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Design and Development of a Flood Detection Device for Drainage Systems Utilizing Float Switch Water Level Sensors

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Abstract

Indonesia ranks second in Asia Pacific in the list of the highest number of deaths due to natural disasters. In a year, more than 300 flood events occur, resulting in large losses, environmental damage and even loss of life. To overcome this problem, it is necessary to design a tool for monitoring water levels and rainfall. This research aims to design a flood detection system using the fuzzy method and using a float switch water level sensor. The results of the research show that this system can monitor water levels and rainfall using a web server. In the first test, it produces a fuzzy warning level in a safe condition. In the second test, the water level reached 51 cm with rainfall of 0.47 mm, and the fuzzy warning level was in a safe condition. Finally, in the third test, the average water level reached 99 cm with rainfall of 0.69 mm, resulting in a fuzzy warning level in an alert state. It can be concluded that this system needs to be improved in quality by adding items to the system.

Keywords: *Flood, Mamdani, Sensors float switch water level.*

Abstrak

Indonesia menempati urutan kedua di Asia Pasifik dalam daftar jumlah kematian terbanyak tertinggi akibat bencana alam. Dalam setahun, lebih dari 300 peristiwa banjir terjadi, dan mengakibatkan timbulnya kerugian besar, kerusakan lingkungan hingga korban jiwa. Untuk mengatasi masalah ini, maka perlu dirancang alat monitoring ketinggian air dan curah hujan. Penelitian ini bertujuan untuk merancang sistem pendeteksi banjir dengan metode fuzzy dan menggunakan *sensor float switch water level*. Hasil dari penelitian menunjukkan sistem ini dapat memantau ketinggian air dan curah hujan menggunakan webserver. Pada pengujian pertama, menghasilkan tingkat *warning level fuzzy* dalam keadaan aman. Pada pengujian kedua, ketinggian air mencapai 51 cm dengan curah hujan 0,47 mm, serta tingkat peringatan *warning level fuzzy* dalam keadaan aman. Terakhir, pada pengujian ketiga, rata-rata ketinggian air mencapai 99 cm dengan curah hujan sebesar 0,69 mm, menghasilkan tingkat *warning level fuzzy* dalam keadaan waspada. Dapat disimpulkan bahwa sistem ini perlu ditingkatkan kualitas dengan penambahan item pada sistem.

Kata kunci: *Banjir, Fuzzy mamdani, Sensor Float Switch Water level.*

Introduction

Indonesia, geographically spanning from 6˚ S to 11˚ N and 92˚ E to 142˚ E, is an archipelagic nation comprising 17,504 islands, making it one of the countries with the highest number of islands globally. Recognized internationally through the United Nations Convention on the Law of the Sea 1982 [1], Indonesia is vulnerable to various disasters, ranking second in the Asia-Pacific region for the highest number of deaths due to natural disasters [2]. Over the past 20 years, natural disasters in Indonesia have resulted in significant economic losses, amounting to at least US $22.5 billion. This data is derived from The Asia Pacific Disaster Report 2010, compiled by The Economic and Social Commission for Asia and the Pacific (ESCAP) and The UN International Strategy for Disaster Reduction (UNISDR). The United Nations (UN) first prepared a report on natural disasters in the Asia-Pacific region, published on October 26, 2010 [2].

Indonesia, with its tropical climate and high rainfall, is prone to flooding [3]. Prolonged rainfall can lead to floods causing both human and material losses [4]. During the rainy season, several areas in Indonesia experience annual floods, affecting more than 300 flood events covering 150,000 hectares and resulting in significant damage to the environment and loss of lives [5]. Floods are a natural disaster that can cause extensive damage and casualties. They result from two main factors: natural and human-induced. Natural factors include rainfall intensity, erosion, sedimentation, physiography, river capacity, and tidal influence. Meanwhile, human-induced floods are caused by human activities altering the environment, such as settlements near riverbanks, damaged land drainage, changes in Watershed Conditions (DAS), damage to flood management buildings, and deforestation [2]. Floods occur suddenly and unpredictably, making it challenging to prevent them. Building a resilient environment can help mitigate the impact of floods [6].

Jambi City, traversed by the major Batanghari River, is one of the areas frequently affected by floods. Despite its smaller size compared to the Batanghari River basin, flood conditions in Jambi City result from changes and growth within the city. In 2019, floods impacted 1,283 houses and 11,669 people in 19 locations in Jambi City [7]. Therefore, there is a need for flood disaster management efforts in the Jambi City region. With the rapid development of technology, systems have emerged to assist governments and communities in developing security technologies that provide warning systems for detecting suspicious water levels in drainage. A study by [8] on flood detection in drainage systems using ultrasonic sensors was less effective due to the limitations of ultrasonic sensors in detecting liquids. Ultrasonic sensors can detect the water bottom when it is too clear, detect other objects around the target, and require a wide field with no surrounding objects to detect a single object [9].

Addressing these issues, this study employs a float switch water level sensor. This sensor has a magnetic float that can rise and fall with changing water levels. The magnetic float moves with the gravitational force of water, activating the switch when the liquid level reaches a predetermined level. This action closes the electrical circuit, sending a signal and activating an alarm to indicate rising water levels in the drainage [10]. One method to predict flood levels in Jambi City is the fuzzy logic method. Fuzzy logic is defined as something vague, utilizing clear definitions, operations, and descriptions based on fuzzy logic theory. The fuzzy Mamdani method is applied in designing the flood prediction system in Jambi City, chosen for its detailed system control and higher accuracy in detecting floods, with a 70% accuracy compared to the Sugeno fuzzy method, which has a 48.33% accuracy [12].

