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DESIGN OF RULE BASED ALGORITHM BASED ON IOT (INTERNET OF THINGS) AND WATER LEVEL SENSOR TO MONITOR THE TIDE OF BENGAWAN SOLO

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ABSTRACT

Laren Village in Laren District, Lamongan Regency, is traversed by the Bengawan Solo River, which is crucial for agriculture, fisheries, industry, and domestic needs. However, excessive use poses risks of pollution and flooding. Floods can cause material losses, infrastructure damage, environmental contamination, disease outbreaks, traffic disruption, and water scarcity. Effective mitigation measures are vital to reduce these risks. Internet of Things (IoT)-based technology offers an effective solution for flood risk mitigation. IoT enables real-time monitoring and decision-making using rule-based algorithms that analyze data patterns, set conditions, and automatically respond to potential threats. On August 6, 2024, observation data showed Bengawan Solo's water level ranged between 119 cm and 170 cm, mostly categorized as "Safe." However, the last two measurements, at 117 cm and 119 cm, shifted the status to "Caution," signaling a need for vigilance. The average water level of 151.7 cm indicated an overall "Safe" condition, yet the sudden drop underscores the importance of continuous monitoring. IoT systems with rule-based algorithms can detect real-time changes, enabling swift risk mitigation. This technology enhances safety, supports environmental sustainability, and preserves the Bengawan Solo River's ecosystem.

Keywords**—** *Flood, IoT, Rule Based Algorithm, Telegram, Ultrasonic Sensor,*

I. INTRODUCTION

Laren Village is a village located in Laren District, Lamongan Regency, one of which is passed by the Bengawan Solo River. Bengawan Solo River water is utilized for various purposes such as agriculture, fisheries, industry and even domestic activities that have the potential to pollute the Bengawan Solo River so that one of them will cause an impact, namely flooding (Wibowo et al., 2018).

Flooding is often a natural challenge in several sub-districts in Lamongan Regency, especially in Laren Sub-district which coincides in Laren Village. The impact of flooding in Lamongan Regency is expanding and intensifying from year to year, causing considerable losses to the population (Bianto and Aprillya, 2022). Some of the impacts caused by flooding include causing material losses, damaging buildings, causing the environment to become dirty and muddy, spreading disease seeds, disrupting traffic and scarcity of clean water (Salim and Siswanto, 2021).

With this event, researchers implemented a natural disaster early warning system that requires appropriate technology. One of the technologies commonly used in the development of the latest technology-based systems is the Internet of Things (IoT)-based disaster warning information system. This technology has several advantages, such as the ability to operate automatically and provide real-time information for 24 hours. The data collected can be used to anticipate potential disasters in various regions, and can also be integrated with Input Output devices to take action automatically. Thus, disaster management and mitigation can be done quickly and efficiently (Usmanto and Budi, 2018). The utilization of IoT technology provides benefits in the form of increasing speed, convenience, and efficiency in the implementation of human tasks (Nursobah et al., 2022).

Water level sensors are commonly used for various touchless distance measurement applications. These sensors emit sound waves towards a target, which then reflects the waves back to the sensor. The system then measures the time it takes for the waves to reach the target and return to the sensor, and calculates the distance of the target using the speed of sound in the medium (Arief, 2019).

Rule-based algorithms are methods designed to solve problems by deciphering patterns from the problem. Typically, a rule in a rule-based method consists of two parts: a condition and an action that is performed if the condition is satisfied in whole or in part. The rules obtained will be implemented in an algorithm. This algorithm will determine the most appropriate rule for a problem (Rahman et al., 2021).

Based on these problems, the author is interested in creating a system "Design of Bengawan Solo Tidal Monitoring Tool Based on IoT (Internet of Things) Using Rule Based Algorithm and Water Level Sensor" so that this research produces an information system in the form of a web that can provide Bengawan Solo tidal parameters in real time and online. This system presents the value of water level and determines the depth of water, so that it can provide danger notifications via Telegram if the water level value has exceeded the threshold limit.

