Design and Build Telecontroling Temperature and Water Quality of Turtle Aquascapes Based on Fuzzy Logic

Amar Farrichil Ayyubi[1], Azam Muzakhim Imammuddin[2]*, Mila Kusumawardani[3]

1,2,3 Digital Telecommunication Network Study Program, Department of Electrical Engineering, State Polytechnic of Malang, 65141, Indonesia.

[1]amarfarric@gmail.com , [2] azam@polinema.ac.id , [3]milakusumawardani@polinema.ac.id

***Abstract*— Aquascape is one of the media for water pets that is quite popular during the pandemic. One of the animals that can be kept with aquascape media is a turtle. Maintenance of turtles in aquascapes requires accuracy and persistence in maintaining water quality in aquascapes to have stable conditions for turtles in them. Temperature, turbidity and water level are some of the parameters that need to be considered in order for turtles to survive in the aquascape. Thus, we need a technology that has a function as a monitoring of temperature, turbidity and water level as well as having a direct connection to the user. In this study, the use of the DS18B20 temperature sensor, water turbidity sensor and ultrasonic sensor as a water level meter has a connection that is connected to the user using ESP32. In addition, the existence of pumps, filters and water coolers can support the quality of water in the aquascape to be maintained either automatically or manually. The results of this study indicate that the existence of this system can maintain the quality of water in the aquascape in real time to the user. This is demonstrated by three sensors that have a 98% accuracy level so that it can turn on the output components well. The three sensors also have delays of 240.006315 ms and are in the category of good delay quality.**

***Keywords*— Aquascape, ESP32, Internet of Things, turtle monitoring system, water level sensor, water quality monitoring, water turbidity sensor, water temperature sensor**

I. INTRODUCTION

Turtles are one type of animal that is quite popular to be kept. The tortoise or also known as the red-eared turtle or in Latin Trachemys scripta elegans comes from the southern United States, and is a popular animal to be kept. The physical characteristics of turtles are quite unique with a dark green body accompanied by yellow stripes. In addition, the docile character makes this turtle favored by many keepers . on the other hand in keeping turtles, water quality in the habitat/aquascape has the most important role for the survival of turtles.

Maintaining optimal water quality is a critical factor in aquascape turtle cultivation, as parameters such as water temperature, turbidity, and water level directly affect turtle health and habitat stability. Conventional aquascape maintenance is generally performed manually, requiring frequent monitoring and adjustment, which is inefficient and prone to human error. Inadequate control of water conditions can lead to stress, disease, and reduced survival rates of turtles [1], [2].

Recent advancements in the Internet of Things (IoT) have enabled the development of smart monitoring and control systems for aquatic environments. IoT-based systems allow real-time data acquisition, remote monitoring, and automated control through interconnected sensors, microcontrollers, and cloud platforms [3], [4]. Several studies have shown that IoT integration significantly improves water quality management by enabling continuous monitoring and timely system responses [5], [6].

Among various intelligent control techniques, fuzzy logic has been widely applied to systems characterized by uncertainty and non-linear behavior, including water quality and environmental control applications. Fuzzy logic controllers can translate human reasoning into linguistic rules, making them suitable for controlling parameters such as temperature and turbidity that do not have fixed threshold values [7], [8]. Previous studies have demonstrated that fuzzy logic-based control systems provide more adaptive and stable performance compared to conventional control methods in aquatic environments [9], [10].

In terms of hardware implementation, the ESP32 microcontroller has become a popular platform for IoT-based monitoring and control systems due to its low power consumption, high processing capability, and integrated wireless communication features. ESP32-based implementations have been successfully applied in water quality monitoring systems, showing reliable performance and scalability [11], [12]. In addition, cloud-based platforms such as Firebase support real-time data synchronization between devices and user interfaces, enabling remote monitoring and telecontrolling through mobile applications [13], [14].

