AUTOMATION OF DISTRIBUTION TANK WATER MONITORING USING ULTRASONIC SENSORS WITH FUZZY LOGIC

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***Abstract*— Air Water plays a vital role in supporting industrial activities, ranging from production processes to operational needs such as cooling systems and restrooms. Unstable water availability, particularly in locations with limited access, often poses challenges in monitoring water levels in distribution tanks, a task that is still performed manually. This study aims to design an automated monitoring system for distribution tanks that displays water levels, categories, and percentages without requiring on-site inspections. The system uses a JSN-SR04T ultrasonic sensor to measure water levels, and the data is processed by an Arduino Uno microcontroller using Fuzzy Logic to determine water categories and percentages. The resulting data is sent via the SX1278 LoRa module to an ESP32 microcontroller and forwarded to a WhatsApp Bot via the CallMeBot API as a notification for employees. The research methodology includes hardware and software design, Fuzzy Logic implementation, and system testing. Test results show that the ultrasonic sensor is capable of reading water levels with high accuracy after calibration, specifically 99.5%, and the Fuzzy Logic system successfully classified the data according to the established rules. Data transmission via LoRa remains stable up to a distance of 150 meters with 100% effectiveness and no data packet loss. This system has proven effective, with an overall success rate of 99.73% in helping employees automatically monitor water availability.**

Keywords: Monitoring, Water Tank, Ultrasonic, Fuzzy Logic, LoRa.

I. INTRODUCTION

Water is a vital component for all living things and a basic necessity across various sectors, ranging from households and agriculture to industry[1]. In the industrial sector, water plays a crucial role in various production processes, such as painting, room cooling, fabrication, machining, and general needs like toilets. Given the high demand for water in industrial areas, water availability is a critical factor for the continuity of a company's operations.

However, not all companies have stable access to water, particularly those located in higher-elevation areas where water supply is inconsistent. For this reason, distribution tanks are used as temporary reservoirs; however, monitoring is still conducted manually, which has many drawbacks—especially during rainy weather and when access to the site is difficult[2]. Based on these issues, a Water Distribution Tank Monitoring Automation System was designed using Ultrasonic Sensors with the Fuzzy Logic Method to display the water volume, percentage, and category. This system is expected to streamline the monitoring process and reduce risks for employees.

II. RESEARCH METHODOLOGY

Pada This chapter discusses the overall design and development of the system. The process of creating this device uses the reverse engineering method; reverse engineering is the activity of identifying the technological principles of a tool, object, or system by analyzing its structure, functions, and how it works. This process typically involves an in-depth examination of its operational mechanisms. This method is widely used in the development of products capable of performing the same functions without replicating elements from the original version [7].

Device design is the first step in the device creation process, which involves identifying problems and finding solutions by defining the device's specifications, its operational mechanism, and the scope of its limitations. Device design begins with system design, hardware design, software design, physical device design, fuzzy process design, and testing the device's functionality in accordance with the operational principles established during the design process.

A. System Design

1. System Block Diagram

To clearly illustrate the system diagram that has been created, it is important to provide a detailed explanation using a block diagram. This is a block diagram of the Water Tank Distribution Monitoring Automation System Using Ultrasonic Sensors and Fuzzy Logic, which consists of an Arduino Uno R3, an ESP32, an ultrasonic sensor, and an SX1278 LoRa module.

The following is an overview of the block diagram:

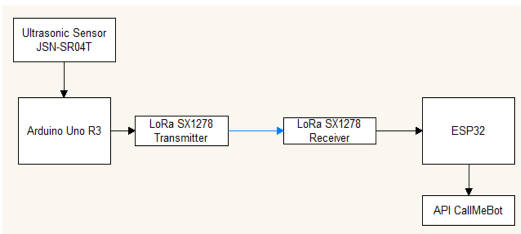

Figure 1. Block Diagram

2. System Flowchart

A program flowchart is used to logically depict each step in a computer program. The system flowchart is shown in the figure below.