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Rule-based algorithms are methods designed to solve problems by deciphering patterns from the problem. Typically, a rule in a rule-based method consists of two parts: a condition and an action that is performed if the condition is met in whole or in part. The rules obtained will be implemented in an algorithm. This algorithm will determine the most appropriate rule for a problem (Rahman et al., 2021). The system presents the water level value and determines the water depth, so that it can provide danger notifications via Telegram if the water level value has exceeded the threshold limit.

II. METHOD

A. Flooding

Flooding is often a natural challenge in several sub-districts in Lamongan Regency, especially in Laren Sub-district, which coincides in Laren Village. The impact of flooding in Lamongan Regency is expanding and increasing intensively from year to year, causing significant losses to the population (Bianto and Aprillya, 2022). Some of the impacts caused by flooding include causing material losses, damaging buildings, causing the environment to become dirty and muddy, spreading disease seeds, disrupting traffic and scarcity of clean water (Salim and Siswanto, 2021).

B. Internet Of Things (Iot)

Internet of Things (IoT) is a concept that integrates various devices through the internet network to share data and perform tasks automatically without requiring direct human interaction. This technology has become an important element in the development of modern industry because it provides a variety of significant benefits.

The main goal of IoT implementation is to improve operational efficiency in various sectors. This technology enables process automation and real-time data collection, which supports data-driven decision-making. For example, IoT has been applied in resource usage optimization, such as energy and waste management (Nimodiya and Ajankar, 2022). In addition, IoT is also designed to improve the quality of human life through applications in smart homes and technology-based health services, which provide greater comfort, safety, and efficiency (Tamrakar et al., 2022).

IoT development and deployment are not free from challenges. One of the main issues is data security, where IoT devices are vulnerable to cyber threats due to limited protection. In addition, large-scale data collection by IoT devices raises concerns regarding user privacy (Nimodiya and Ajankar, 2022). IoT technology infrastructure limitations, the inability of devices from various vendors to integrate with each other (interoperability), and high initial investment costs (Tamrakar et al., 2022).

C. Ultrasonic Sensor

An ultrasonic sensor operates on the principle of sound wave reflection. The sensor emits sound waves and then captures the reflection, using the time difference between transmission and reception as the basis for measurement. This time difference is related to the distance or height of the object reflecting the waves. This sensor can measure distances ranging from 2 cm to 300 cm (Elisawati, 2018). In this sensor, ultrasonic waves are generated by a component called a piezoelectric, which produces ultrasonic waves at a frequency of 40 kHz when provided with an oscillator. Ultrasonic sensors are commonly used in various applications for non-contact distance measurement. The device directs ultrasonic sound waves at an object, which then reflects the waves back to the sensor. The system calculates the time it takes for the waves to reach the object and return to the sensor, and then determines the object's distance based on the speed of sound in that medium (Arief, 2019). This can be seen in Figure 1

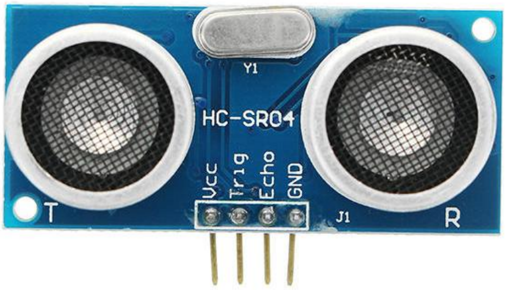

Figure 1. Ultrasonic Sensor

Ultrasonic sensors work on the principle of sound wave reflection. They emit sound waves and then recapture them, using the time difference between emission and reception as the basis for sensing. This time difference is proportional to the distance or height of the reflecting object. This sensor is capable of measuring distances from 2 cm to 300 cm (Elisawati, 2020).

Table 1. Water level distance to ultrasonic sensor

No	Water level distance to ultrasonic sensor	Status	Description
1.	> 121 CM	Safe	Safe for swimming
2.	85 – 121 CM	Alert	Be aware of water levels
3.	< 85 CM	Safe	Danger, Avoid high water

To determine the status automatically When the tool system detects the water level made when the system reads the water level of more than 121 cm, the status displayed is “SAFE” with the description “Safe for swimming” while the sensor distance with a value of 85 - 121 cm, the status displayed is “WARNING” with the description “be aware of the water level” and a value of less than 85 cm, the status displayed is “WARNING” with the description “danger, avoid high water” (Samantha and Almalik, 2019).