Based on these considerations, this research proposes an IoT-based telecontrolling system for aquascape turtle environments using fuzzy logic control. The system integrates temperature, turbidity, and water level sensors with an ESP32 microcontroller, Firebase real-time database, and an Android application for monitoring and control. The proposed system aims to improve water quality stability, reduce manual intervention, and enhance aquascape turtle management by combining IoT technology with intelligent fuzzy logic control [15][16][17][18][19][20].

II. METHOD

The type of research to be carried out is research methods and tool making. The purpose of the research with the nature of the manufacture is to create a useful tool to facilitate the owner of the turtle in terms of telecontrolling temperature, altitude and turbidity of the water in the aquascape and create a tool that can stabilize the aquascape and monitor through the website android owned by the owner.

A. Hardware System Design Flow Diagrams

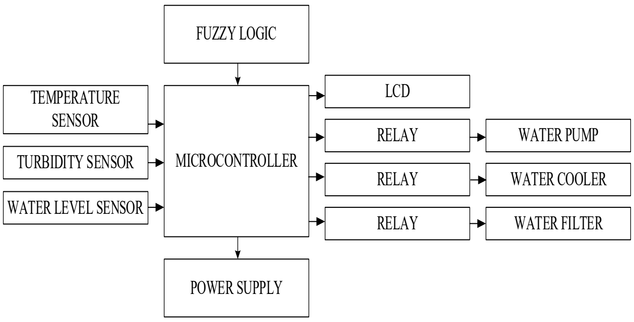


Figure 1 Hardware System Design Flow Diagram

The following is a description of each function of the input, process and output systems are designed based on the block diagram of Figure 1:

1. Smartphone as a media owner to get information about water quality that contains temperature, altitude and turbidity of water in Aquascape via the website.
2. The temperature sensor serves to measure the temperature of the water in the aquascape, so it can activate the peltier cooler so that the temperature decreases.
3. Water level sensor to measure the water level in the aquascape.
4. Water turbidity sensor to measure the level of water turbidity in aquascape.
5. Microcontroller ESP32 as the Control Center and control system to be designed.
6. The water pump is used to maintain the water level in the aquascape to keep it clean based on the value of the height sensor and water turbidity.
7. Water filters are used to filter water and improve water quality for the better.
8. Relay is an electronic switch to control electrical devices that require voltage and current.
9. Peltier is used for electric solid-state coolers that work as a "heat-pump" in the cooling process
10. 16X2 LCD is used to display water quality based on temperature, altitude and turbidity of water.
11. Power supply as a power supply for components that have been designed.
12. Fuzzy logic that will act as a decision-making process for the output of water pumps and coolers based on temperature parameters, turbidity and water level in aquascape.
13. Internet as a network that connects the hardware and the owner through a smartphone with an intermediary website.

B. Fuzzification

Fuzzification is the process of converting non-fuzzy variables (numerical variables) into fuzzy variables (linguistic variables) [9]. In this case to maintain the temperature and water quality will use the parameters of temperature, turbidity and water level. With these three parameters will produce a healthy aquascape conditions for turtles in it [10].

a. Degrees Membership Water Temperature, as shown in Table I

TABLE I
MEMBERSHIP WATER TEMPERATURE

Function	Variable Name	Membership
Temperature	Too cold	[0 10 20]
	Ideal	[20 23 26]
	Too hot	[26 27 28]

To calculate the membership value, the following formula is used:

For value range: 0 < Temperature < 20 (Too Cold), as shown in Equation 1.

$$Too\ Cold = \begin{cases} 0, \\ \frac{Temperature-0}{20-0}, Temperature \leq 0, 0 < \\ 1 \end{cases}$$
$$Temperature < 20, Temperature \geq 10 \quad (1)$$

For value range: 20 < Temperature < 26 (Ideal) , as shown in Equation 2.

$$Ideal = \begin{cases} \frac{Temperature-20}{23-20}, \\ \frac{26-Temperature}{26-23}, 0, 20 < Temperature < \\ 1 \end{cases}$$
$$23, 23 < Temperature < 25, Temperature = 23 \quad (2)$$

For value range: 27 < Temperature < 30 (Too Hot), as shown in Equation 3.

$$Murky = \begin{cases} \frac{Temperature-27}{28,5-27}, \\ \frac{30-Turbidity}{30-28,5}, \ 0, 27 < Turbidity < \\ 1 \end{cases}$$
$$30, 27,5 < Turbidity < 30, Turbidity = 28,5 \quad (3)$$

b. Degrees Membership Water Turbidity, as shown in Table II.