This study incorporates a flood and rainfall monitoring system with a website developed under the name sibanjirjambi.xyz. Two input variables, water level height (H) and rate of change in water level (ΔH/ΔT), are utilized in this research. H represents the current water conditions in the drainage, while ΔH/ΔT indicates an increase in water level in the drainage. These input variables are chosen based on a study by [13], which reported a 90% accuracy in predicting low-level floods, 85% for moderate-level floods, and 80% for high-level floods.

Method

This study is designed with an empirical approach through the construction of a flood detection tool. The research employs an open-loop control system comprising input, process, and output. In this study, an open-loop control system is utilized, consisting of input, process, and output components. The input of the system consists of water level and rainfall. In the process, these variables are read by the Float Switch Water Level sensor and the rainfall sensor. The obtained data is then processed by the Arduino Uno, which subsequently sends it to the Esp-8266 through serial communication. If the sensor detects a high-water level, the indicator lights and buzzer will activate, and vice versa. This information is received by the Esp-8266, which sends the data to the website. The system's output is displayed on the sibanjirjambi.xyz website, accessible on smartphones or laptops connected through the IoT platform.

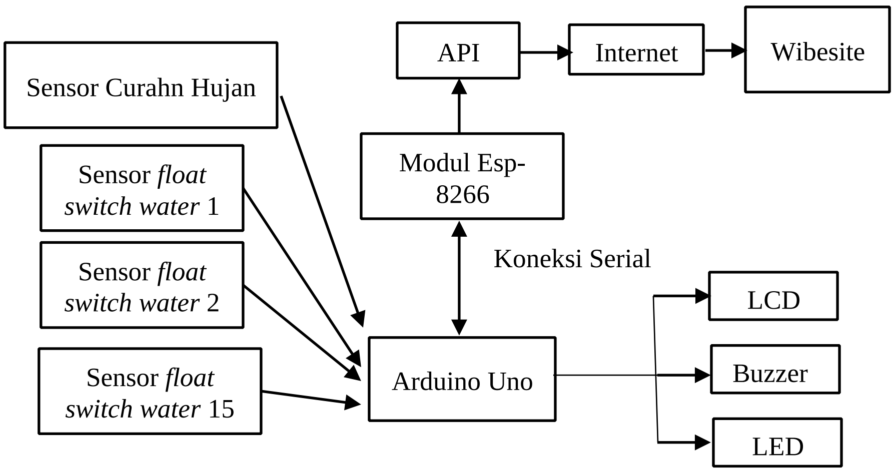

Figure 1. System Block Diagram

a. Hardware Design

The hardware design in this research is carried out once all the necessary information for the flood detection tool has been gathered. The device design is created using SketchUp 2017 software and then proceeds with the physical construction of the device as a unified whole. One crucial component of this device is the Float Switch Water Level sensor and the rainfall sensor.

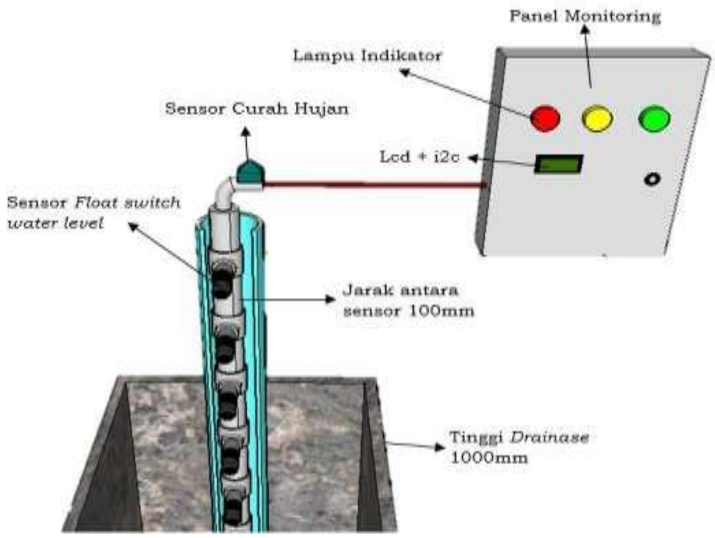

Figure 2. Hardware Design

The Float Switch Water Level sensor functions to read the water level in the drainage simulator with a height of 1000 mm. Fifteen sensors are installed vertically at intervals of 100 mm from the base of the drainage simulator. The rainfall sensor is designed to measure the precipitation in the area. The higher the rainfall in a particular region, the higher the water level becomes.