D. Rule Based System

The method designed to solve problems by breaking down the patterns of the problem is known as the rule-based method. Typically, a rule in the rule-based method consists of two parts: conditions and actions that are taken if the conditions are met, either fully or partially. The rules obtained are implemented in an algorithm. This algorithm will determine the most appropriate rule for a given problem (Rahman et al., 2021). A rule-based system consists of if-then rules, a set of facts, and an interpreter that controls the application of the rules. There are two approaches used in the implementation of a rule-based system, namely the forward chaining and backward chaining approaches. In a forward chaining system, facts are processed first, and then the existing rules are used to draw new conclusions (Rakhmawati et al., 2018).

E. Microcontroller ESP32

ESP32 is a microcontroller introduced by Espressif Systems, serving as the successor to the ESP8266 microcontroller. This microcontroller comes with an integrated WiFi module on the chip, making it highly suitable for creating Internet of Things (IoT) applications. ESP32 also offers several advantages over other microcontrollers, including more pinouts, additional analog pins, larger memory, and built-in Bluetooth 4.0 Low Energy (Table 1). Additionally, the microcontroller features a dual-core processor that runs on Xtensa LX16 instructions, further supporting the development of IoT applications (Wurdiana Shinta, 2021). The differences between ESP32 and other microcontrollers are presented in.

Table 1. Differences Between ESP32 and Other Microcontrollers

	Arduino Uno	Node MCU (ESP8266)	ESP32
Tegangan	5 *Volt*	3.3 *Volt*	3.3 *Volt*
CPU	ATmega328 - 16MH	*Xtensa single* core L106 - 60 MHz	*Xtens a dual core* LX6 - 160M Hz
Arsitektur	8 bit	32 bit	32 bit
Flash Memory	32 KB	16 MB	16 MB
SRAM	2 KB	160 KB	512 KB
GPIO pin (ADC/DAC)	14 (6/-)	17 (1/-)	36 (18/2)
Bluetooth	None	None	Available
WIFI	None	Available	Available
SPI/12C/UART	1/1/1	2/1/2	4/2/2

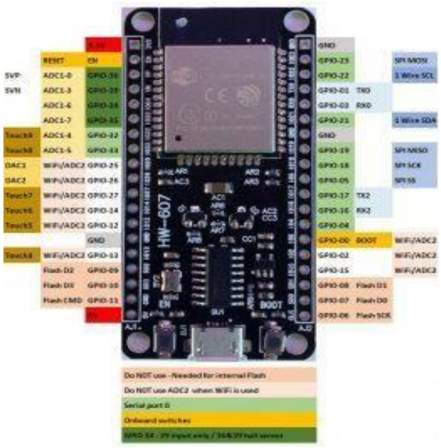

Figure 2. ESP32 Microcontroller

The advantages of the ESP32 microcontroller compared to other microcontrollers are evident, including its greater number of pinouts, more analog pins, larger memory, integrated Bluetooth 4.0 Low Energy, and built-in WiFi, making it ideal for implementing IoT applications with the ESP32 microcontroller (Imran and Rasul, 2020).

F. Arduino ide

The Arduino IDE (Integrated Development Environment) is an application that includes both an editor and a compiler, used for various Arduino models. Arduino itself is an electronics platform with different models such as Arduino Duemilanove, Uno, Bluetooth, and Mega. However, some types of Arduino boards use microcontrollers outside the AVR series, such as ARM microprocessors. For these types of boards, the Arduino IDE functions as a compiler that translates C language into machine language that can be understood by the microcontroller. Thus, the Arduino IDE provides a complete development environment for programming various Arduino models with different types of microcontrollers. The Arduino IDE is equipped with a code editor, a message area, and a read console. As a tool useful for writing and compiling programs, the Arduino IDE also allows users to upload those programs to the Arduino board (Awwal, 2023).