TABLE II
MEMBERSHIP WATER TURBIDITY

Function	Variable Name	Membership
Turbidity	Clean water	[0 12.5 23]
	cloudy	[23 24 25]
	Too cloudy	[25 26 27]

To calculate the membership value, the following formula is used:

For value range: 0 < Turbidity < 23 (Clean Water) , as shown in Equation 4.

$$Clean\ Water = \begin{cases} \frac{Turbidity-0}{12,5-0} \\ \frac{23-Turbidity}{23-12,5}, 0, 0 < Turbidity < \\ 1 \end{cases}$$
$$12,5, 12,5 < Height < 23, Turbidity = 12,5 \quad (4)$$

For value range: 23 < Turbidity < 25 (Turbidity) , as shown in Equation 5

$$Murky = \begin{cases} \frac{Turbidity-23}{24-23}, \\ \frac{25-Turbidity}{25-24}, 0, 23 < Turbidity < 24, 24 < \\ 1 \end{cases}$$
$$Turbidity < 25, Turbidity = 24 \quad (5)$$

For value range: 25 < Turbidity < 27 (Too Turbid) , as shown in Equation 6

$$Too\ Turbid = \begin{cases} \frac{Turbidity-25}{26-25}, \\ \frac{27-Turbidity}{27-26}, 0, 25 < Turbidity < \\ 1 \end{cases}$$
$$26, 26 < Turbidity < 27, Turbidity = 2 \quad (6)$$

c. Degrees Membership Water Level, as shown in Table III.

TABLE III
MEMBERSHIP WATER LEVEL

Function	Variable Name	Membership
Height	Too low	[-3 0 3]
	Ideal	[3 5 7]
	Too high	[7 10 10]

To calculate the membership value, the following formula is used:

For value range: -3 < High < 3 (Too Low), as shown in Equation 7

$$Too\ Low = \begin{cases} 0, \\ \frac{Height-0}{3-0}, Height \leq 0, -3 < Height < \\ 1 \end{cases}$$
$$3, Height \geq 3 \quad (7)$$

For value range: 20 < Temperature < 25 (Ideal), as shown in Equation 8

$$Ideal = \begin{cases} \frac{Height-3}{5-3}, \\ \frac{7-Height}{7-5}, 0, 3 < Height < 5, 5 < Height < \\ 1 \end{cases}$$
$$7, Height = 5 \quad (8)$$