b. Software Design

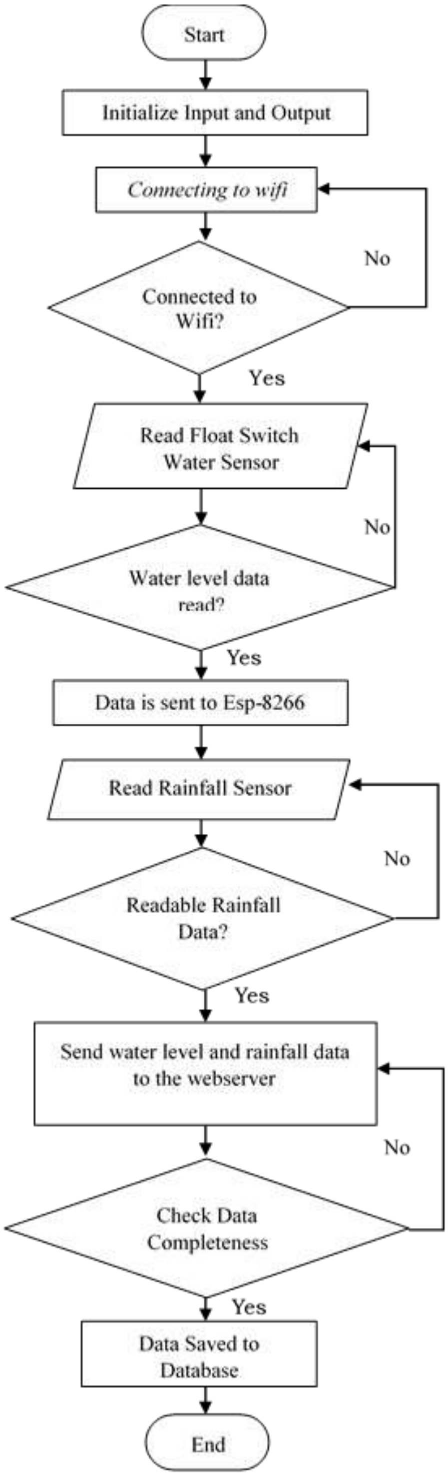

Figure 3. Software Flow Diagram

Figure 3 represents the flowchart for the software of a system designed to detect floods and rainfall. The process begins with initialization, where input/output pins are set. Next, Arduino reads the values from the float switch water level sensor. Once the water level data is obtained, the next step is to perform a decision control to check whether the float switch water level sensor reading is successful or not. If yes, the data is sent to Esp-8266 via serial connection.

In the subsequent stage, Esp-8266 reads the values from the rainfall sensor. Afterward, there is an additional decision control that checks whether the rainfall sensor reading is successful or not. If both conditions are met, the device proceeds to the next step, which is sending the water level and rainfall data to a website. Subsequently, a data check is performed on the sent data. If the data sent by Esp-8266 is complete, the data will be stored in the webserver database. In the software design, the fuzzy Mamdani method will be implemented on the Arduino Uno microcontroller. The various stages in the fuzzy method design include:

1. Formation of Mamdani Fuzzy Sets

There are two input variables to be utilized, a. Water level (H) with three fuzzy sets: low, medium, high; b. Rate of water level change per 1 minute (ΔH/ΔT) consisting of three fuzzy sets: small, medium, and fast. Meanwhile, there is only one output variable, which is the flood potential, comprising three fuzzy sets: safe, alert, and danger.

2. Membership Degree Function

Based on the data from the fuzzy set that has been determined, it is then operated on the membership degree function, a. Variable Input H. The H input uses the range [0 – 150] in units of centimeters cm.

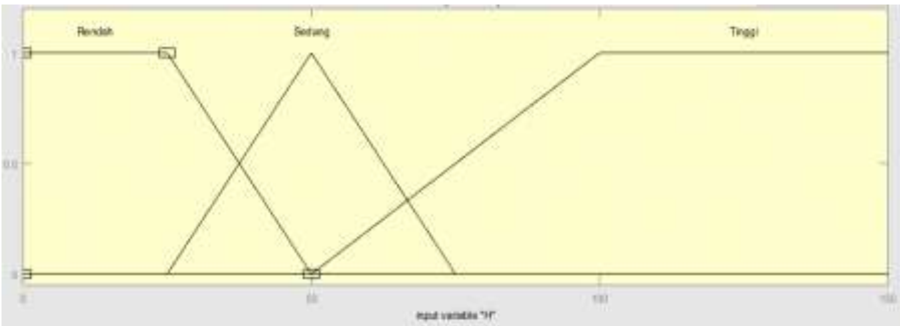

Figure 4. Degree of Membership H

Curve membership function on the input variable H:

a. On μ_{Low} Using equations (2)

$$\mu_{Low}\,[x] : \begin{cases} 0, & x \geq 50 \\ \frac{50-x}{50-25} & 25 \leq x \leq 50 \\ 1, & x \leq 25 \end{cases}$$

b. On $\mu_{Intermediate}$ Using equations (3)

$$\mu_{Intermediate}\,[x] : \begin{cases} 0, & x \leq 25 \text{ or } x \geq 75 \\ \frac{x-25}{50-25} & 25 \leq x \leq 50 \\ 1, & x = 50 \\ \frac{50-x}{75-50} & 50 \leq x \leq 75 \end{cases}$$

c. On μ_{Tall} Using equations (1)

$$\mu_{Tall}\,[x] : \begin{cases} 0, & x \leq 50 \\ \frac{x-50}{150-50} & 50 \leq x \leq 150 \\ 1, & x \geq 150 \end{cases}$$

Variable input ΔH/ΔT. The ΔH/ΔT input uses the range [0 - 150] in centimeters (cm).

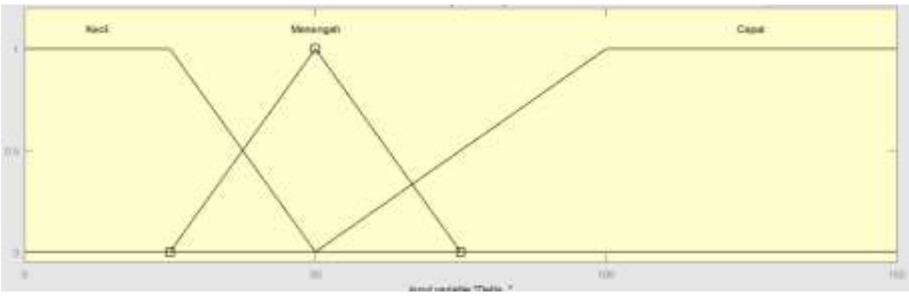

Figure 5. Degree of Membership ΔH/ΔT.

