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An IoT-Based Water Level Control Information System with a Hysteresis Algorithm

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ABSTRACT

Water level management in storage tanks requires a system capable of monitoring water conditions and automatically controlling the pump to prevent the tank from becoming empty or overflowing. This study aims to develop an Internet of Things (IoT)-based Water Level Control Information System using a hysteresis algorithm. The system employs an ESP32, a JSN-SR04T sensor, a relay, a pump, and Blynk Cloud. The hysteresis algorithm applies a lower threshold of 20% and an upper threshold of 80% to determine the pump condition. Testing was conducted to evaluate sensor accuracy, control response, manual operation, and IoT communication. The results showed an average sensor error of 0.877% and an accuracy of 99.123%. Hysteresis testing demonstrated that the pump operated according to the predefined control thresholds. Manual control was tested using ON and OFF commands through the Blynk App. The five tested information parameters were successfully transmitted and received, with an average response time of 128.4 milliseconds. These results demonstrate that the system can integrate monitoring, decision-making, pump control, and user interaction through an IoT platform.

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1. INTRODUCTION

Water availability in storage tanks is one of the aspects that needs to be managed effectively, particularly in facilities that rely on pumps to maintain a continuous water supply. Manual control has limitations because users must directly observe the tank condition to determine when the pump should be turned on or off. This condition may increase the risk of the tank becoming empty or overflowing and may cause the pump to operate longer than necessary. The development of Internet of Things (IoT) technology provides an opportunity to address these problems through the integration of sensors, computing devices, communication networks, and applications, allowing water conditions to be monitored in real time and control actions to be performed automatically. A review of smart water management indicates that IoT technology is increasingly being applied to obtain real-time water condition data, improve management efficiency, and support data-driven decision-making (Palermo et al., 2022; Singh & Ahmed, 2021; Soares Ascenção et al., 2023)

The application of IoT in water level management has been implemented through various approaches. (Nanda Ramadhani & Hamna Zakiya, 2026) developed an IoT-based water level monitoring and control system using an ESP32, HC-SR04 sensor, and Blynk. The system was capable of monitoring water levels in real time and automatically controlling the pump based on water level conditions. Similar IoT-based approaches have been proposed for smart water tanks, integrating water level monitoring with automatic pump control and remote access to system information (Jan et al., 2022). Another study developed an IoT-based smart water tank system that integrates sensors and communication devices to monitor tank conditions and operate the pump (Parenreng et al., 2023). Meanwhile, a water level monitoring study using an ESP32 and the Antares platform demonstrated that sensor measurement data could be transmitted in real time and displayed through a dashboard, with testing resulting in an average error of 0.2 cm and a delay of 129.15 ms (Diono et al., 2026). These findings indicate that IoT can be used not only as a means of device communication but also as an infrastructure for transforming sensor data into information that can be utilized by users.

From an Information Systems perspective, IoT becomes more valuable when data from physical devices can be integrated with data processing, information presentation, and user interaction.

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An IoT system for water management can establish an information flow ranging from sensor data acquisition, network transmission, processing, data storage or exchange, to information presentation through an application (Alshami et al., 2024). Research on automatic water level monitoring systems has demonstrated that sensor data can be transmitted to a cloud platform and displayed through an application to help users obtain information about water level conditions without performing direct measurements (Jan et al., 2022; Karthikeyan M et al., 2025). This approach demonstrates a shift from conventional measurement systems toward systems that provide continuous information about object conditions and can be accessed remotely (Khairullah et al., 2025).

Nevertheless, some studies on IoT-based water level control still emphasize hardware aspects and control methods as their primary focus. For example, the application of PID in water level control systems is primarily directed toward obtaining a stable control response to the setpoint. Other studies focus on sensor accuracy, data communication, or the monitoring capabilities of IoT platforms. These conditions indicate an opportunity to develop an approach that positions the control information system as an integrated entity consisting of sensor data, tank condition information, decision-making mechanisms, actuator control, and user access.

In addition to monitoring aspects, pump control mechanisms need to consider unnecessary status changes caused by fluctuations in sensor values. ON/OFF control using a single decision threshold may cause the pump to repeatedly switch between active and inactive states when the measured value is around the threshold. A hysteresis algorithm provides two different threshold values so that the actuator status is maintained within a specific range, and a status change occurs only when the input value exceeds the specified threshold. (Harpawi et al., 2021) Specifically, a hysteresis method was applied for water level control using a lower threshold of 20% to activate the pump and an upper threshold of 80% to deactivate it, with a testing success rate of 100%. Research on hysteresis control in pump-based systems has also demonstrated that this mechanism can be used to reduce mode-switch oscillations in systems that use pumps as actuators (Kärnell & Ericson, 2022).

Based on these studies, the use of IoT for water level monitoring has demonstrated its ability to provide information in real time, while control algorithms such as PID and hysteresis have been used to automate pump operation. However, there are differences in focus between studies emphasizing control algorithm performance and those emphasizing IoT-based monitoring. Nevertheless, existing studies generally emphasize individual aspects of IoT-based water-level systems, such as sensor measurement, automatic pump control, communication, or remote monitoring. The integration of these functions from an Information Systems perspective, particularly the connection between physical data acquisition, data processing, information presentation, automatic decision-making, actuator control, and user interaction within a single system, remains insufficiently addressed. This gap provides the basis for developing an integrated IoT-based Water Level Control Information System that combines water-level sensing, hysteresis-based control, IoT information presentation, and application-based manual control.

This study positions these two aspects within an IoT-based Water Level Control Information System by integrating water level data acquisition, data transformation into information, decision-making using a hysteresis algorithm, pump control, and information presentation and user interaction through an IoT platform. With this approach, IoT does not merely function as a communication medium for devices but also becomes part of an information system that connects the physical condition of the tank with the information received by users and the control actions performed by the system.

This study uses an ESP32 as the processing and communication device, a JSN-SR04T ultrasonic sensor as the source of water level data, a relay as the actuator controller, a pump as the tank-filling device, and Blynk Cloud as the IoT platform for monitoring and user interaction. The hysteresis algorithm is implemented with a lower threshold of 20% and an upper threshold of 80%. When the water level reaches or falls below the lower threshold, the system activates the pump, whereas the pump is deactivated when the water level reaches or exceeds the upper threshold. Water level data, pump status, control mode, threshold values, and sensor distance are provided through the dashboard, allowing users to monitor system conditions remotely.