C. System Flow Diagrams

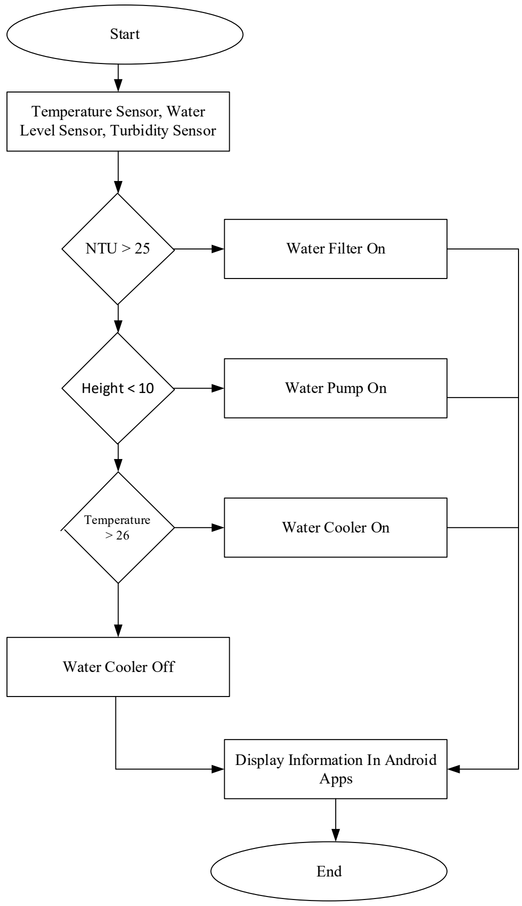


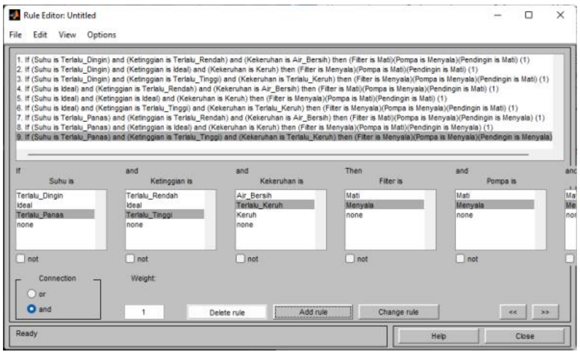
Figure 2 System Flow Diagrams

Explanation of the overall system flowchart in Figure 2 above is as follows:

1. Start
2. Turn on the device to be implemented every day to perform the process of monitoring the temperature sensor, turbidity and water level.

3. Reads temperature, turbidity and water level sensors that have been powered on
4. Sends temperature, cloudiness and altitude sensor data to the firebase database to be stored for future decision making
5. If the temperature sensor reads the temperature in conditions of more than 25 degrees Celsius will automatically turn on the coolant to lower the temperature that falls into the category of too hot. The cooler can be turned off and on directly via the android app.
6. If the water level sensor reads the height under conditions of less than 10 cm, it will automatically turn on the water pump to drain water from the previously prepared container to the aquascape. The water pump can be turned off and on directly via the android app.
7. If the turbidity sensor reads the level of turbidity under conditions of more than 25 NTU, it will automatically turn on the water filter to lower the level of turbidity so that the water becomes clearer and does not enter in cloudy or overly cloudy conditions. The water filter can be turned off and on directly via the android app.
8. Once all three sensors are sent to the firebase database, the read values are displayed through a pre-designed android app.
9. Done.

D. Determination Of Rules



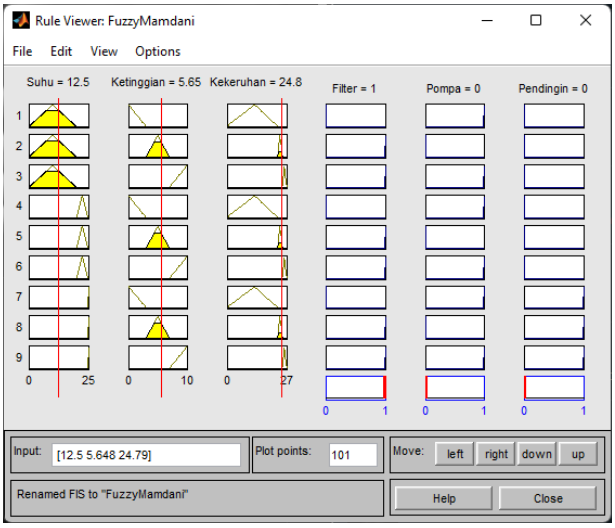


Figure 3 Fuzzy Rules

Figure 3 above is a view when the rules have been completed and into the form of columns and rows. For example, the image above that uses values at a temperature of 12.5, height of 5.65 and turbidity of 24.8 will turn on the filter only. While the condition of the pump and also the coolant is in a dead condition.

III. RESULTS AND DISCUSSION

A. Application Interface Results

Figure 4 Firebase Realtime Database

In order for this tool can be used and run in accordance with the concept that has been prepared, it takes a planning software that can then be used to operate this system as shown in Figure 4. This Software will be used by Turtle owners to monitor water conditions in the aquascape and display information on temperature, altitude and also the level of water turbidity. In this research, the database used is Firebase Realtime Database using JSON Tree structure or commonly called hierarchy. Here is an image of the Firebase Realtime Database shown in Figure 5.