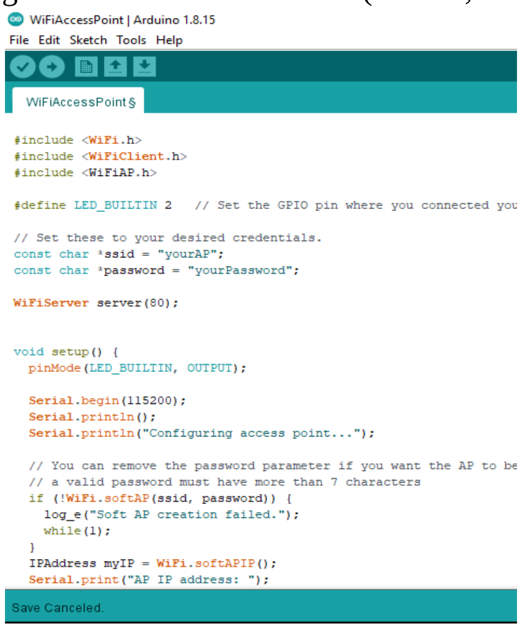

Figure 3. Arduino IDE

G. Telegram

Telegram Bot is a computer program designed to interact with users through the Telegram messaging application. This bot can perform various tasks, such as responding to messages, providing information, sending notifications, and more. Users can access the bot by adding it as a contact on Telegram or via available links and QR codes. To create a Telegram Bot, users can use the Telegram Bot API, which provides a programming interface (API) for development. Telegram Bots can be developed using various programming languages such as Python, Java, PHP, and others. With a Telegram Bot, users can easily access information or complete specific tasks without needing to leave the application. Additionally, the bot can enhance efficiency and productivity by providing quick and effective services and can be integrated with other applications and third-party platforms like Google Assistant, Twitter, and so on.

H. Flowchart System

Flowchart system serves as a tool to provide visualization of the steps involved in the development of a system (**Figure 4**). This flowchart displays the processes of data collection, processing, and output within the system, as shown in the accompanying diagram.

I. Rule-Based

The water level monitoring system is designed to monitor the conditions of the Bengawan Solo River in real-time via an internet connection. Users can remotely monitor the river's condition through a dedicated website. The working mechanism of the sensor is illustrated in Figure 5.

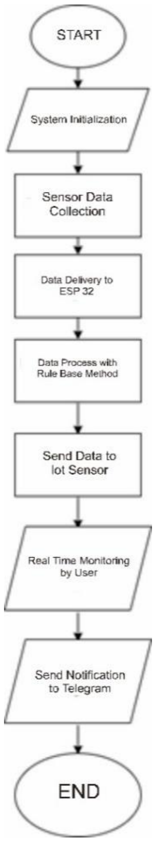

Figure 4. Flowchart System

The process depicted in Figure 3 shows how the sensor operates. First, the system is initiated, and then the ultrasonic sensor detects the water level. If the water level is below 85 cm, the status displayed on the website will be "Danger" with the suggestion "avoid high water levels." If the water level is within the range of 85-121 cm, the status changes to "Caution" with the suggestion "be cautious of the water level." If the water level exceeds 121 cm, the status changes to "Safe" with the suggestion "Safe for swimming." This data is then uploaded by the ESP32 microcontroller to the website as the final stage of the Rule-Based system, completing the implementation process.

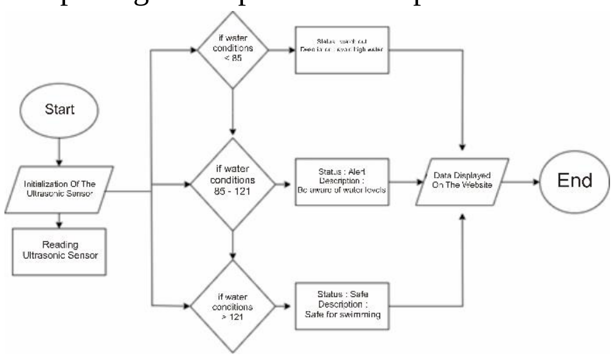

Figure 5. Rule-Based Water Level System

1. Desain System

The design of this sensor includes an overview of the current system's procedures for designing a new system, as well as information regarding the placement location of the device by the author. The schematic of the ultrasonic sensor is placed in the central area of the Bengawan Solo River, on the bridge piers, and connected to an ESP32. This sensor is connected via Wi-Fi, and the collected data is processed and displayed on a website. In case of danger, the system will send a notification to Telegram. This can be seen in Figure 6.