From an Information Systems perspective, the proposed system integrates physical data acquisition, data processing, information presentation, decision-making, control action, and user interaction into a continuous information flow. The JSN-SR04T provides physical measurement data, which are processed by the ESP32 into water-level information. The processed information is

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transmitted through the IoT infrastructure and presented through the Blynk App. The information is then used by the hysteresis algorithm to support automatic pump control, while users can monitor system conditions, issue manual commands, and adjust threshold parameters through the application. Thus, the proposed system integrates sensing, processing, information presentation, decision-making, action, and user interaction as an information system rather than functioning solely as a sensor-actuator control device.

The contribution of this study is the implementation and functional evaluation of an IoT-based Water Level Control Information System that integrates JSN-SR04T water-level sensing, ESP32-based data processing, hysteresis-based automatic pump control, Blynk-based information presentation, and application-based manual control. The system also provides adjustable lower and upper threshold parameters through the Blynk App. The evaluation covers sensor measurement accuracy, sequential hysteresis behavior, manual control functionality, and IoT communication response. From an Information Systems perspective, this integration connects physical data acquisition, information processing, decision-making, control action, and user interaction within a single system.

Therefore, the objective of this study is to develop and evaluate an IoT-based Water Level Control Information System using a hysteresis algorithm capable of acquiring water level data, generating real-time information on tank conditions, automatically controlling the pump, and providing monitoring and user interaction through an IoT platform. Testing was conducted on sensor accuracy, control response, and IoT connectivity to evaluate the overall performance of the system.

2. METHOD

The research method was designed to develop and evaluate an Internet of Things (IoT)-based Water Level Control Information System using a hysteresis algorithm. The system integrates sensors as the data source, an ESP32 as the processing and communication device, a relay and pump as control components, and Blynk Cloud and the Blynk App as media for information presentation and user interaction. The research stages included system design, hardware and software implementation, control algorithm implementation, IoT integration, and testing of the system's functions and performance.

2.1 Research Stages

This study employed an experimental approach to develop and evaluate an IoT-based Water Level Control Information System using a hysteresis algorithm. The experimental approach was selected because the study focused on prototype design, hardware and software implementation, system integration, and testing of measurement, control, communication, and monitoring functions. A similar approach has been applied in the development of IoT-based water level monitoring and control systems integrating sensors, microcontrollers, communication networks, and monitoring platforms (Diono et al., 2026).

The research stages consisted of system architecture design, hardware design, software design, hysteresis algorithm implementation, IoT system integration, and system testing. These stages were conducted sequentially to ensure that sensor measurement data could be processed into water level information, used as the basis for pump control decisions, and transmitted to users through the IoT platform. In general, the research stages consisted of:

1. System requirements identification
2. System architecture design
3. Hardware design and assembly
4. Software design and implementation on the ESP32
5. Implementation of the hysteresis algorithm
6. Integration of the ESP32 with Wi-Fi and Blynk Cloud
7. Implementation of the dashboard and user interaction
8. Testing of the sensor, pump control, and IoT communication
9. Analysis of the test results

2.2 System Architecture

The developed system consists of water level measurement components, processing and control devices, a communication network, a cloud platform, and a user interface. The JSN-SR04T is used as a sensor to measure the distance between the sensor position and the water surface. The

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measurement data are transmitted to the ESP32 and processed into water level information. The use of ultrasonic sensors integrated with microcontrollers to obtain water level information has also been implemented in various IoT-based monitoring systems (Nasruloh & Baswara, 2021).

The ESP32 functions as the central processing unit of the system as well as the communication device. The sensor data received by the ESP32 is processed into a water level percentage and used as input for the control algorithm. In automatic mode, the hysteresis algorithm determines the pump condition based on the lower and upper water level thresholds. The control signal from the ESP32 is transmitted to the relay module, which functions as a switch to control the water pump.

On the communication side, the ESP32 is connected to a Wi-Fi router to obtain Internet access. The system data are then transmitted to the Blynk Cloud Server and forwarded to the Blynk App as the user interface. The use of the ESP32 and IoT platforms for real-time water level monitoring has been implemented in previous studies, including the integration of the ESP32 with an IoT platform for sensor data transmission and data presentation through a dashboard (Diono et al., 2026).

The system architecture is illustrated in Figure 1.

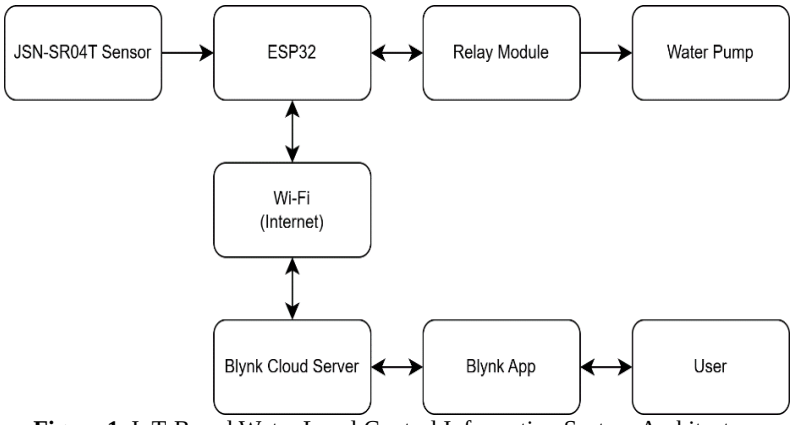


Figure 1. IoT-Based Water Level Control Information System Architecture

The architecture consists of two main pathways. The first is the physical measurement and control pathway, which comprises the JSN-SR04T, ESP32, relay module, and water pump.

The second is the information and communication pathway, which comprises the ESP32, Wi-Fi router, Internet, Blynk Cloud Server, Blynk App, and user.

Both pathways are integrated through the ESP32, allowing physical tank condition data to be used for control decision-making while simultaneously being presented as information to the user. This integration enables the system to connect the physical measurement and control processes with remote monitoring and user interaction through the IoT platform.