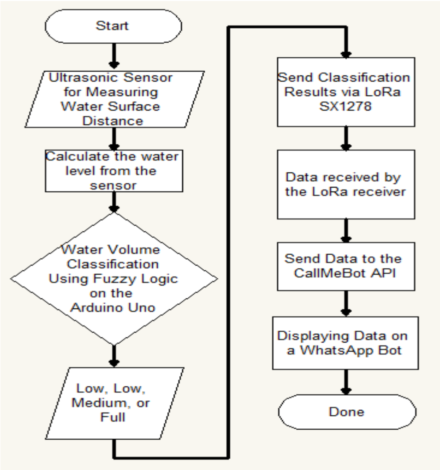

Figure 2. System Flowchart

B. Fuzzy System Design

The fuzzy method is used here to help employees identify water categories and their respective percentages, even when the input data is uncertain or unstable.

1. Membership Fuzzy

Fuzzy membership is an input in the fuzzy method; in this system, there is one membership, namely Water Volume (m³), derived from the readings of the JSN-SR04T ultrasonic sensor.

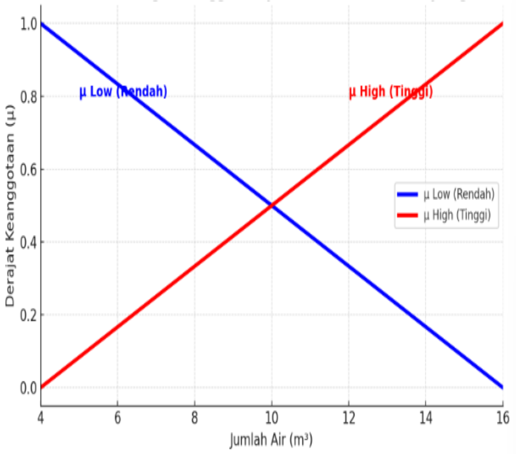

Figure 3. Membership Water Conditions

2. Fuzzification

The process of converting crisp values into fuzzy sets and determining membership degrees within fuzzy sets.

Formula::

Low (rendah)

μ_{low} (x) = 16 - x/12 untuk 4 $\leq x \leq$ 16

High (tinggi)

μ_{high} (x) = x - 4/12 untuk 4 $\leq x \leq$ 16

3. Rule Base Fuzzy

Fuzzy rules are formulated using the IF-THEN format, with constant output values.

Table 1. Rule Base Fuzzy

	IF-THEN Rule
1.	Z_{Low} = IF Water Level is Low THEN Output 20
2.	Z_{High} = IF Water Level is High THEN Output 90

4. Defuzzification

Defuzzification is the process of converting fuzzy output—which consists of the membership degrees of each fuzzy input—into crisp values. The defuzzification method used is the Weighted Average method, which produces crisp output in the form of percentages (%).

The formula used (Weighted Average):

$$Z = \frac{(\mu low \text{ X } Zlow)+(\mu high \text{ X } Zhigh)}{\mu low + \mu high}$$

III. RESULTS AND DISCUSSION

A. Results

1. Sensor testing prior to calibration

The first test was conducted to determine the initial accuracy of the ultrasonic sensor prior to calibration. The test involved comparing the sensor's readings with manual measurements taken using a meter.

Table 2. Sensor Test Results Before Calibration

No	Amount of Water (m^3)	Water Level Reading (cm)		Difference / Error (cm)
		Sensor	Meter	
1	4	189	185	4
2	5	177	173	4
3	6	164	160	4
4	7	151	147	4
5	8	141	137	4
6	9	128	124	4
7	10	112	108	4
8	11	97	95	2
9	12	79	77	2
10	13	64	62	2
11	14	50	48	2
12	15	39	37	2
13	16	23	21	2

2. Sensor testing after calibration

The second test was conducted after the sensor was calibrated to correct any discrepancies or errors that occurred during the previous test. The calibration process involved adjusting the sensor's measurements to match the manual measurements from the previous test.