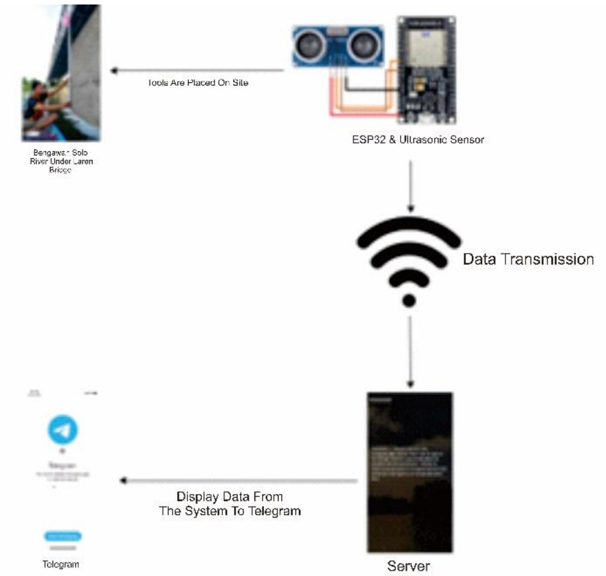

Figure 6. System Design Tool

J. Entity Relationship Diagram (ERD)

The initial step is to create an Entity Relationship Diagram (ERD), which is a graphical representation of the interactions between entities (such as users) and the system. The ERD displays the system's functionality from the user's perspective, making it easier to understand and analyze software requirements. This diagram ensures that the tables within the designed database have relationships with one another. This functionality is implemented in the Bengawan Solo water level monitoring system, which uses IoT-based water level sensors, as illustrated in the diagram.

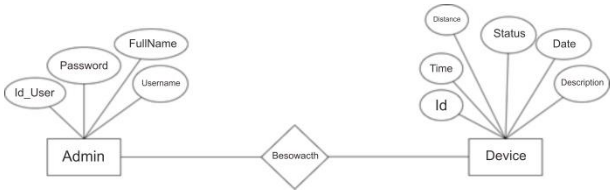

Figure 7. Entity Relationship Diagram

Based on the diagram of the designed database, there are two tables that have relationships with each other: the admin table and the device table. Below is a description of the relationships between these tables as shown in Figure 7:

Admin Table: This table has four attributes: Username, Password, Id_User, and Fullname. The Username attribute stores the username for each admin, serving as the primary key and distinguishing the admin from other users in the system. The Password attribute stores the password used by the admin to access the system, ensuring secure authentication. The Fullname attribute stores the full name of the administrator, which can be used for documentation or interface display.

Device Table: This table contains six attributes: Id_data, Status, Jarak (Distance), Jam masuk (Entry Time), Tanggal (Date), and Keterangan (Description). Id_data is the primary key in this table, serving as a unique identifier for each piece of data generated by the device. The Status attribute describes the current water condition, such as normal, caution, or danger, providing a qualitative attribute to help understand the water condition status. The Jarak (Distance) attribute indicates the distance between the water surface and a certain reference point (e.g., sensor or safe limit). The Jam masuk (Entry Time) and Tanggal (Date) attributes store the time and date when the water level data was recorded. The Keterangan (Description) attribute provides additional notes or descriptions regarding the water condition or any relevant situation at the time of data recording.

K. Data Flow Diagram (DFD)

Data Flow Diagram (DFD) is a graphical representation that illustrates the interaction between actors (users) and the system. The DFD shows how data flows through the system and where it is processed. It reflects the system's functionality from the user's perspective, which is highly useful for understanding and analyzing software requirements. There are two types of DFDs designed: Level DFD or Context Diagram and Level 1 DFD. Below is an example of a Level 0 DFD for the Bengawan Solo river water level system using an ultrasonic sensor, as shown in the following diagram. The Level 0 DFD shown on Figure 8.