2.3 Hardware Design

The hardware used in the system consists of an ESP32, JSN-SR04T ultrasonic sensor, relay module, water pump, and Wi-Fi router. The ESP32 was selected as the main processing device because it provides the processing capability and Wi-Fi connectivity required for IoT system implementation. Previous research on water level monitoring also used the ESP32 for sensor data processing and communication with an IoT platform (Diono et al., 2026)

The JSN-SR04T sensor is used to obtain water surface distance data. Ultrasonic sensors can measure water level without direct contact with the water, making them suitable for measuring the surface height from the top of the tank. The implementation of ultrasonic sensors for water level measurement has been applied in IoT-based monitoring and control systems (Nasruloh & Baswara, 2021).

The JSN-SR04T sensor is connected to the ESP32 through the following interfaces. The VCC and GND pins of the sensor are connected to the 5 V DC power supply and common ground, respectively. The TRIG pin is connected to GPIO26 of the ESP32, while the ECHO pin is connected to GPIO27. The TRIG and ECHO connections are used as signal interfaces for initiating the ultrasonic measurement and receiving the reflected echo signal, respectively. The ESP32 processes the received echo signal to determine the distance between the sensor and the water surface.

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The relay module is used as a control interface between the ESP32 and the water pump. The ESP32 provides a control signal to the relay, while the relay performs switching of the pump's power supply. The water pump is used as an actuator to fill the tank based on the system's control decisions. The interconnections between the hardware components are presented in Table 1.

Table 1. Hardware Connections

No.	Component	Pin/Terminal	Connected to
1	ESP32	5V	Output (+) of 5 V 10 A Power Supply
2	ESP32	GND	Output (−) of 5 V 10 A Power Supply
3	ESP32	GPIO 26	TRIG of JSN-SR04T
4	ESP32	GPIO 27	ECHO of JSN-SR04T
5	ESP32	GPIO 14	IN of Relay Module
6	JSN-SR04T	VCC	Output (+) of 5 V 10 A Power Supply
7	JSN-SR04T	GND	Output (−) of 5 V 10 A Power Supply
8	JSN-SR04T	TRIG	GPIO 26 of ESP32
9	JSN-SR04T	ECHO	GPIO 27 of ESP32
10	Relay Module	VCC	Output (+) of 5 V 10 A Power Supply
11	Relay Module	GND	Output (−) of 5 V 10 A Power Supply
12	Relay Module	IN	GPIO 14 of ESP32
13	Relay Module	COM	L of 220 V AC power source
14	Relay Module	NO	L of Water Pump
15	Water Pump	L	NO of Relay Module
16	Water Pump	N	N of 220 V AC power source
17	Power Supply	L	L of 220 V AC power source
18	Power Supply	N	N of 220 V AC power source
19	Power Supply	+	ESP32, JSN-SR04T, Relay Module
20	Power Supply	−	GND of ESP32, JSN-SR04T, Relay Module

Based on Table 1, the hardware circuit consists of two main sections: the low-voltage control circuit and the 220 V AC pump load circuit. A 5 V 10 A power supply is used to provide DC power to the ESP32, JSN-SR04T sensor, and relay module. Therefore, these three components share the same power source and ground reference.

For sensor communication, GPIO 26 of the ESP32 is connected to the TRIG pin of the JSN-SR04T to provide the trigger signal for measurement, while GPIO 27 is connected to the ECHO pin to receive the reflected ultrasonic signal. The signal's time of flight is then processed by the ESP32 to determine the distance to the water surface.

GPIO 14 is used as the relay control line. When the ESP32 sends a control signal, the relay performs switching through the COM–NO contacts. The COM terminal is connected to the phase (L) line of the 220 V AC power source, while the NO terminal is connected to the L terminal of the water pump. The N terminal of the pump is connected directly to the N line of the 220 V AC power source. With this configuration, the relay functions as an electrically controlled switch that regulates the electrical supply to the pump according to the control decision made by the ESP32.

It should be noted that the 220 V AC section of the circuit is functionally separated from the 5 V DC control section. For physical implementation, the AC connections must use appropriate insulation, terminals, cables, and protective devices to minimize the risk of electric shock and short circuits.

The water pump operates using a 220 V AC power supply, while the relay serves as a switching device that separates the microcontroller control side from the pump load side. The hardware circuit of the system is shown in Figure 2.

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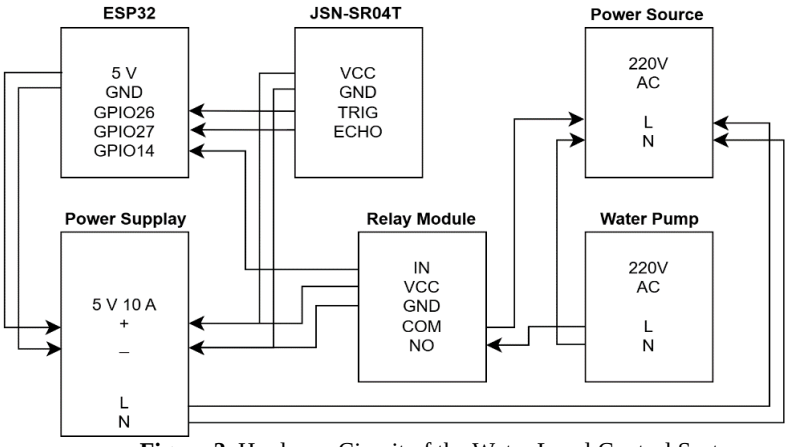


Figure 2. Hardware Circuit of the Water Level Control System

2.4 Water Level Measurement

Water level measurement is performed using the JSN-SR04T sensor based on the distance measurement principle using the time of flight of ultrasonic waves. The sensor transmits ultrasonic waves through the TRIG pin and receives the reflected waves through the ECHO pin. The wave propagation time is then used by the ESP32 to determine the distance between the sensor and the water surface.

The use of ultrasonic sensors for ESP32-based water level measurement has been implemented in IoT-based water monitoring research (Diono et al., 2026). For example, Diono et al. 2026)used an ultrasonic sensor integrated with an ESP32 to obtain water level data and transmit it to an IoT platform in real time. (Kalbii et al., 2022) also applied an ultrasonic sensor and ESP32 for water level monitoring through Blynk.