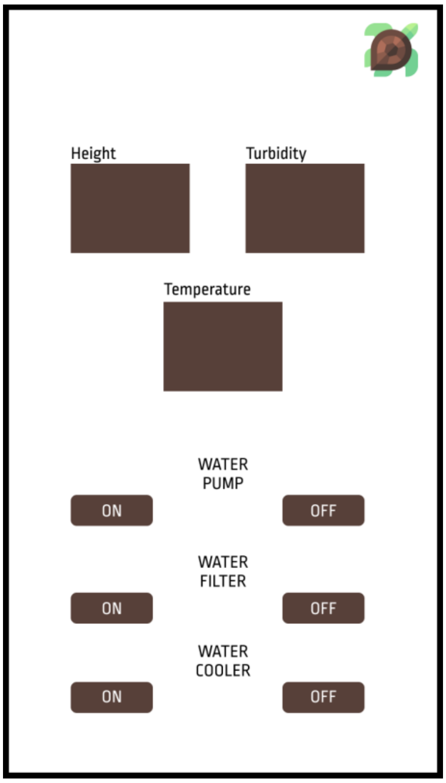


Figure 5 Manual System Interface

Figure 6 above is a display image on the manual system menu that contains information on temperature values obtained from data stored in the Firebase Realtime Database. As for the buttons for turning on and off the pump, filter and also the coolant manually.

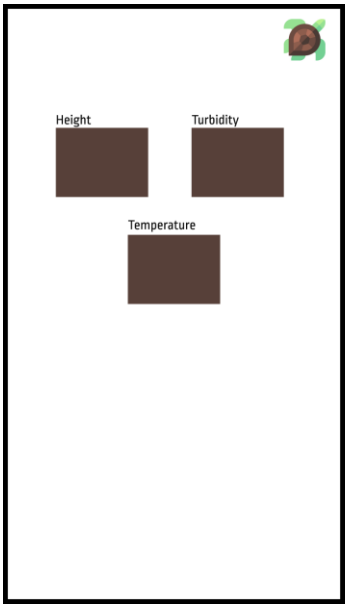


Figure 6 Automatic System Interface

Then there is figure 6 display of an automated system that only has temperature value information obtained from the Firebase Realtime Database without the feature to turn off and turn on filters, pumps and coolers manually.

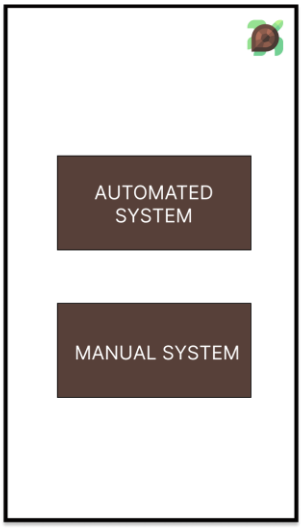


Figure 7 Homepage Interface

Furthermore, figure 7 above is the appearance of the Android application homepage that will be used later which contains menu options for automatic systems that only contain Aquascape State Information and menus for manual systems that have additional features to turn off pumps, filters and coolers.

B. Hardware Design Results

System testing is carried out when all components have been arranged and can function properly. So it can be done at the same time taking the test to get the data. Here are some pictures showing the whole system circuit.