Curve membership function on the input variable ΔH/ΔT:

a. On μ_{Small} Using equations (2)

$$\mu_{Small}\,[x] : \begin{cases} 0, & x \geq 50 \\ \frac{50-x}{50-25} & 25 \leq x \leq 50 \\ 1, & x \leq 25 \end{cases}$$

b. On $\mu_{intermediate}$ Using equations (3)

$$\mu_{intermediate}\,[x] : \begin{cases} 0, & x \leq 25 \text{ or } x \geq 75 \\ \frac{x-25}{50-25} & 25 \leq x \leq 50 \\ 1, & x = 50 \\ \frac{50-x}{75-50} & 50 \leq x \leq 75 \end{cases}$$

c. On μ_{Fast} Using equations (1)

$$\mu_{Fast}\,[x] : \begin{cases} 0, & x \leq 50 \\ \frac{x-50}{150-50} & 50 \leq x \leq 150 \\ 1, & x \geq 150 \end{cases}$$

Flood Potential Output Variable, the flood potential input uses the range [0 – 100] in percent units (%).

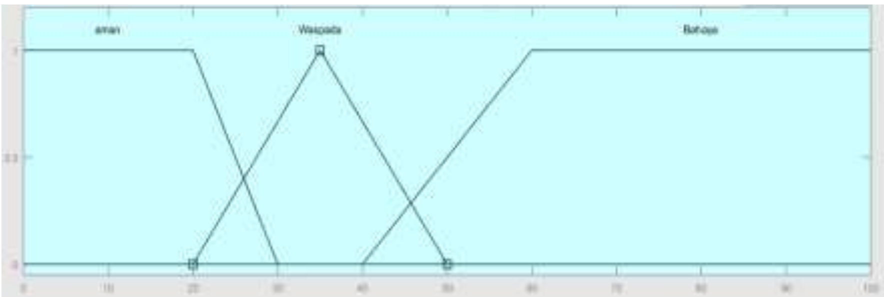

Figure 6. Flood Potential Membership Degree

Curve membership function on the output variable:

a. On μ_{Safe} Using equations (2)

$$\mu_{Safe}\,[x] : \begin{cases} 0, & x \geq 30 \\ \frac{30-x}{30-20} & 20 \leq x \leq 30 \\ 1, & x \leq 20 \end{cases}$$

b. On μ_{Alert} Using equations (3)

$$\mu_{Alert}\,[x] : \begin{cases} 0, & x \leq 20 \text{ or } x \geq 50 \\ \frac{x-20}{35-20} & 20 \leq x \leq 35 \\ 1, & x = 35 \\ \frac{35-x}{100-35} & 35 \leq x \leq 100 \end{cases}$$

c. On μ_{Danger} Using equations (1)

$$\mu_{Danger}\,[x] : \begin{cases} 0, & x \leq 40 \\ \frac{x-40}{100-40} & 40 \leq x \leq 100 \\ 1, & x \geq 100 \end{cases}$$

c. Implication Function

After the process of forming fuzzy sets, fuzzy rules are then formed using a matrix. There are 9 rules, namely:

Table 1. Matrix Rules Fuzzy

H / ΔH/ΔT	Low	Currently	Tall
Small	Safe	Safe	alert
Intermediate	Safe	Alert	alert
torrential	alert	Danger	danger

a. If (H is Low) and (ΔH/ΔT is Small), then (Flood Potential is Safe).
b. If (H is Medium) and (ΔH/ΔT is Small), then (Flood Potential is Safe).
c. If (H is High) and (ΔH/ΔT is Small), then (Flood Potential is Alert).
d. If (H is Low) and (ΔH/ΔT is Medium), then (Flood Potential is Safe).
e. If (H is Medium) and (ΔH/ΔT is Medium), then (Flood Potential is Alert).
f. If (H is High) and (ΔH/ΔT is Medium), then (Flood Potential is Danger).
g. If (H is Low) and (ΔH/ΔT is Fast), then (Flood Potential is Alert).
h. If (H is Medium) and (ΔH/ΔT is Fast), then (Flood Potential is Danger).
i. If (H is High) and (ΔH/ΔT is Fast), then (Flood Potential is Danger).

d. Defuzzification

Defuzzification in the Mamdani rule composition is performed using the centroid method. The application of Fuzzy Mamdani logic analysis which can be used for parameters such as turbidity, color, solids, temperature and pH has proven to be effective in determining water safety status [14]. In this method, a crisp solution is obtained by taking the center point of the fuzzy region. The fuzzy affirmation process will be implemented on the Arduino Uno microcontroller using the fuzzy.h library. After the system performs the defuzzification process to obtain the fuzzy output, the next step involves transmitting the data managed by the Arduino to the NodeMCU. Subsequently, this data will be displayed on the 16 x 2 LCD and the sibanjirjambi.xyz website, accessible on user devices connected to the NodeMCU through a network.

e. Testing And Evaluation

After the system design in the research, the next stage involves testing to determine the error tolerance level of each sensor used. Therefore, it is necessary to compare with conventional measurements using equation (4).

$$\text{Error} = \frac{\text{Sensor values} - \text{Values of conventional toolsl}}{sensor\ value}\, x100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Result

a. Float Switch Water Level Sensor Test Results

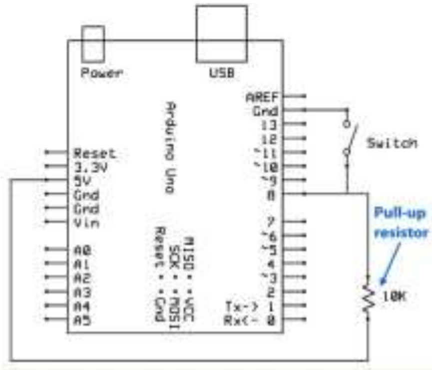

Figure 7. Float Switch Sensor Circuit

In Figure 7. the resistor will limit the current entering the Float switch sensor switch, so that if the switch is open, it will have a voltage of 5 V and if it is not open it will record a logic high, and record a logic low if it is closed.

