system in the aquarium was carried out for 15 seconds. This test aims to find out how long the motor takes to reach the reference value (set-point). Testing the system response of when the water is in acidic conditions can be seen in Fig. 8. The first measurement using the sensor obtained a pH value of 4.3. The pH up motor responds to the existing conditions to increase the pH value into a value that matches the set point. The time required to reach the set-point is 11 seconds, the delay time t_d is 4 seconds, the rise time t_r is 3 seconds, and without overshoot.

Meanwhile, the test for alkaline water conditions produces a response as shown in Fig. 9. At the beginning of the test, the sensor reads a pH of 9.3. The pH down motor responds to existing conditions to lower the pH value in order to match the predetermined set-point value. The time required to reach the set point value is 11 seconds, the delay time t_d is 3 seconds, the rise time t_r is 2 seconds, and without overshoot.

With a pH set-point value of 7, a comparison of the response is conducted, when the water is acidic, the systems using Fuzzy and without Fuzzy are carried out. The comparison of the results obtained can be seen in Fig. 10, the system with Fuzzy takes 11 seconds to reach the set point and the system response is steady in 12 to 15 seconds, while the system response without Fuzzy reaches the set point within 3 seconds, but there is an overshoot and it does not reach the steady state position.

IV. CONCLUSION

In this study, a Fuzzy-based control system was successfully created to control the pH value in aquaponics. The test results for the response of the acid water system took 11 seconds to reach the set-point, the delay time t_d was 4 seconds, and the rise time t_r was 3 seconds, while alkaline water took 11 seconds to reach the set-point, the delay time t_d was 3 seconds, rise time t_r was 2 seconds, and without overshoot. When compared, the system response from acidic conditions with an experiment for 15 seconds, between systems using fuzzy logic and systems without using fuzzy logic showed that the fuzzy logic system reached the set-point within 11 seconds and the steady in 12 to 15 seconds, while the system without Fuzzy logic reached the set-point within 3 seconds but overshoots and it did not reach steady state position.

REFERENCES

[1] A.K. Pasha, E. Mulyana, C. Hidayat, M.A. Ramdhani, O.T. Kurahman and M. Adhipradana, "System Design of Controlling and Monitoring on Aquaponic Based on Internet of Things," 4th International Conference on Wireless and Telematics (ICWT), pp. 1-5, 2018.

[2] I. Taufik, "Pendederan ikan nila (oreochromis niloticus) dengan sistem akuaponik pada berbagai lokasi yang berbeda," (in Bahasa), Prosiding Indoaqua-ForumInovasi Teknologi Akuakultur, p. 10. 2012.

[3] Z. Zulhelman, H.A. Ausha, and R.M. Ulfa, "Pengembangan sistem smart aquaponik," (in Bahasa), Jurnal Poli-Teknologi, vol. 15, no. 2, 2016.

[4] H. Fakhrurroja, S.A. Mardhotillah, O. Mahendra, A. Munandar, M.I. Rizqyawan and R.P. Pratama, "Automatic pH and Humidity Control System for Hydroponics Using Fuzzy Logic," International Conference on Computer, Control, Informatics and its Applications (IC3INA), pp. 156-161, 2019.

[5] A. Nichani, A. Kumar, S. Iyer and M.A. Ramya, "Environmental parameter monitoring and data acquisition for aquaponics," Int. J.Emerg. Technol. Comput. Sci. Electron, vol. 24, no. 9, pp. 29–34, 2017.

[6] Y. Wei, W. Li, D. An, D. Li, Y. Jiao and Q. Wei, "Equipment and Intelligent Control System in Aquaponics: A Review," IEEE, vol. 7, pp. 169306-169326, 2019.

[7] J. P. Mandap, D. Sze, G.N. Reyes, S.M. Dumlao, R. Reyes and W.Y. Danny Chung, "Aquaponics pH Level, Temperature, and Dissolved Oxygen Monitoring and Control System Using Raspberry Pi as Network Backbone," Tencon 2018 Region 10 Conference . IEEE, pp. 1381-1386, 2018.