Table 3. Test Results for the Sensor After Calibration

No	Amount of Water (m^3)	Water Level Reading (cm)		Difference/ Error (cm)
		Sensor	Meter	
1	4	186	185	1
2	5	174	173	1
3	6	161	160	1
4	7	148	147	1
5	8	138	137	1
6	9	124,5	124	0,5
7	10	108,5	108	0,5
8	11	95,5	95	0,5
9	12	77,33	77	0,33
10	13	62,21	62	0,21
11	14	48,13	48	0,13
12	15	37,15	37	0,15
13	16	21,1	21	0,1

3. Testing the SX1278 LoRa module

LoRa module testing was conducted to assess the wireless communication capabilities between the transmitter and receiver at various distances and under various environmental conditions, such as the presence of obstacles. In this test, two key metrics were observed: RSSI (Received Signal Strength Indicator) and packet loss. The RSSI value indicates the strength of the signal received by the receiver, measured in decibels per milliwatt (dBm); the closer the value is to zero, the stronger the received signal. Meanwhile, Packet Loss indicates the percentage of data lost during transmission; a value of 0% means all data was successfully transmitted. This test was conducted at distances of 50 meters, 150 meters, and 180 meters.

Table 4. Test Results for the LoRa Module

Data Transmission	LoRa Range					
	50 meter		150 meter		180 meter	
	RSSI (dBm)	Packet Loss (%)	RSSI (dBm)	Packet Loss (%)	RSSI (dBm)	Packet Loss (%)
1	-43	0.0	-99	0.0	0	0.0
2	-43	0.0	-100	0.0	0	0.0
3	-44	0.0	-101	0.0	0	0.0
4	-46	0.0	-97	0.0	0	0.0
5	-50	0.0	-98	0.0	0	0.0
6	-46	0.0	-100	0.0	0	0.0
7	-47	0.0	-100	0.0	0	0.0
8	-42	0.0	-98	0.0	0	0.0
9	-44	0.0	-96	0.0	0	0.0
10	-50	0.0	-94	0.0	0	0.0
11	-50	0.0	-93	0.0	0	0.0
12	-49	0.0	-96	0.0	0	0.0
13	-50	0.0	-97	0.0	0	0.0
14	-44	0.0	-92	0.0	0	0.0
15	-45	0.0	-99	0.0	0	0.0
16	-45	0.0	-98	0.0	0	0.0
17	-42	0.0	-99	0.0	0	0.0
18	-47	0.0	-99	0.0	0	0.0
19	-45	0.0	-101	0.0	0	0.0
20	-50	0.0	-100	0.0	0	0.0

4. Testing of Fuzzy Tools and Methods

This testing was conducted to determine whether the fuzzy tools and methods were consistent with those specified in the design section.

Table 7. Results of Testing the Fuzzy Tool and Method

No	**Amount of Water (m^3)**	***Fuzzy*** **(%)**	**Category**	**Description**	
				Yes	**No**
1	4	20	Low	✓	
2	5			✓	
3	6			✓	
4	7	40	A little	✓	
5	8			✓	
6	9			✓	
7	10			✓	
8	11	60	Medium	✓	
9	12			✓	
10	13			✓	
11	14	90	Full	✓	
12	15			✓	
13	16			✓	

5. WA Bot Notification Display

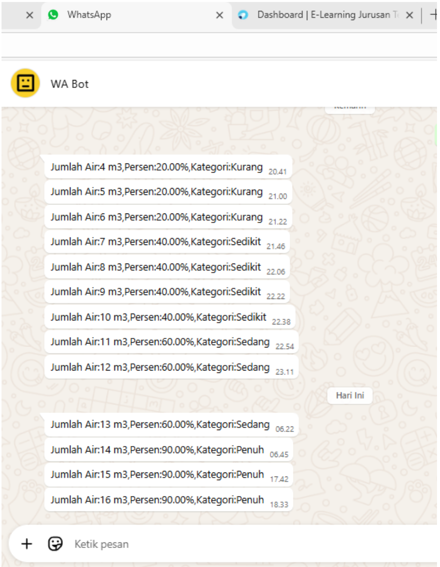

Figure 4. Notification Display on the WhatsApp Bot

Figure 4. Shows the system output displayed on the WhatsApp Bot via the CallMeBot API. The data sent includes the water volume in m³, the percentage (%), and the water category. This data aligns with the test results table: water volume of 4 m³ with 20% falls into the “low” category; water volume of 5 m³ with 20% falls into the “low” category; water volume of 6 m³ with 20% falls into the “low” category; water volume of 7 m³ with 40% falls into the ‘slight’ category; water volume of 8 m³ with 40% falls into the “slight” category; a water volume of 9 m³ with a percentage of 40% falls into the “slightly” category, a water volume of 10 m³ with a percentage of 40% falls into the “slightly” category, a water volume of 11 m³ with a percentage of 60% falls into the “moderate” category, a water volume of 12 m³ with a percentage of 60% falls into the ‘moderate’ category, a water volume of 13 m³ with a percentage of 60% falls into the “moderate” category, a water volume of 14 m³ with 90% falls into the full category, a water volume of 15 m³ with 90% falls into the full category, a water volume of 16 m³ with 90% falls into the full category.