Table 2. Float Switch Water Level Sensor Test Results

Sensor	Logic	Active
1	High	Yes
	Low	Yes
2	High	Yes
	Low	Yes
3	High	Yes
	Low	Yes
4	High	Yes
	Low	Yes
5	High	Yes
	Low	Yes
6	High	Yes
	Low	Yes
7	High	Yes
	Low	Yes
8	High	Yes
	Low	Yes
9	High	Yes
	Low	Yes
10	High	Yes
	Low	Yes
11	High	Yes
	Low	Yes
12	High	Yes
	Low	Yes
13	High	Yes
	Low	Yes
14	High	Yes
	Low	Yes
15	High	Yes
	Low	Yes

In Table 2, the test results for each Float Switch Water Level sensor can only produce high and low voltage output because this type of sensor is a digital sensor. The test results show that each sensor is active and there are no errors.

Table 3. Initialize sensor readings in cm units

Sensor \ Height	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
1	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
2	L	H	H	H	H	H	H	H	H	H	H	H	H	H	H
3	L	L	H	H	H	H	H	H	H	H	H	H	H	H	H
4	L	L	L	H	H	H	H	H	H	H	H	H	H	H	H
5	L	L	L	L	H	H	H	H	H	H	H	H	H	H	H
6	L	L	L	L	L	H	H	H	H	H	H	H	H	H	H
7	L	L	L	L	L	L	H	H	H	H	H	H	H	H	H
8	L	L	L	L	L	L	L	H	H	H	H	H	H	H	H
9	L	L	L	L	L	L	L	L	H	H	H	H	H	H	H
10	L	L	L	L	L	L	L	L	L	H	H	H	H	H	H
11	L	L	L	L	L	L	L	L	L	L	H	H	H	H	H
12	L	L	L	L	L	L	L	L	L	L	L	H	H	H	H
13	L	L	L	L	L	L	L	L	L	L	L	L	H	H	H
14	L	L	L	L	L	L	L	L	L	L	L	L	L	H	H
15	L	L	L	L	L	L	L	L	L	L	L	L	L	L	H

In Table 3, there is data on the initialization of the altitude from each sensor. When the sensor is active, it will have a "H" (high) status, while if the sensor is inactive, it will have an "L" (low) status. To enable the sensor to read the altitude per 10 cm, the above program snippet is used to initialize the Float Switch Water Level sensor with an integer data type using an array. This array has a length of 15 elements, adjusted to the number of sensors present. The `updateSensorStatus` function is designed to update the sensor status at a specific position in the array, ensuring that the output will display only the status of the last activated sensor.

b. Rainfall Sensor Test Results

When testing the rain sensor, the first thing to do is connect each cable from the sensor to the Esp8266. The VCC cable or the red cable on the sensor is connected to the Vin pin of the Esp8266, the GND cable or the black cable is connected to the GND pin, and the I/O cable or the white cable is connected to the digital pin. In this case, the researcher is using the digital pin D5. The following is the rain sensor testing circuit, refer to Figure 8.

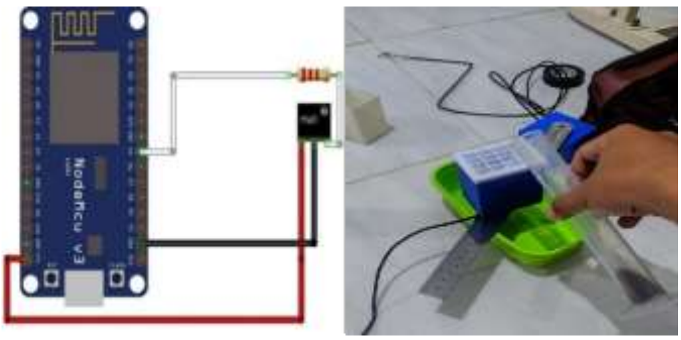

Figure 8. Rainfall Sensor Testing

Table 4. Rainfall Sensor Testing

No	The accumulated volume of water is poured out (mL)	Sensor Reading (mL)	Percentage Error (%)
1	5	5	0,0
2	10	10	0,0
3	15	15	0,0
4	20	20	0,0
5	25	25	0,0
6	30	30	0,0
7	35	35	0,0
8	40	40	0,0
9	45	45	0,0
10	50	50	0,0
	Average		0,0

After connecting the sensor to the Esp8266, the next step is to conduct testing to determine the percentage of error that occurs with the sensor. To assess the magnitude of the error, Equation (5) is employed. The rain sensor testing involves the use of a graduated cylinder to ensure precise and measured water quantities. The selected graduated cylinder has a maximum volume of 50 mL. The testing process involves pouring water from the graduated cylinder in increments from 5 mL to 50 mL. Subsequently, the data obtained from the sensor readings will be displayed on the serial monitor.

As evident from the test result table, there is no discrepancy between the poured amount of water and the amount detected by the sensor. This indicates that there is no error in the readings, resulting in a 0.0% error percentage. This lack of error is attributed to the rain sensor testing being conducted with the use of a measuring glass, which provides a more accurate measurement of water volume.

c. Test Results for Sending Data to the Website

Testing of sending data to the website was carried out to see the performance of the website and the Esp8266 in sending data via a Wifi connection. Testing sending data to the website to observe the input and output that will be sent via Esp8266. The following is the program for sending data to the sibanjirjambi.xyz website:

Table 5. Test Results for Sending Data to the Website

No	Time	water height (cm)	Rainfall (mm)
1	04-08-2023 02:43:10	30	1,346
2	04-08-2023 02:43:08	30	0
3	04-08-2023 02:43:06	30	0
4	04-08-2023 02:43:04	30	1,346
5	04-08-2023 02:43:02	30	0
6	04-08-2023	0	0

	00:49:58		
7	04-08-2023 00:49:58	7	0
8	04-08-2023 00:49:49	50	0
9	04-08-2023 00:49:47	50	0
10	04-08-2023 00:49:46	50	0