The measured distance data are subsequently converted into a water level percentage. The conversion is performed based on the minimum and maximum reference conditions of the tank. The equation used is:

$$Level\ \% = \frac{D_{max} - D_{measur}}{D_{max} - D_{min}} x\ 100$$

Where:
Level = water level percentage
D_{measur} = measured distance from the sensor to the water surface
D_{max}= sensor distance at the maximum water level condition
D_{min}= sensor distance at the minimum water level condition

The calculated result is then used as water level information and as an input to the control algorithm in automatic mode.

2.5 Hysteresis Algorithm Design

The hysteresis algorithm is used as a decision-making mechanism to control the pump in automatic mode. Hysteresis employs two different threshold values, namely the lower and upper limits. The use of two thresholds allows the system to maintain the actuator state within a certain range, preventing small fluctuations in the input value from immediately causing changes in the actuator state. The application of hysteresis for water-level control was investigated by (Harpawi et al., 2021), demonstrating the use of upper and lower thresholds to address unstable input signal conditions in water-level control systems.

In this study, the hysteresis algorithm uses an initial lower threshold of 20% and an initial upper threshold of 80%. These values were selected as design parameters for the experimental evaluation and were not determined through experimental optimization. The system also allows the lower and upper threshold values to be adjusted through the Blynk App according to operational requirements.

When the water level is at or below 20%, and the pump is in the OFF state, the system sends a command to turn the pump ON. When the water level reaches or exceeds 80%, and the pump is in the ON state, the system sends a command to turn the pump OFF. Meanwhile, when the water level is between 20% and 80%, the system maintains the previous pump state. This mechanism creates a

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hysteresis zone that prevents repeated changes in the pump state when the water level fluctuates around the threshold values.

The control logic is formulated as follows:

$$Pump = \begin{cases} ON & Level \leq 20\% \ and \ the \ previous \ status \ OFF \\ OF & Level \geq 80\% \ and \ the \ previous \ status \ ON \\ Pump_{previously} & 20\% < Level < 80\% \end{cases}$$

Thus, the pump state changes only when the water level crosses the predefined decision thresholds.

2.6 System Operating Modes

The system has two operating modes, namely automatic (Auto) and manual (Manual) modes. In Auto mode, pump operation is determined by the water level and the hysteresis algorithm. The ESP32 reads the sensor data, calculates the water level percentage, and then evaluates the measured condition against the lower and upper hysteresis thresholds. The pump is activated when the water level reaches or falls below 20% and is deactivated when the water level reaches or exceeds 80%. Within the range of 20% to 80%, the pump state is maintained.

In Manual mode, the user can issue control commands through the Blynk App. The commands from the user are received by the system and used to control the relay connected to the pump. The approach of monitoring and controlling devices through an IoT application has been implemented in an ESP32- and Blynk-based water-level control system (Nanda Ramadhani & Hamna Zakiya 2026).

The use of these two operating modes provides flexibility in system operation. The automatic mode is used for control based on the water-level condition, whereas the manual mode provides a mechanism for direct interaction between the user and the actuator through the application.

2.7 IoT-Based Information System Design

The information system in this study was developed through the integration of sensor devices, ESP32, a communication network, Blynk Cloud, and the Blynk App. Data obtained from the sensor is not only used as input for the control process but is also transformed into information that can be monitored by users. The data transmitted to the IoT platform includes:

1. Water level percentage
2. Distance between the sensor and the water surface
3. Pump status
4. Operating mode
5. Threshold values

The data flow begins with the data acquisition process performed by the JSN-SR04T. The ESP32 then processes the data and determines the system condition. The processed results are transmitted through a Wi-Fi network to Blynk Cloud and subsequently displayed on the Blynk App. This concept is consistent with an IoT-based water-level monitoring system developed by Diono et al. 2026), which utilizes the ESP32 as a data acquisition and processing device and a cloud platform as a medium for presenting information in real time.

In this study, the information flow can be described as follows: sensor data, ESP32 data processing, water-level information, decision-making, pump control, Blynk Cloud, Blynk App, and user. Through this flow, IoT functions as an integral part of the information system, connecting physical objects, data processing, control mechanisms, and users.

2.8 Software Design

The software implemented on the ESP32 is designed to perform several main processes, including device initialization, sensor reading, water-level calculation, operating mode selection, application of the hysteresis algorithm, relay control, communication with Blynk Cloud, and system information updates. The process begins with system initialization and network connection. Once the system is ready, the ESP32 reads data from the JSN-SR04T sensor and calculates the water level percentage. The system then checks the currently selected operating mode.

If Auto mode is active, the system applies the 20%–80% hysteresis algorithm. If Manual mode is active, the system uses the command provided by the user through the Blynk App. After the control

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process is completed, the system status information is updated on Blynk Cloud. The system status is also displayed on the Serial Monitor as local information to support system monitoring and testing.

After these processes are completed, the system pauses for 5 seconds before returning to the sensor-reading process and executing the subsequent operations. The system workflow is shown in Figure 3.