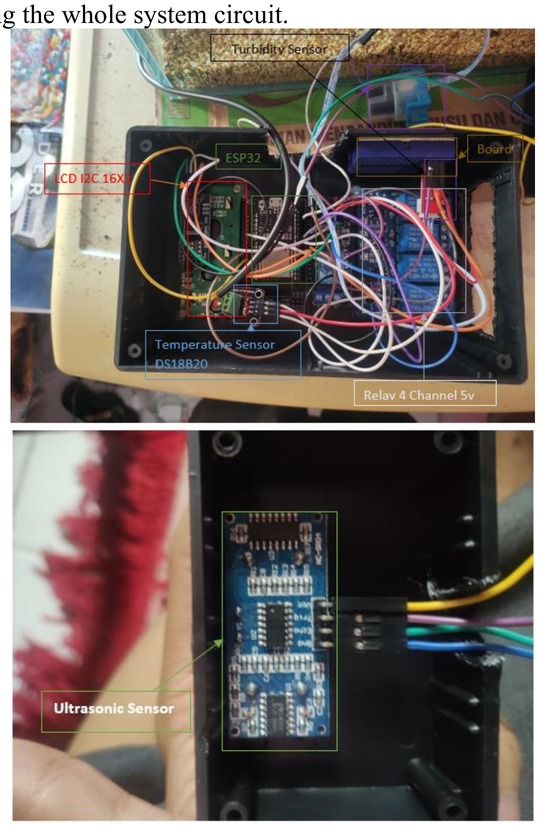


Figure 8 System Circuit

In Figure 8, is a series of systems 1 and 2 containing components LCD 16X2 I2C, ESP32, Relay 4 Channel 5VDC, DS18B20 Temperature Sensor, Turbidity Sensor and Sensor to measure the water level using ultrasonic sensors. After the pins consisting of 16X2 I2C LCD components , ESP32, 4 Channel 5VDC Relay, DS18B20 Temperature Sensor, turbidity Sensor and Sensor for measuring water level using ultrasonic sensors have been neatly arranged, the next step is to assemble the output and power supply components. Here is a picture of the output circuit as well as installation on Aquascape :

Figure 9 Harware Implementation

The sensor is then checked to ensure it works properly. Below is a table IV containing calibrations on each sensor used.

TABLE IV
CALIBRATION OF ULTRASONIC SENSORS

Number	Disctances from sensor	Distances from rules	Difference
1	9,98	10	0,20%
2	4,91	5	1,80%
3	4,15	4,1	1,22%
4	9,1	9	1,11%
5	6,9	7	1,43%
6	11,2	11,3	0,88%
7	12,04	11,9	1,18%
8	13,97	14	0,21%
9	15,74	15,5	1,55%
10	20,09	20	0,45%
Average Error			2%

The test results (Table V) obtained from the comparison of the measurement values manually with the bars and measurements using the ultrasonic sensor had a small difference of 1%. So the ultrasonic sensor as a height measuring device can function with appropriate measurement results and also precision. This shows that the ultrasonic sensor works well with a small difference of 1%.

TABLE V
CALIBRATION OF TURBIDITIY SENSORS

Fluid Used	Turbidity Meter	Turbidity Sensors	Difference
Fluid from Turbidity Meter Set	10,8 NTU	9,98 NTU	0,10 NTU
	21,4 NTU	20,5 NTU	0,9 NTU
	106 NTU	102,32 NTU	0,368 NTU
Tea	19,8 NTU	18,4 NTU	0,6 NTU
Aqua Water	2,07 NTU	2,3 NTU	0,23 NTU
Average Error			2 %

The results (Table VI) obtained from the measurement of water stiffness sensors and also using Turbiditiy Meter show good results. The water condition used when measured using a turbidity meter and a shrinkage sensor has a total difference of only 2%, so it can be used as a measuring tool in the aquascape to be used.

TABLE VI
CALIBRATION OF TEMPERATURE SENSORS

Time	TDS Meter	Temperature Sensors DS18B20	Difference
14.00	27,2	26,25	4%
14.10	27	26,31	3%
14.20	27,2	26,56	2%
14.30	27,4	26,62	3%
14.40	27,5	26,81	3%
14.50	27,2	26,94	1%
15.00	27,1	26,88	1%
15.10	27,8	27	3%
15.20	27,8	27,31	2%

Time	TDS Meter	Temperature Sensors DS18B20	Difference
15.30	27,8	27,31	2%
	Average Error		2 %

The results obtained from the comparison of the values of the temperature sensor DS18B20 and also the TDS Meter that has the temperature and water temperature reading features have a small value in terms of the difference of 2%. Thus it can be concluded that the temperature sensor DS18B20 can work optimally to measure the temperature in the aquascape.