As seen in Table 5, testing the data transmission to the website sibanjirjambi.xyz has been successfully conducted. There were several challenges encountered during the data transmission to the website, such as frequent disconnection of the WiFi connection to the Esp-8266 due to an unstable network. The second challenge involved parsing data sent from Arduino Uno to Esp-8266 using serial communication.

d. Mamdani fuzzy testing

Mamdani fuzzy testing was carried out to prove the correctness of the fuzzy association matrix applied to the system and to look for fuzzy output with safe, alert and dangerous flood level conditions, the following test result data:

Table 6. Fuzzy Test Results

No	Current H	Previous H	ΔH/ΔT	Output *Fuzzy*
1	30cm	10cm	20cm	Safe
2	60cm	30cm	30cm	Alert
3	60cm	10cm	50cm	Danger

Table 6 presents the test output data to validate the correctness of the fuzzy association matrix. Three flood categories were identified using Equation (2):

1. Safe Category

   ΔH/ΔT = Current H – Previous H

   ΔH/ΔT = 30 – 10

   ΔH/ΔT = 20

Table 7. Fuzzy Association Matrix

H / ΔH/ΔT	Low	Currently	Tall
Small	Safe	Safe	alert
Intermediate	Safe	alert	alert
torrential	alert	danger	danger

2. Alert Category

   ΔH/ΔT = Current H – Previous H

   ΔH/ΔT = 60 – 30

   ΔH/ΔT = 30

Table 8. Fuzzy Association Matrix

H / ΔH/ΔT	Low	Currently	Tall
Small	Safe	Safe	alert
Intermediate	Safe	alert	alert
torrential	alert	danger	danger

3. Danger Category

$\Delta H/\Delta T$ = Current H – Previous H

$\Delta H/\Delta T = 60 - 10$

$\Delta H/\Delta T = 50$

Table 9. Fuzzy Association Matrix

H / ΔH/ΔT	Low	Currently	Tall
Small	Safe	Safe	alert
Intermediate	Safe	alert	alert
torrential	alert	danger	danger

The researcher poured water into the water reservoir quickly and in large quantities so that the water filling the volume of the water reservoir had a speed that was not constant so that it got a fuzzy output in the alert and danger categories.

e. Overall System Testing

Figure 9. Hardware System

During the system testing, the apparatus will be tested using water in the water tank or a drainage simulator with a height of 90 cm. This system testing aims to determine whether the components in the system are functioning normally or not. In the system testing, the rate of water level change (ΔH) has a sampling period of 1 minute or ΔH/1 minute. Data transmission in the study is algorithmically divided into two conditions. This is done to avoid RTO (Recovery Time Objective) issues caused by sending excessive data, leading to data spam. Therefore, two conditions are established. In the first condition, if there is no rain, data is sent to the website every 10 minutes/data. In the second condition, if it is raining, data is sent to the website every 1 minute/data. The testing is conducted three times, each lasting for 2 hours per test. Below are the test results data for the entire system.

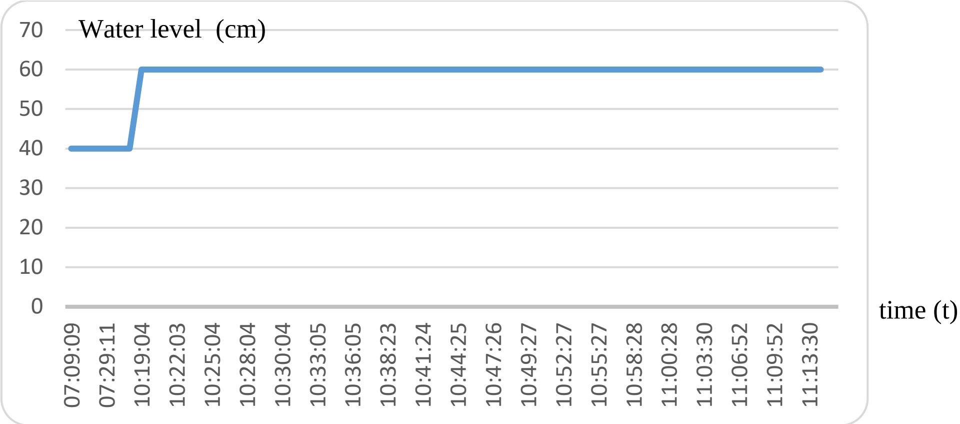

Figure 10. First System Test Results Data, Water Level

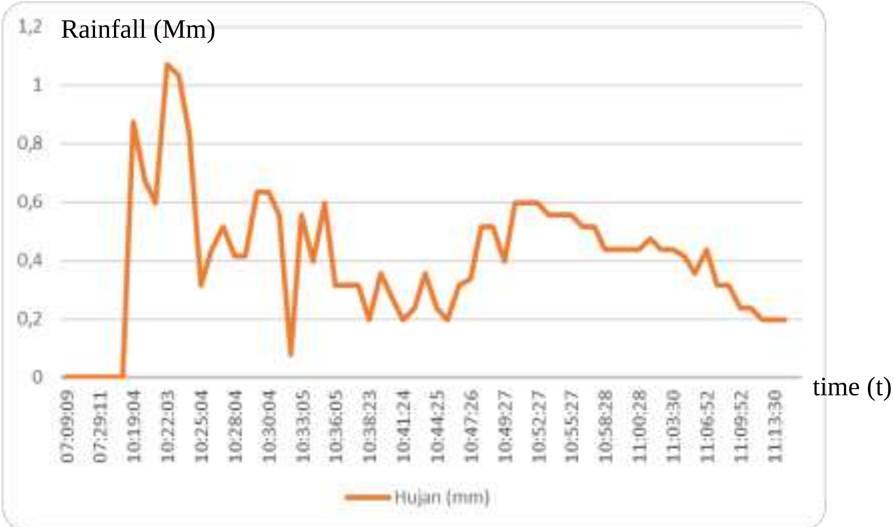

Figure 11. First System Test Results Data, Rainfall

In Figures 10 and 11, the graphs depict readings of water level and rainfall on September 24, 2023, from 07:09 AM to 11:18 AM WIB (Waktu Indonesia Barat). The graph has the x-axis representing time and the y-axis indicating water level and rainfall. It can be observed from the graph that the rainfall is quite high, reaching its peak value of 1.66 mm. The water level in the drainage simulator starts to rise from 30 cm at 07:59