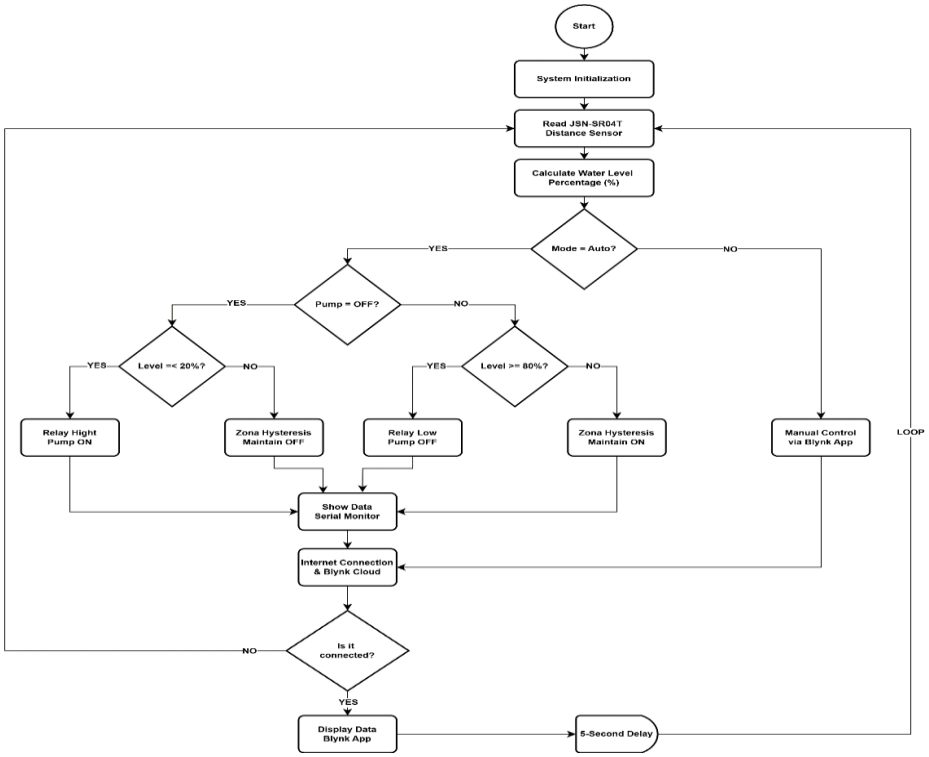


Figure 3. Flowchart of the IoT-Based Water Level Control System

2.9 Testing Method

Testing was conducted to evaluate the functionality and performance of the system based on several aspects, namely water-level measurement, the hysteresis algorithm, manual mode, and IoT communication. The testing method was designed before system evaluation so that each function could be assessed using appropriate parameters.

1. Sensor Accuracy Testing

   Accuracy testing was performed by comparing the measurement results obtained from the JSN-SR04T with the reference values. The test aimed to determine the sensor's capability to measure the distance to the water surface and the accuracy of its conversion into the water level. The error percentage was calculated using the following equation:

$$Error\ (\%) = \frac{Sensor_{value} - value_{reference}}{Value_{reference}}\ x\ 100$$

   The error values obtained from each test were subsequently used to determine the measurement characteristics of the sensor. Ultrasonic sensor testing in water-level monitoring systems has also been employed in previous research to evaluate the accuracy of water-level measurements (Kalbii et al., 2022).

2. Hysteresis Algorithm Testing

   Testing of the hysteresis algorithm was performed by applying changes in the water level that crossed the predefined lower and upper thresholds. The testing focused on three conditions:

   a. Water level ≤ 20%
   b. Water level between 20%–80%
   c. Water level ≥ 80%

   The test was conducted to determine whether the system activates the pump at the lower threshold, maintains the pump state within the hysteresis zone, and deactivates the pump at the

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upper threshold. This testing approach was used to evaluate whether the implementation of the two thresholds operated according to the designed hysteresis principle (Harpawi et al., 2021).

3. Manual Mode Testing

   Manual mode testing was performed by issuing ON and OFF commands through the Blynk App. The test aimed to determine the system's ability to receive user commands and transmit them to the relay to control the pump. The observed parameters included the command issued through the application, relay status, and pump status.

4. IoT Communication Testing

   IoT communication testing was performed to evaluate the data exchange process among the ESP32, Blynk Cloud, and Blynk App. The observed parameters included data transmission success, information updates on the dashboard, and communication response time.

   Communication testing is an important component of an IoT-based monitoring system because the system must be capable of transmitting sensor data and presenting the information on the monitoring platform. (Diono et al., 2026) used accuracy and delay as parameters to evaluate communication performance in an ESP32-based water-level monitoring system integrated with an IoT platform.

3. RESULT AND DISCUSSION

The system implementation was carried out based on the hardware, software, and Internet of Things (IoT) architecture described in the methodology section. The developed system integrates the JSN-SR04T ultrasonic sensor to obtain water-level data, the ESP32 as the processing and communication device, a relay as the pump controller, and Blynk Cloud and the Blynk App as media for monitoring and user interaction. Testing was conducted to evaluate the system's capability to measure the water level, control the pump using the hysteresis algorithm, perform manual control, and support IoT communication.

3.1 System Implementation

The system was implemented by integrating the hardware and software into a unified water-level control system. The JSN-SR04T sensor was installed at the top of the tank to measure the distance between the sensor and the water surface. The measurement data were received by the ESP32 and converted into a water-level percentage. This value was subsequently used as the input for the hysteresis algorithm in automatic mode. The integration of the ESP32, JSN-SR04T sensor, actuator, and IoT platform for monitoring and controlling water systems has also been implemented in previous research (Anak Agung Ngurah & Agus Putu Abiyasa, 2025).

The ESP32 also functions as a communication device that transmits system data to Blynk Cloud through a Wi-Fi network. The transmitted information includes the water level, pump status, operating mode, sensor distance, and threshold parameters. The information is then displayed on the Blynk App dashboard, allowing users to monitor the tank condition without direct observation.

On the actuator side, the ESP32 controls the relay module connected to the water pump. The relay functions as a switch to activate or deactivate the pump based on the system's control decisions. In addition to automatic operation, users can operate the pump manually through the Blynk App using manual mode.

The implemented hardware system is shown in Figure 4.



Figure 4. Hardware Implementation of the Water-Level Control System

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Figure 4 shows the hardware implementation of the water-level control system used in this study. The system consists of an ESP32 microcontroller as the central data processing unit, a JSN-SR04T ultrasonic sensor for measuring the water level in the tank, and a relay module for controlling the water pump. The JSN-SR04T sensor is installed at the top of the tank to measure the distance to the water surface using a non-contact measurement method. This implementation demonstrates the integration of the sensor, processing unit, and actuator components in forming an Internet of Things (IoT)-based water-level control system.

The implementation of the monitoring interface on Blynk is shown in Figure 5.

