Digital Zone
Jurnal Teknologi Informasi dan Komunikasi
Vol: 15 No 02 2024 E-ISSN: 2477-3255
Accepted by the Editor: 09-10-2024 | Revision: 08-11-2024 | Published: 30-11-2024

Implementation of Fuzzy Logic Sugeno on a Website-Based for Flood Monitoring and Early Detection System

Fadlyani Pohan[1], Mukti Qamal[2], Said Fadlan Anshari[3]
[1,2,3] Informatics Engineering Study Program, Department of Informatics, Malikussaleh University
[1,2,3] Jl. Unimal Bukit Indah Campus, Lhokseumawe City, 24351, Indonesia
e-mail: [1]fadlyani.200170223@mhs.unimal.ac.id, [2]mukti.qamal@unimal.ac.id, [3]saidfadlan@unimal.ac.id

Abstract

Floods are common in Indonesia, especially in Aceh, and are caused by various factors, such as high rainfall during the rainy season, resulting in material and life losses. Developing a flood monitoring and early detection system is essential to reduce the negative impact of flooding. This research introduces the implementation of the Fuzzy Logic Sugeno method on a web-based flood monitoring and early detection system, which uses ESP32 and accurate sensors to monitor water level and water flow. Testing is done through two approaches. First, the water level and flow parameters were manipulated manually to test the system's response to changing conditions. Secondly, tests were conducted automatically until the prototype aquarium was complete to see the system's ability to detect potential flooding. The test results show that the system can automatically recognize potential flooding, take preventive actions, such as opening or closing floodgates, and provide real-time condition information through a Website.

Keywords: *Flood, Monitoring System, ESP32, Fuzzy Logic Sugeno, Real-time Website*

1. Introduction

Flooding remains a recurring issue in Indonesia, particularly in Aceh. Floods often occur during the rainy season when heavy rainfall causes rivers and waterways to overflow beyond their capacities. According to the Meteorology, Climatology, and Geophysics Agency (BMKG), the rainy season in Aceh begins in October and peaks between November and December. Flooding is a natural phenomenon that frequently impacts communities due to excess water accumulation in specific areas [1]. This phenomenon results in numerous losses, both material, such as damage to infrastructure and economic disruptions, and humanitarian, including loss of life [2]. Floods not only cause significant material damage but also have severe effects on people's lives, including fatalities and long-term socioeconomic consequences [3].

Flood early detection systems are designed to quickly and accurately detect potential flooding and warn the public [4]. These systems rely on Internet of Things (IoT) technology, which enables them to connect to the internet and transmit sensor data effectively [5]. In the development of flood early detection systems, it is important to consider diverse environmental conditions, including varying weather patterns and possible sensor failures. Weather variability can affect measurement accuracy and system response. Therefore, this research also includes strategies to improve the system's resilience to changing environmental conditions, as well as mechanisms to address possible sensor failures. To enhance the reliability of such systems, this research also integrates a fallback mechanism that ensures local data collection and allows the use of alternative communication channels when internet connectivity is disrupted [6].

The Fuzzy Logic Sugeno method is employed in this study to develop a more precise and efficient flood early detection system [7]. The Sugeno method is advantageous as it processes numerical information from measured variables, making it effective for addressing unpredictable scenarios [8]. The primary objective of this research is to design an efficient and accurate flood early detection system by leveraging the Fuzzy Logic Sugeno method to improve responsiveness to unpredictable flood conditions [9]. In applying IoT technology for early flood detection, fuzzy logic is implemented in the control system, enabling decisions to be made based on system requirements, which ensures effective and efficient operation [10]. Fuzzy Logic Sugeno is specifically applied to categorize conditions into safety, alert, and emergency levels, ensuring the system operates accurately and provides real-time, fast information to the public [11]. This method is particularly effective for monitoring and detecting conditions in rivers or areas prone to flooding by measuring unpredictable water levels [12].