[8] I. Zidni, I. Iskandar, A. Rizal, Y. Andriani, and R. Ramadan, "The Effectiveness of Aquaponic Systems with Different Types of Plants on the Water Quality of Fish Culture Media," Fisheries and Marine Journal, vol 9, no.1, pp. 81-94, 2019.

[9] G. Imaduddin, A. Saprizal, "Otomatisasi monitoring dan pengaturan keasaman larutan dan suhu air kolam ikan pada pembenihan ikan lele," (in Bahasa), JUST IT Jurnal Sistem Informasi, Teknologi Informasi dan Komputer, vol.7 no.2, pp. 28-35, 2017.

[10] M.N.R. Ibrahim, M. Solahudin and S. Widodo, "Control system for nutrient solution of nutrient film technique using fuzzy logic," Telkomnika, vol. 13, no. 4, pp. 1281-1288, 2015.

[11] S. Mikkili, A.K. Panda, "Types-1 and -2 fuzzy logic controllers-based shunt active filter Id-Iq control strategy with different fuzzy membership functions for power quality improvement using RTDS hardware," Power Electronics IET, vol. 6, no. 4, pp. 818-833, 2013.

[12] D. Yolanda, H. Hindersah, F. Hadiatna and M.A. Triawan, "Implementation of Real-Time Fuzzy logic control for NFT-based hydroponic system on Internet of Things environment," 6th International Conference on System Engineering and Technology (ICSET), pp. 153-159, 2016.

[13] M. Fuangthong, P. Pramokchon, "Automatic control of electrical conductivity and PH using fuzzy logic for hydroponics system," Digital Arts Media and Technology (ICDAMT) 2018 International Conference, pp. 65-70, 2018.

[14] Kuswinta, A. Jiwa, and I.W.A. Arimbawa. "Implementasi IoT cerdas berbasis inference fuzzy Tsukamoto pada pemantauan kadar pH dan ketinggian air dalam akuaponik," (in Bahasa), Journal of Computer Science and Informatics Engineering (J-Cosine), vol. 3, no. 1, pp. 65-74, 2019.

[15] M.R. Emami, I.B. Turksen and A.A. Goldenberg, "Development of a systematic methodology of fuzzy logic modeling," IEEE. Transactions on Fuzzy Systems, vol. 6, no. 3, pp. 346-361, Aug 1998.

[16] Y. Tipsuwan and Mo-Yuen Chow, "Fuzzy logic microcontroller implementation for DC motor speed control," Conference Proceedings 25th Annual Conference of the IEEE Industrial Electronics Society, vol.3, pp. 1271-1276, 1990.

[17] B. Cakir, A.B. Yildiz, N. Abut and N. Inanc, "DC motor control by using computer based fuzzy technique," IEEE APEC '99. Applied Power Electronics Conference and Exposition 1999. Fourteenth Annual, vol. 1, pp. 391-395, 1999.

[18] J.L. Afonso, J. Fonseca, J.S. Martins and C.A. Couto, "Fuzzy logic techniques applied to the control of a three-phase induction motor," ISIE '97. Proceedings of the IEEE International Symposium on Industrial Electronics, vol. 3, pp. 1179-1184, 1997.

[19] A.E. Setiawan, R. Mardiati and E. Mulyana, "Design of automatic under water robot system based on mamdani fuzzy logic controller," IEEE. 6th International Conference on Wireless and Telematics (ICWT), pp. 1-5, 2020.

[20] A. Mutolib, R. Mardiati, E. Mulyana, A.E. Setiawan and A. Fathonih. "Design of automatic goods carrier robot system based on line sensor and fuzzy logic control mamdani," IEEE .6th International Conference on Wireless and Telematics (ICWT), pp. 1- 4, 2020.

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