Figure 12. Fuzzy Output Results

AM and reaches its peak at 60 cm at 11:18 AM. The fuzzy output generated by the system indicates a warning level, signaling a safe condition. In Figures 10 and 11, two different data transmission conditions can be observed. The first data transmission occurs every 10 minutes when the water level is at 30 cm, and there is no rainfall. Subsequently, the second data transmission occurs every 1 minute when the water level starts to rise to 60 cm, and there is a rainfall of 1 mm. In the initial testing, the average water level in the drainage simulator is 57 cm, with an average rainfall of 0.47 mm.

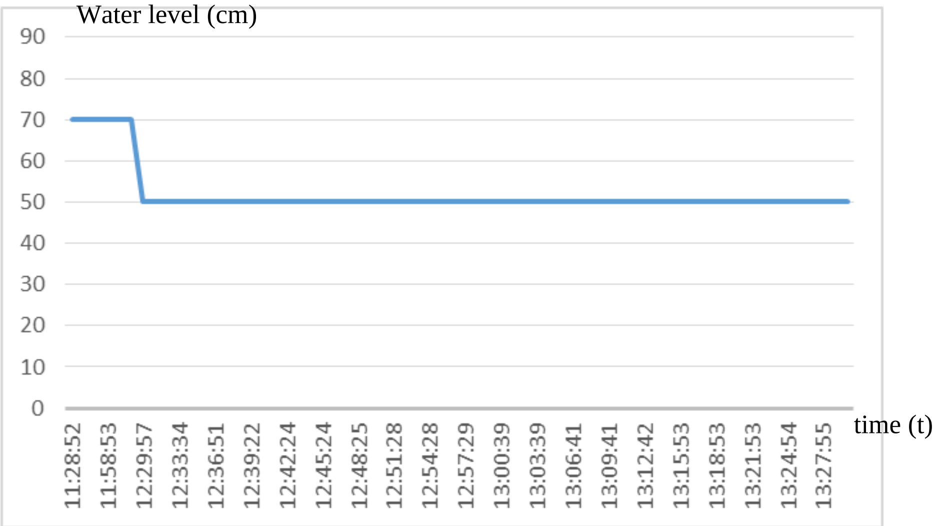

Figure 13. Second System Test Results Data, Water Level

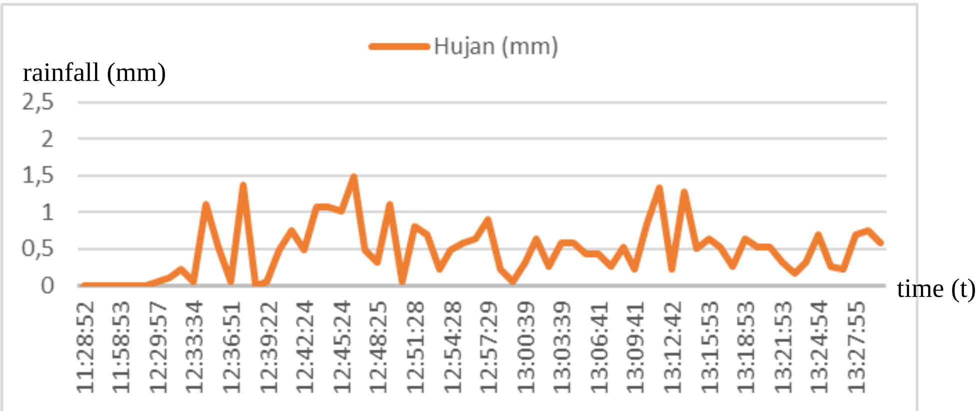

Figure 14. Second System Test Results Data, Rainfall

In Figures 13 and 14, the graphs depict readings of water level and rainfall on September 24, 2023, from 11:29 AM to 1:29 PM WIB. The graph has the x-axis representing time and the y-axis indicating water level and rainfall. It can be observed from the graph that the rainfall is quite high, reaching its peak value of 1.483 mm at 12:46 PM WIB. The water level in the drainage simulator starts to decrease from 70 cm at 11:28 AM and reaches 50 cm at 12:29 PM. The fuzzy output generated by the system indicates a warning level, signaling a safe condition.

Figure 15. Fuzzy Output Results

In Figures 13 and 14, two different data transmission conditions can be observed. The first data transmission occurs every 10 minutes when the water level is at 70 cm, and there is no rainfall. Subsequently, the second data transmission occurs every 1 minute when the water level starts to rise to 50 cm, and there is a rainfall of 0.053 mm. In the initial testing, the average water level in the drainage simulator is 51 cm, with an average rainfall of 0.47 mm.