Figure 5. Comparison of Results from the WhatsApp Bot with Measurements from the 11 m³ Tank

Figure 5. Shows the consistency between the WA Bot notification and the actual tank conditions, as seen in the figure, where the water level is 11 m³. Under these conditions, the system outputs a “moderate” category with a 60% probability. This consistency between the tank measurements and the WA Bot notifications proves that the LoRa transmission system and the CallMeBot API are functioning properly, ensuring that the displayed data matches the actual conditions in the tank.

B. Discussion

In this subsection, we discuss the results obtained from the final project, namely the automated monitoring system for distribution water tanks. This system uses an ultrasonic sensor to measure water levels, an Arduino to process the data using fuzzy logic, LoRa to transmit the processed data, and an ESP32 to send the results via the CallMeBot API for display on a WhatsApp Bot.

Based on the test results, the automated monitoring system for distribution water tanks using ultrasonic sensors with fuzzy logic demonstrated good performance and aligned with the research objectives. The ultrasonic sensor used is capable of reading water levels with high accuracy after undergoing a calibration process. Before calibration, the difference between the sensor reading and manual measurements reached 4 cm; however, after calibration, this difference was successfully reduced to 1 cm or even lower. This indicates that the sensor operates with a high level of reading accuracy.

The accurate sensor readings are then processed using a fuzzy logic method to classify the water level into four categories: low, slightly low, moderate, and full. Test results show that the fuzzy system produces consistent outputs that align with the rule base established during the design phase. The outputs, presented as percentage values of 20%, 40%, 60%, and 90%, provide users with clearer information regarding the actual water level in the tank.

Furthermore, the communication system using the LoRa SX1278 module also demonstrated good performance. Based on range test results, LoRa was able to transmit data stably up to a distance of 150 meters without data loss, even when there was a single wall obstruction. This proves that LoRa technology is efficient for use in monitoring systems at distances of 150 meters or less. However, it is not suitable for distances of 200 meters or more, which can serve as the system’s effective operational limit.

The overall performance of the system has proven to be good, as evidenced by the notifications sent via the CallMeBot API to the WhatsApp Bot, as shown in the results section above. The data sent and displayed includes water volume in m³, percentage in %, and water level categories—low, low, medium, and full—based on manual measurements. This demonstrates that the integration between the sensor, Arduino, LoRa, ESP32, and the CallMeBot API is functioning effectively. The system can provide information to employees without the need to physically inspect the tank location. Thus, this system offers a practical solution to the challenges associated with manual monitoring.

Compared to previous studies that used Blynk or Firebase to display data, this system has advantages in terms of practicality and communication efficiency. Using the WhatsApp Bot as a notification medium is more effective because almost all users have this app on their phones. Additionally, the use of the LoRa module offers advantages in areas without internet access.

Overall, the results show that this automated water tank monitoring system has functioned in accordance with the research objectives. The system is capable of automatically detecting water levels, converting the data into categories and percentages using fuzzy logic, transmitting data via LoRa seamlessly, and displaying the results through the CallMeBot API to a WhatsApp Bot. With these capabilities, the system has proven to enhance efficiency and practicality in the water monitoring process and can be implemented in environments without internet access.

IV. CONCLUSION

Based on the results of the research conducted, it can be concluded that the water tank monitoring system developed for the distribution tanks at PT. Labtech Penta Internasional has been successfully implemented. This system is capable of automatically monitoring water levels in real time.

The application of fuzzy logic for categorization and percentage calculations was also successful, making it easy to determine the percentage and category of the water when notifications are sent.

Test results show that the system operates in accordance with its primary objective, which is to enable employees to automatically determine the water level, percentage, and category in the water tanks without having to visit the tank location, thereby addressing the shortcomings associated with manual monitoring.

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