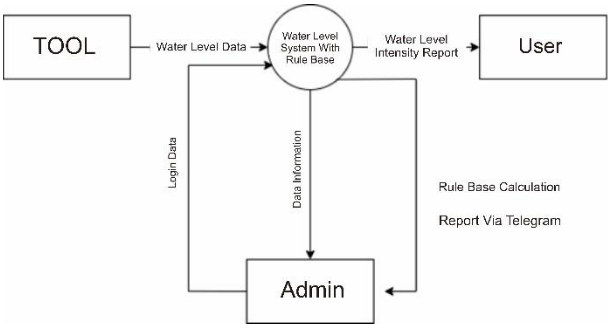

Figure 8. DFD Level 0 Water Level System

The water level measurement tool collects data related to the tides of the Bengawan Solo River and sends this information into the system.

The system then processes this data to calculate the water level and sends a report to the user.

Additionally, the system sends the calculated Rule-Based data and reports via Telegram to the admin for further monitoring and management.

The admin can log in to the system to access and manage the data, as well as take actions based on the received reports. The system also provides login information for the admin to ensure they can access and manage the system effectively.

After the Level 0 DFD design is completed, the next step is to create a Level 1 DFD design, which is used to explain in detail the flow of data within the system. This design provides a more detailed explanation of how data flows from external entities to processes within the system. The Level 1 DFD for the water level monitoring system using the Rule-Based Algorithm is shown in Figure 9.

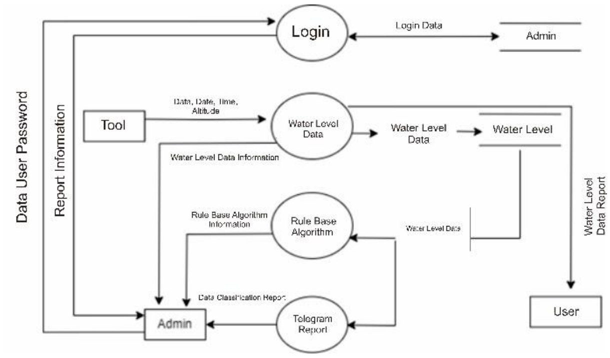

Figure 9. DFD Level 1 Water Level System

In the Level 1 Data Flow Diagram (DFD) for the Bengawan Solo water level monitoring system, there are four main processes performed by the admin and visible to the user. The explanations for each process are as follows:

Admin Login Process: The admin sends login data (username and password) to the system. The system verifies the data and provides feedback to the admin regarding the success or failure of the login. If the login is successful, the admin can access the system's features.

Water Level Data Processing: The measurement tool sends water level data (including date, time, and level) to the system. This data is then processed and stored by the system. The system then sends the water level data information to the admin for monitoring and also generates a water level report that is sent to the user.

Rule-Based Algorithm Calculation Process: The water level data from process 2 is used for calculations with the Rule-Based method. The calculation results are sent to the admin for evaluation and are also forwarded to the report generation process (process 4).

Telegram Report Process: The data from the Rule-Based algorithm calculation is used to generate a report that is sent via Telegram. This report also includes the classification of the data sent to the admin and the water level report sent to the user.

III. RESULT AND DISCUSSION

A. Interface Implementation

It is crucial to realize the planned design into a tangible and functional form. In this phase, interface design elements such as layout, icons, buttons, and other interactive components are integrated into the system or platform being used. This integration ensures that users can interact with the website or application intuitively and efficiently. Figure 10 shown the image of the Index Page.

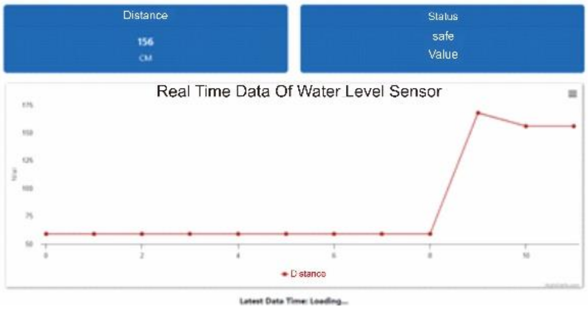

Figure 10. Index Page

B. Dashboard Login

The admin login page shown in the Figure 11 is the interface used in the Bengawan Solo tidal monitoring system. This interface provides text boxes for entering a username and password, which must be filled in by the admin. Additionally, there is a "login" button used to access the system and proceed to the admin dashboard. With this interface, users can easily input their login information and access the services provided by the tidal monitoring system more efficiently. Below is the view of the login page for the Bengawan Solo water level monitoring system.