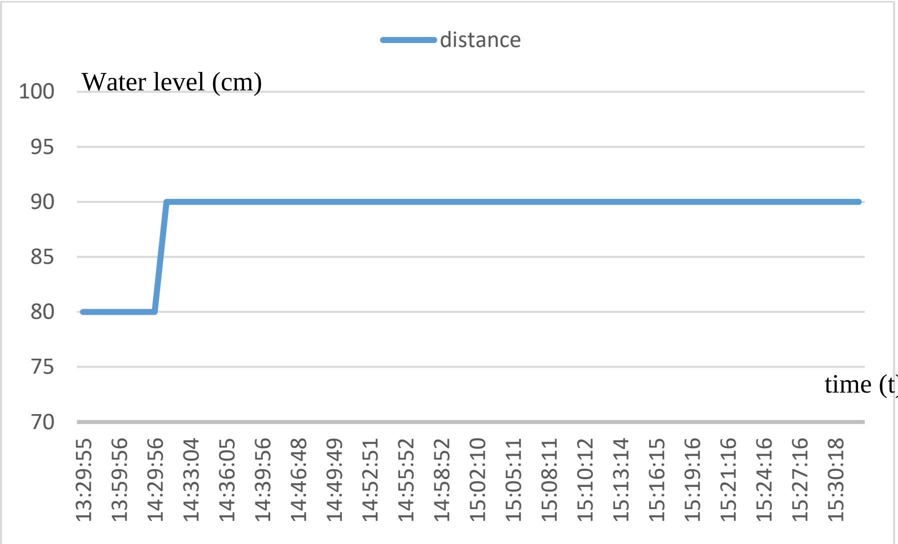

Figure 15. Third System Test Results Data, water level

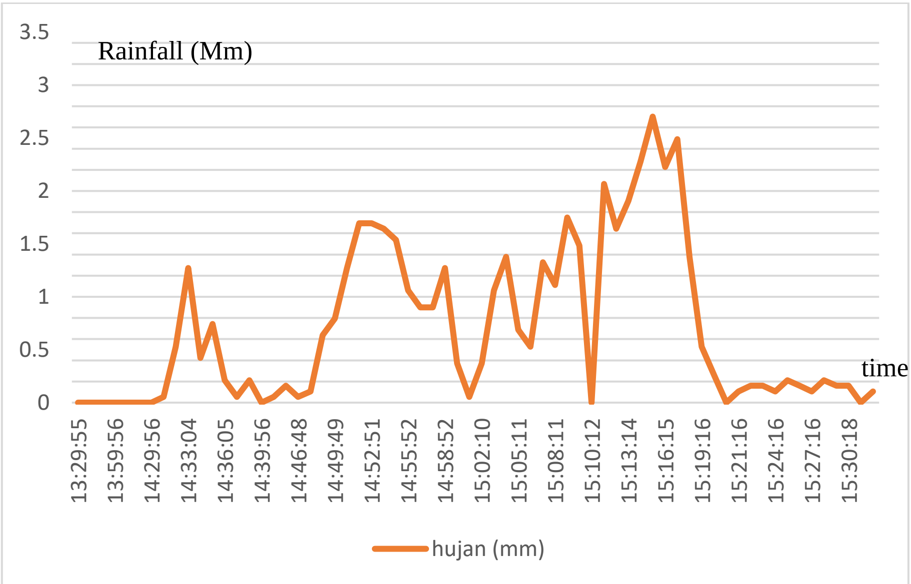

Figure 16. Third System Test Results Data, Rainfall

Figures 16 and 17 show graphs of water level readings and rainfall on 09-24-2023 at 13:29 – 15:31 WIB. The graph has an x-axis showing time and a y-axis showing water level and rainfall. It can be seen in the graph that the rainfall is quite high, with the highest

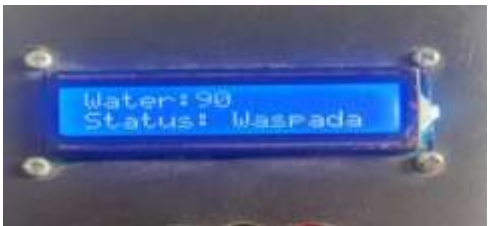

Figure 18. Fuzzy Output Results

value reaching 2,703 mm at 15:15 WIB, and the water in the drainage simulator began to rise from a height of 80 cm at 13:29 and reached its peak at a height of 90 cm at 13:29. 14:31, the resulting fuzzy output is a warning level in an alert state.in a vigilant state given the challenging conditions.

In Figures 16 and 17, two different data transmission conditions are observed. The first data transmission occurs every 10 minutes when the water level is at 80 cm and there is no rainfall. Subsequently, the second data transmission occurs every 1 minute when the water level begins to rise to 90 cm, and there is a rainfall of 0.053 mm. In the initial testing, the average water level in the drainage simulator is 88 cm, with an average rainfall of 0.69 mm. Based on the three testing sessions, the researcher concludes that the data transmission to the website aligns with the established algorithm. There is no occurrence of Recovery Time Objective (RTO) issues on the website, and the Esp-8266 successfully sends data to the webserver without errors. Furthermore, the implementation of the Mamdani fuzzy logic on the Arduino Uno microcontroller has been successful.

Conclusion

Based on the implementation of the flood detection system using the float switch water level sensor with the Mamdani fuzzy method, the conducted tests can be summarized that this system effectively monitors water levels and rainfall. In the test results, there is accuracy in determining the flood hazard level based on the measured water level and rainfall. In the first test, the average water level is 57 cm with rainfall of 0.47 mm, resulting in a fuzzy warning level indicating a safe condition. In the second test, the water level reaches 51 cm with rainfall of 0.47 mm, producing a fuzzy warning level indicating a safe condition. Meanwhile, in the third test, the average water level reaches 99 cm with rainfall of 0.69 mm, resulting in a fuzzy warning level indicating a cautious condition.

The advantage of the fuzzy system in this research lies in its ability to process data and handle uncertainty or ambiguity, such as variations in water level and rainfall. This enables the system to provide fuzzy warning levels while taking into account the uncertainty that may occur in environmental conditions. The fuzzy method allows the representation of warning levels in linguistic terms, such as "safe" and "cautious," which are easier for users to understand. This capability can assist decision-makers in making faster and more effective decisions, as information is presented in a more intuitive format.

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