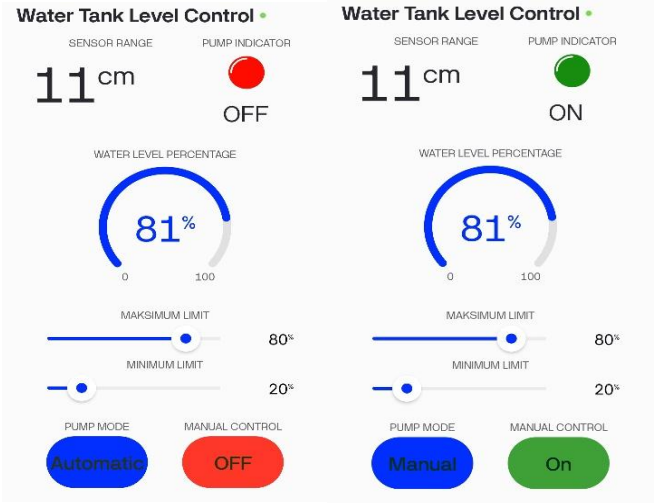


Figure 5. System Monitoring and Control Dashboard

Overall, the implementation resulted in a system that connects the physical object, namely the water tank, with data processing, communication, data exchange, and the user interface components. This integration enables physical condition data from the tank to be transformed into information that can be accessed by users through the Internet (Az-Zikri et al., 2025).

3.2 JSN-SR04T Sensor Testing Results

Testing of the JSN-SR04T sensor was conducted to evaluate its measurement accuracy by comparing the sensor readings with reference distances. The reference distances ranged from 5 cm to 60 cm with a 5 cm interval. At each testing point, the reference distance between the sensor and the measurement target was established using a measuring tape, while the distance measured by the JSN-SR04T was recorded through the ESP32. The difference between the reference distance and the sensor measurement was then used to calculate the measurement error and percentage error.

Table 2. JSN-SR04T Sensor Testing Results

No.	Reference Distance (cm)	JSN-SR04T Distance (cm)	Difference (cm)	Error (%)
1	5.0	5.2	0.2	4.00
2	10.0	10.3	0.3	3.00
3	15.0	15.0	0.0	0.00
4	20.0	20.1	0.1	0.50
5	25.0	25.2	0.2	0.80
6	30.0	30.3	0.3	1.00
7	35.0	35.0	0.0	0.00
8	40.0	40.1	0.1	0.25
9	45.0	45.2	0.2	0.44
10	50.0	50.0	0.0	0.00
11	55.0	55.2	0.2	0.36
12	60.0	60.1	0.1	0.17
Average			0.142	0.877

Based on the test results presented in Table 2, the JSN-SR04T sensor was capable of measuring the distance to the water surface over a range of 5–60 cm, with a measurement difference

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from the reference distance ranging from 0.0 to 0.3 cm. The average measurement difference was 0.142 cm, while the average percentage error was 0.877%. Based on these results, the measurement accuracy of the sensor reached 99.123%. The test results indicate that the JSN-SR04T provides good measurement precision within the tested range and can therefore be used as a water-level data source for the control system.

The use of the JSN-SR04T for water-level measurement has also been reported in previous studies, with test results demonstrating measurement accuracy that can serve as a comparative reference (Cherqui et al., 2020; Syafei et al., 2025)

3.3 Automatic Mode Testing Results Based on the Hysteresis Algorithm

Testing of the hysteresis algorithm was conducted as the main evaluation to determine whether the pump control mechanism operated according to the system design. The system uses a lower threshold of 20% and an upper threshold of 80%.

When the water level reaches or falls below 20%, the system should activate the pump if it was previously in the OFF state. Conversely, when the water level reaches or exceeds 80%, the system should deactivate the pump if it was previously in the ON state. When the water level is between the two thresholds, the system maintains the previous pump state.

Table 3. Hysteresis Algorithm Testing Results

No.	Water Level (%)	Previous Pump State	Expected Pump State	Actual Pump State	Result
1	15	OFF	ON	ON	Match
2	49	ON	Remain ON	ON	Match
3	81	ON	OFF	OFF	Match
4	32	OFF	Remain OFF	OFF	Match

Based on the data presented in Table 3, the pump changed its state when the water level reached the hysteresis thresholds. At a water level of 20% or below, the pump was activated, whereas at a water level of 80% or above, the pump was deactivated. Within the range of 20% to 80%, the pump state was maintained based on its previous condition. These results can also be compared with previous studies on IoT-based water-level control systems that implement automatic decision-making mechanisms based on water-level conditions (Hidayat et al., 2024; Ummi Hanik et al., 2025). The distinction of this study lies in the implementation of two configurable hysteresis thresholds, initially set at 20% and 80%, to maintain the pump state within a predefined range.

This characteristic demonstrates the primary function of hysteresis, namely providing a tolerance range for input variations before changing the actuator state. The test results demonstrate that changes in the water level within the hysteresis range do not immediately change the pump state. However, the test scenarios in this study were designed to verify the threshold and state-retention behavior of the hysteresis algorithm and did not quantitatively evaluate pump switching frequency under repeated water-level fluctuations around the threshold values.

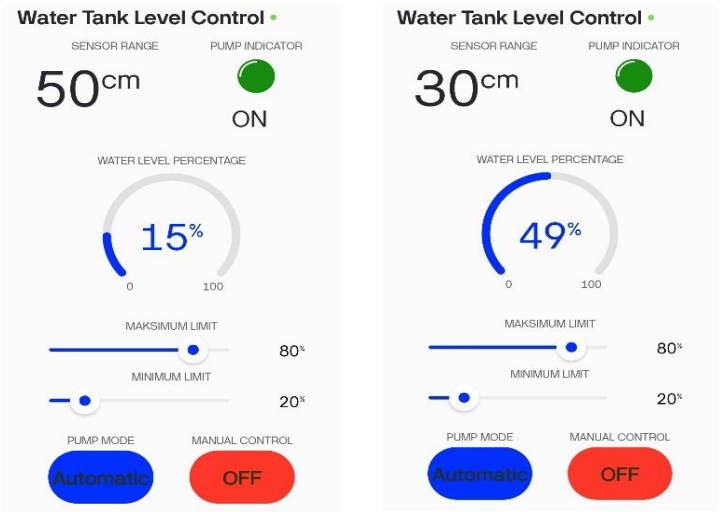


Figure 6. Hysteresis Algorithm Testing Results Based on the Previous Pump OFF State

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Based on the data presented in Figure 6, the hysteresis algorithm was tested by observing the pump state after the water level reached 15% and subsequently increased to 49%. At a water level of 15%, which was below the lower threshold of 20%, the pump changed from OFF to ON. When the water level subsequently increased to 49%, the pump remained ON because the water level was still within the hysteresis range between the lower threshold of 20% and the upper threshold of 80%. Therefore, the increase in water level from 15% to 49% did not cause the pump to turn OFF. The pump would only be deactivated when the water level reached or exceeded the upper threshold of 80%. This result demonstrates the state-retention behavior of the hysteresis algorithm when the water level changes within the predefined hysteresis range.