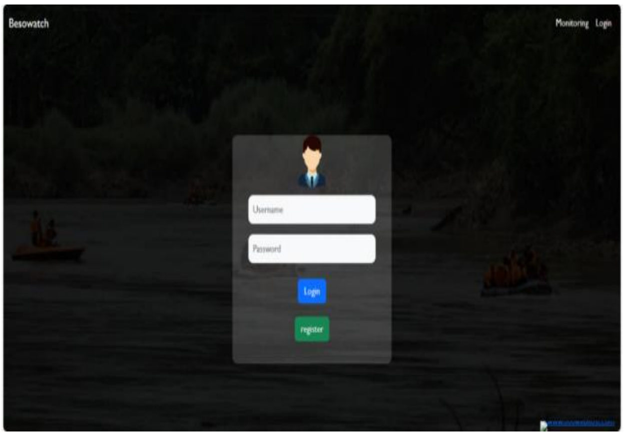

Figure 11. Login Page

C. System Testing Results

The placement of water level system equipment in Bengawan Solo requires careful planning and consideration of various factors such as strategic location, accessibility, safety, and environmental conditions. The use of ultrasonic and pressure sensor technology that enables real-time monitoring of water levels, which is essential for flood disaster mitigation and effective management of water resources. As seen in figure 12.

Figure 12. Deployment of water level system in Bengawan Solo

In this research, data from the system testing of the Internet of Things (IoT) based tidal monitoring system for the Bengawan Solo River, utilizing a rule-based algorithm and a water level sensor, was obtained. This data can be seen in Table 2.

Table 2. IoT data based on tidal monitoring system for Bengawan Solo River

No	Date	Time	distance	Status	Description
1	8/6/2024	08.08.03	170	state	Safe for swimming
2	8/6/2024	08.08.06	170	state	Safe for swimming
3	8/6/2024	08.08.09	165	state	Safe for swimming
4	8/6/2024	08.08.12	119	state	Safe for swimming
5	8/6/2024	08.08.24	121	state	Safe for swimming
6	8/6/2024	08.08.30	165	state	Safe for swimming
7	8/6/2024	08.08.39	167	state	Safe for swimming
8	8/6/2024	08.08.48	167	state	Safe for swimming berenang
9	8/6/2024	08.08.55	117	alert	Be aware of water levels
10	8/6/2024	08.08.58	119	alert	Be aware of water levels

Based on data from August 6, 2024, the water level mostly ranged between 119 cm and 170 cm, with a "Safe" status for swimming during most of the time. However, the last two measurements showed a drop in water level to 117 cm and 119 cm, which changed the status to "Caution," indicating potential danger and requiring increased vigilance. Overall, the water level conditions were stable and safe for swimming. However, the sudden drop at the end of the observation period underscores the importance of continuous monitoring. When the status changes to "Caution," vigilance must be heightened to prevent potential risks. From these calculations, it can be concluded that the average value of the Bengawan Solo River water level monitoring system is 151.7, leading to the conclusion that the water conditions in Bengawan Solo are "SAFE" with a status of "Safe for Swimming."

IV. CONCLUSION

Research on the development of an IoT-based tidal monitoring system for Bengawan Solo River using rule-based algorithms and water level sensors concluded that the monitoring system has been successfully developed and implemented in real-time. These tools and systems effectively process data in real-time and display the results on a user-friendly website, presenting values, status, recommendations and graphs.

Data processing for the Bengawan Solo River tidal system was successfully carried out using ultrasonic sensors and an ESP32 microcontroller, programmed with Arduino IDE software and using a rule-based approach to assess predefined limits. The results validate the accuracy and effectiveness of the system in monitoring water levels.

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