After the preparation of the component is complete, it is necessary to take data when the component is on to see if it is working properly which will then be used as a basis for improvement or improvement in the future. Based on the test table below. The results from the table indicate that the output component can work well. Proved by the output output of the pump, the filter and the refrigerator can light up when in a particular condition. It can be concluded that the built system can work well Below is Table VII which shows the results of data retrieval.

TABEL VII
DATA RETRIEVAL

Time	Temperature	Turbidity	Height	Pump	Filter	cooler
07.00	22.13 ºC	3,33	12.67cm	Dead	Dead	Dead
07.15	22.25 ºC	3,34	12.67cm	Dead	Dead	Dead
07.30	22.52 ºC	3,32	12.65cm	Dead	Dead	Dead
07.45	22.78 ºC	3.35	12.67cm	Dead	Dead	Dead
08.00	22.97 ºC	3,33	12.67cm	Dead	Dead	Dead
08.15	23.46 ºC	3,33	12.64cm	Dead	Dead	Dead
08.30	23.68 ºC	3,34	12.67cm	Dead	Dead	Dead
08.45	23.89 ºC	3,33	12.67cm	Dead	Dead	Dead
09.00	24.11ºC	3,33	12.67cm	Dead	Dead	Dead
09.15	24.48 ºC	3,33	12.67cm	Dead	Dead	Dead
09.30	24.77 ºC	3,33	12.67cm	Dead	Dead	Dead
09.45	24.96ºC	3,32	12.67cm	Dead	Dead	Dead
10.00	25.13 ºC	3,33	12.69cm	Dead	Dead	Dead
10.15	25.34 ºC	3,33	12.67cm	Dead	Dead	Dead
10.30	25.61 ºC	3,33	12.67cm	Dead	Dead	Dead
10.45	25.85ºC	3,33	12.67cm	Dead	Dead	Dead
11.00	26.06 ºC	3.35	12.67cm	Dead	Dead	Light up
11.15	25.94 ºC	3,33	12.68cm	Dead	Dead	Dead
11.30	26.27 ºC	3,33	12.67cm	Dead	Dead	Light up
11.45	25.91ºC	3,33	12.67cm	Dead	Dead	Dead
12.00	26.61 ºC	3,33	12.67cm	Dead	Dead	Light up
12.15	26.42 ºC	3,33	12.67cm	Dead	Dead	Light up
12.30	25.98 ºC	3,34	12.67cm	Dead	Dead	Dead
12.45	26.32 ºC	3,33	12.66cm	Dead	Dead	Light up
13.00	26.05 ºC	3,33	12.67cm	Dead	Dead	Light up
13.15	25.95 ºC	3,33	12.67cm	Dead	Dead	Dead
13.30	26.38 ºC	3,33	12.67cm	Dead	Dead	Light up
13.45	26.01 ºC	3,32	12.67cm	Dead	Dead	Light up
14.00	25.95 ºC	3,33	12.64cm	Dead	Dead	Dead
14.15	26.22 ºC	3,33	12.67cm	Dead	Dead	Light up
14.30	25.87 ºC	3,33	12.67cm	Dead	Dead	Dead
14.45	25.81 ºC	3,33	12.67cm	Dead	Dead	Dead
15.00	25.80 ºC	3.35	12.68cm	Dead	Dead	Dead

IV. CONCLUSION

Based on the results of the discussion in this study, the following conclusions is To maintain the values of temperature, height, and water rigidity on the aquascape requires the design of a telecontrolling system that uses ESP32 as a microcontroller and then connects it to the DS18B20 temperature sensor, the water rigidsensor and the ultrasonic sensor. The three sensors work well with their respective accuracy levels of approximately 98% and have connections with water pumps, water filters and coolers so that they meet to keep the water condition normal assisted by fuzzy logic for decision-making assistants. In addition, data collection resulted that some conditions that have an influence on the output are running well and have the ability to maintain values of temperature, altitude and water purity remain in normal conditions.