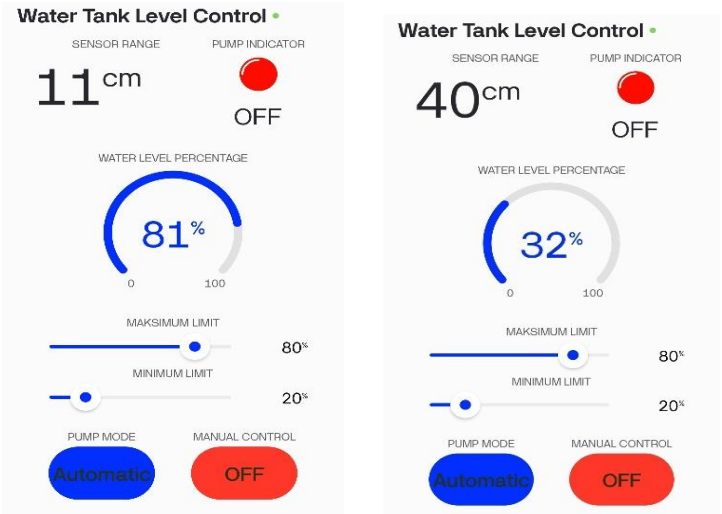


Figure 7. Hysteresis Algorithm Testing Results Based on the Previous Pump ON State

Based on the data presented in Figure 7, the hysteresis algorithm was tested by observing the pump state after the water level reached 81% and subsequently decreased to 32%. At a water level of 81%, which exceeded the upper threshold of 80%, the pump changed from ON to OFF. When the water level subsequently decreased to 32%, the pump remained OFF because the water level was still within the hysteresis range between the lower threshold of 20% and the upper threshold of 80%. Therefore, the decrease in water level from 81% to 32% did not cause the pump to turn ON. The pump would only be activated when the water level reached or fell below the lower threshold of 20%. This result demonstrates the state-retention behavior of the hysteresis algorithm when the water level changes within the predefined hysteresis range.

Therefore, the experimental results confirm the threshold-crossing and state-retention behavior of the implemented hysteresis algorithm. Nevertheless, these results should not be interpreted as a quantitative measurement of switching reduction. A quantitative evaluation of switching frequency would require repeated experiments involving water-level fluctuations around the lower and upper thresholds, with the number of pump state changes recorded and compared.

3.4 Manual Mode Testing Results

Manual mode testing was conducted to evaluate the system's ability to receive user commands through the Blynk App. In this mode, users can issue commands to activate or deactivate the pump without waiting for the water level to reach the automatic control thresholds. The test focused on functional command execution and did not evaluate user usability, user experience, or user satisfaction. These results demonstrate the functional operation of the manual control feature, rather than user-level usability or interaction performance.

Table 4. Manual Mode Testing Results

No.	Blynk App Command	Relay Status	Pump Status	Result
1	ON	ON	ON	Successful
2	OFF	OFF	OFF	Successful

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Table 4 presents the results of manual mode testing through the Blynk App. Two functional command scenarios were tested, namely ON and OFF, with each scenario tested once. The results show that the relay and water pump responded according to the command issued through the application. These results confirm the functional execution of the tested manual control commands.

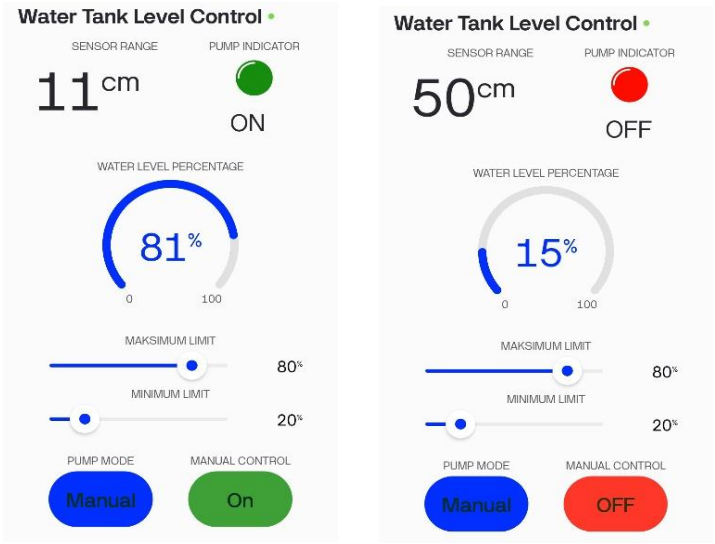


Figure 8. Manual Pump Mode Testing Results

Based on Figure 8, manual mode testing provides users with direct control over the pump without relying on the water-level thresholds used in the hysteresis algorithm. The test results show that the pump could still be manually activated when the water level was at 81%. Conversely, the pump could also be manually deactivated when the water level was at 15%. These results demonstrate that, in manual mode, the water-level value does not restrict the user's command to change the pump state. Thus, manual mode provides flexibility in system operation, while automatic control continues to use the hysteresis rules to determine the pump state based on the water level.

3.5 IoT Communication Testing Results

IoT communication testing was performed to evaluate the data exchange process among the ESP32, Blynk Cloud, and Blynk App. Five types of system information were tested, namely water level percentage, sensor distance, pump status, operating mode, and threshold values. Each parameter was tested once by observing whether the information transmitted from the ESP32 was successfully received and displayed on the Blynk App dashboard. The communication response time was recorded for each tested parameter as the time required for the transmitted information to be received and displayed on the IoT platform. The measured response times were then used to determine the average communication response time. The use of the ESP32 and an IoT platform to transmit sensor measurement data and provide remote monitoring has also been implemented in previous research (Kusumastuti et al., 2025).

Table 5. IoT Communication Testing Results

No.	Parameter	Data Transmitted	Data Received	Delay (ms)	Status
1	Water level	Yes	Yes	128	Successful
2	Sensor distance	Yes	Yes	132	Successful
3	Pump status	Yes	Yes	125	Successful
4	System mode	Yes	Yes	130	Successful
5	Threshold	Yes	Yes	127	Successful
Average				128.4	

Based on the data presented in Table 5, all parameters were successfully received by Blynk Cloud, with varying response times for each test. In the context of Information Systems, IoT communication is an important component because it enables data from physical objects to be transmitted and transformed into information that can be accessed by users (Fauzi Ariyo et al., 2026).

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Thus, successful communication not only determines the monitoring functionality but also affects the user's ability to obtain system condition information promptly.

3.6 Discussion of the Water-Level Control Information System

The implementation results show that the developed system integrates several functional layers, namely data acquisition, processing, decision-making, control, communication, information presentation, and user interaction. The JSN-SR04T functions as the source of physical condition data from the tank, while the ESP32 performs data processing and executes the control logic.

The sensor data, which initially consist of distance measurements, are processed into water-level information expressed as a percentage. This information is then used as the basis for decision-making through the hysteresis algorithm. The system decision generates an actuator action in the form of activating or deactivating the water pump.

At the same time, system condition data are transmitted to Blynk Cloud and presented to the user through the Blynk App. Through this mechanism, the system extends beyond device automation and establishes an information flow from the physical object to the user. From an Information Systems perspective, this integration can be represented as (Input, Processing, Information, Decision, Action, Feedback).

The Input is obtained from the JSN-SR04T sensor. Processing is performed by the ESP32 to transform sensor data into water-level information. The Information is presented through the Blynk App. A decision is made based on the hysteresis algorithm or the user's manual command. The Action is realized through pump control. Subsequently, changes in the system condition generate new data, thereby forming an information and control cycle.

This approach represents an important distinction between the proposed system and systems that focus solely on device measurement or control. The developed system integrates sensor data, decision-making processes, actuators, communication networks, a cloud platform, and users within a single IoT-based information system ecosystem.

From the control perspective, the implementation of 20%–80% hysteresis provides a mechanism for maintaining the pump state when the water level remains between the two thresholds. From the Information Systems perspective, this mechanism generates pump status information that can be presented to users, enabling them to understand the relationship between the water-level condition and the resulting control action.

To further position the proposed system in relation to previous studies, a comparison of the main characteristics and reported performance results is presented in Table 6. The comparison considers the sensing approach, control method, IoT platform, and reported performance of each study.

Table 6. Comparison with Previous IoT-Based Water-Level Studies

Study	Main Approach	Control / Monitoring	Quantitative Result
(Harpawi et al., 2021)	Water-level control using hysteresis	Hysteresis control	100% test success rate; pump ON at 20% and OFF at 80%
(Kalbii et al., 2022)	Ultrasonic-based water-level monitoring	IoT monitoring using Blynk	Average measurement error: 0.1%
(Diono et al., 2026)	ESP32-based water-level monitoring	MQTT and Antares	Average error: 0.2 cm; delay: 129.15 ms; no packet loss
This study	JSN-SR04T, ESP32, hysteresis, Blynk	Automatic hysteresis control and manual control	Average measurement error: 0.877%; average communication response time: 128.4 ms

The quantitative comparison shows that the proposed system provides measurable sensor and communication performance under the tested conditions. The average sensor measurement error of 0.877% obtained in this study is higher than the 0.1% error reported by (Kalbii et al., 2022), while the average communication response time of 128.4 ms is slightly lower than the 129.15 ms delay reported by (Diono et al., 2026). However, these values were obtained under different experimental conditions and measurement procedures and therefore should not be interpreted as directly comparable performance indicators. The comparison is presented as a quantitative reference for positioning the results of this study in relation to previous research rather than as an indication of superiority between the systems.

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4. CONCLUSION

This study resulted in an IoT-based Water-Level Control Information System that integrates the JSN-SR04T sensor, ESP32, relay, water pump, and Blynk Cloud using a hysteresis algorithm. The system is capable of acquiring water-level data, processing the measurement results into information on tank conditions, determining control actions based on the hysteresis algorithm, and providing monitoring and user interaction through an IoT platform. The hysteresis algorithm was implemented using a lower threshold of 20% and an upper threshold of 80% to automatically control the pump state.

The JSN-SR04T sensor testing results showed an average measurement difference of 0.142 cm and an average percentage error of 0.877%, corresponding to a measurement accuracy of 99.123%. The hysteresis algorithm testing demonstrated that the pump operated according to the predefined control thresholds, namely being activated when the water level reached or fell below 20% and deactivated when the water level reached or exceeded 80%. Manual mode testing showed that ON and OFF commands issued through the Blynk App were successfully executed by the pump control system, all five tested information parameters were successfully transmitted and received through the IoT platform, with response times ranging from 125 to 132 ms and an average response time of 128.4 ms.

The implementation of hysteresis with two control thresholds allows the pump state to be maintained when the water level remains within the predefined hysteresis range. The system also enables users to obtain information on tank conditions and perform remote pump control through Blynk Cloud. The limitation of this study is the dependence of monitoring and user interaction functions on an Internet connection. The testing was conducted in a prototype environment and therefore did not cover variations in tank capacity and a broader range of operational conditions.

Future development can be directed toward implementing the system in tanks with more diverse capacities and operational conditions, as well as incorporating historical data storage and predictive methods. These developments are expected to improve the system's ability to provide information, recommendations, and more adaptive water-level control based on usage patterns and system conditions.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest in relation to this research and the publication of this article.

DATA AVAILABILITY

The source code used in this study is publicly available in the GitHub repository at the following link: https://github.com/yuliusitkk-ux/water-tank-level-control.

AUTHOR CONTRIBUTIONS

Yulius Yus: Conceptualization; Methodology; Software; Investigation; Writing-Original Draft. Kristian Tengker: Formal Analysis; Visualization. Fransiska Elly Renni Susanti: Supervision; Writing-Review & Editing.

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