REFERENCES

[1] H. Yoon, J. Kim, and S. Park, “Smart water quality monitoring system using IoT,” *Sensors*, vol. 20, no. 21, Art. no. 6102, 2020.

[2] M. R. Alam, M. M. Hassan, and A. Alelaiwi, “A cloud-based IoT framework for fish pond water quality monitoring,” *Future Generation Computer Systems*, vol. 105, pp. 742–753, 2020.

[3] S. Li, L. D. Xu, and S. Zhao, “IoT for smart water systems: Architecture, applications, and challenges,” *Future Generation Computer Systems*, vol. 108, pp. 845–856, 2020.

[4] A. A. Abouelsaad, A. A. Moussa, and M. S. Sayed, “IoT-based water quality monitoring system using ESP32,” *IEEE Access*, vol. 8, pp. 119567–119579, 2020.

[5] A. K. Sharma and P. Kumar, “Energy-efficient IoT-based monitoring systems for smart environments,” *IEEE Access*, vol. 8, pp. 202028–202048, 2020.

[6] Y. Wang, X. Wang, and J. Chen, “Solar-powered wireless sensor networks for environmental and water monitoring,” *Sensors*, vol. 20, no. 6, Art. no. 1725, 2020.

[7] L. A. Zadeh, “Fuzzy sets,” *Information and Control*, vol. 8, no. 3, pp. 338–353, 1965.

[8] K. M. Passino and S. Yurkovich, *Fuzzy Control*. Reading, MA, USA: Addison-Wesley, 1998.

[9] R. M. Rahman, M. M. Hasan, and M. R. Islam, “Design of fuzzy logic controller for water level control,” *International Journal of Fuzzy Systems*, vol. 22, no. 2, pp. 450–461, 2020.

[10] Y. Liu, J. Wang, and X. Zhang, “Fuzzy logic-based temperature control system for aquatic environments,” *Applied Soft Computing*, vol. 96, Art. no. 106672, 2020.

[11] R. K. Kodali and A. Naikoti, “ESP32 based smart water quality monitoring system,” *International Journal of Electrical and Computer Engineering*, vol. 11, no. 1, pp. 451–459, 2021.

[12] S. Wu, H. Liu, and Y. Zhao, “Low-power IoT architecture for environmental monitoring systems,” *Sensors*, vol. 21, no. 3, Art. no. 902, 2021.

[13] A. Rahman et al., “IoT-based real-time water level and turbidity monitoring system,” *Applied Sciences*, vol. 11, no. 8, Art. no. 3567, 2021.

[14] M. S. Mahmoud and A. A. Hossam-Eldin, “Smart water management systems using IoT and fuzzy control,” *Sustainable Computing: Informatics and Systems*, vol. 30, Art. no. 100518, 2021.

[15] J. Gubbi et al., “Internet of Things (IoT): A vision, architectural elements, and future directions,” *Future Generation Computer Systems*, vol. 113, pp. 1–13, 2021.

[16] H. Wang, Z. Li, and M. Sun, “Performance analysis of IoT-based water monitoring systems,” *IEEE Access*, vol. 10, pp. 12234–12246, 2022.

[17] P. Rossi et al., “Energy-aware IoT systems for environmental monitoring,” *Sensors*, vol. 22, no. 9, Art. no. 3475, 2022.

[18] Y. Chen et al., “Cloud-based monitoring and control of aquatic systems using IoT,” *Journal of Cloud Computing*, vol. 11, Art. no. 34, 2022.

[19] A. Putra, R. Wijaya, and D. Kurniawan, “Fuzzy logic-based smart aquaculture monitoring system,” *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 28, no. 3, pp. 1321–1330, 2022.

[20] M. Al-Saidi and K. Elshafei, “Intelligent IoT systems for water quality management,” *Journal of Cleaner Production*, vol. 389, Art. no. 136061, 2024.