Although several previous studies have developed flood detection systems, many failed to address issues such as network instability and IoT integration, which could enhance system effectiveness [13]. Various approaches have been introduced by prior researchers. For instance, one study designed a flood detection system based on ultrasonic sensors and microcontrollers integrated with Thingspeak and Telegram communication media to display real-time water level data and send notifications via the Telegram application. This system achieved a relative error of 0.78% [14].

Additionally, another study developed a flood detection system using ultrasonic sensors, LEDs, and buzzers as indicators of danger levels based on water levels and rainfall intensity. This system demonstrated good performance and readiness for field implementation [15]. Another IoT-based flood detection system used Dual Tone Multi-Frequency (DTMF) technology with a 433 MHz RF module, enabling real-time water level monitoring without requiring internet or telephone signals[16].

Finally, a microcontroller-based flood early detection system utilizing ultrasonic sensors was designed, and the system proved effective for application in flood-prone areas [17].This study utilizes ultrasonic and water flow sensors to monitor real-time water conditions, with the data processed using the Fuzzy Logic Sugeno method to determine appropriate preventive actions.

2. Research Methods

Below is a schematic description of the flood early detection system device:

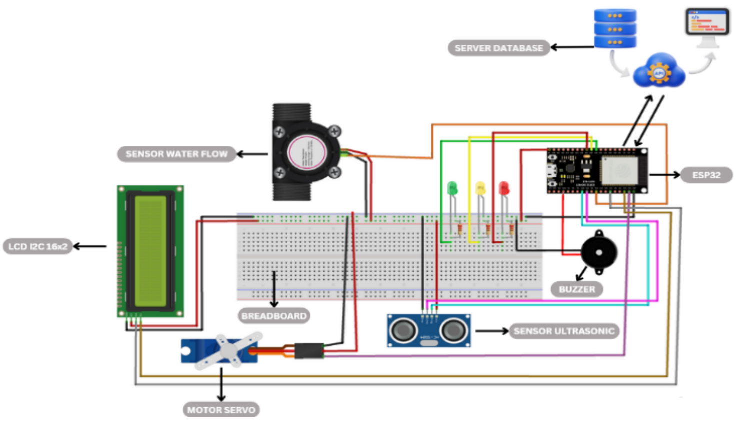


Fig 1 System Schematic

This flood early detection system uses ultrasonic sensors, water flow sensors, LEDs (red, yellow, green), buzzers, and a 16x2 I2C LCD to monitor water conditions and provide warnings. The LED indicates

https://doi.org/10.31849/digitalzone.v15i2. 23356

the water status (safe, alert, dangerous), while the LCDs the sensor data locally. Data from the sensors is processed by the microcontroller using the Fuzzy Logic Sugeno method to determine the position of the sluice gates (open/close) based on the water level and flow rate. Decisions are made through three fuzzy rules (low, medium, high) to prevent flooding, and users can monitor the data through a web interface connected to the server.
Below is a flowchart of the entire flood early detection system:

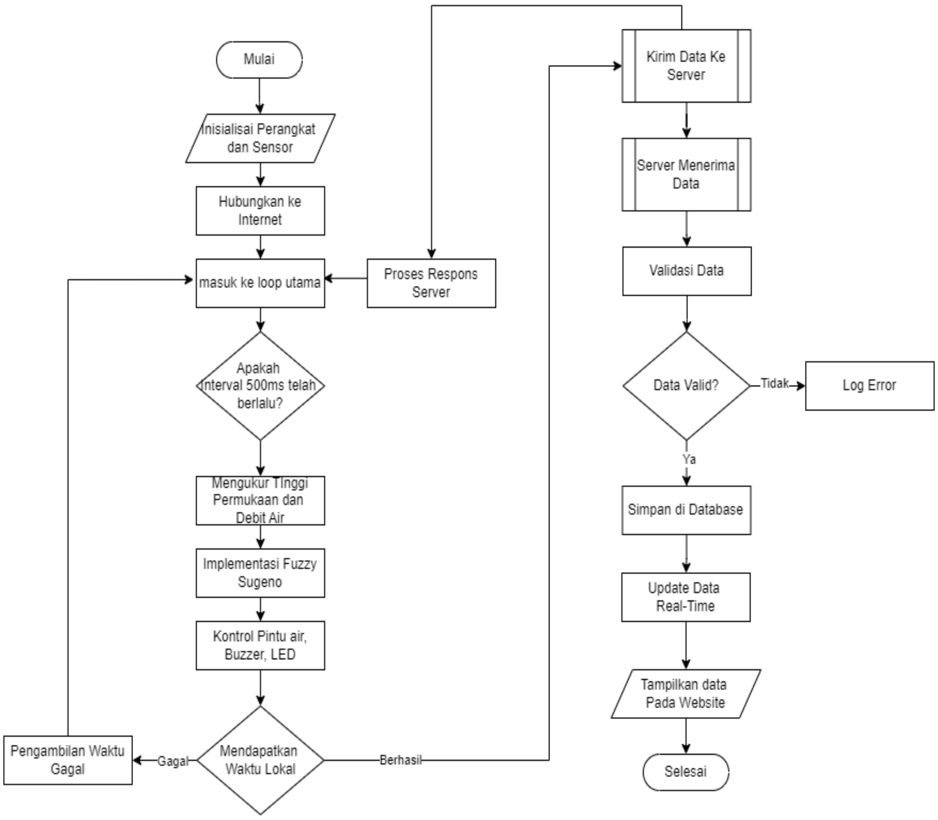


Fig 2 Flowchart

The diagram illustrates the workflow of the ESP32-based flood detection system. The system starts with device initialization and internet connection. Every 500 ms, the system measures the water level with an ultrasonic sensor and the water discharge with a water flow sensor. The data is processed using Fuzzy Logic Sugeno to determine the flood condition. The servo motor controls the floodgates, and the buzzer and LED are activated according to the condition (safe, alert, dangerous). The data is then sent to the server via HTTP, validated, stored, and displayed in real-time on the Website. This cycle repeats every 500 ms for continuous monitoring.

The Fuzzy Logic Sugeno method is utilized to process data obtained from various sensors integrated into the system. This study employs an ultrasonic sensor to monitor and detect rising water levels that could lead to flooding, along with a water flow sensor to measure water flow rates. Furthermore, a motor servo is used to operate the floodgate, allowing the system to respond automatically based on the analyzed sensor data.

Converting numerical values into fuzzy sets and determining their degrees of membership is called fuzzification. This process facilitates the measurement of the degrees involved in this study by using linear and curves.

Fuzzy rule inference is the determination of rules in a fuzzy logic system. The operator used to connect two inputs is the AND operator, while the one used to map between input and output is IF-THEN.
The inference process used in this research is Zero zero-order Sugeno Fuzzy Logic:

$$\boxed{IF\ (x_1\ is\ A_1) AND\ (x_2\ is\ A_2) AND\ \ldots AND\ \ x_n\ is\ A_n\ THEN\ z = k} \tag{1}$$

Description:

- $x_1\ x_2\ x_n$ = input variable
- $A_1\ A_2\ A_n$ = *fuzzy* set for each *input*
- k = constant (strict value) as a consequent

After these rules are obtained, the next step is the reasoning process, which determines the value of $\alpha - predikat$(i) using the *AND* (intersection) operator. In Sugeno's method, the implication function used for the *AND* operator is *MIN*, which is in the form *if* ... *then* ..., with the following equation:

$$\mu A \cap B = MIN\ (\mu A\ [x], \mu B[y]) \tag{2}$$

Description:

- $\mu A[x]$ = the membership degree value of the fuzzy solution to the i-th rule;
- $\mu B[y]$ = membership degree value of the i-th rule fuzzy consequent;

The input of the defuzzification process is a fuzzy set rule obtained from fuzzy rule composition, while the output is a number in the fuzzy set. In other words, from a fuzzy set in a certain range, a crisp value must be taken as output. In Sugeno's method, defuzzification is done by finding a (weighted average).

$$WA = \frac{\sum_{i=1}^{n} a_i z_i}{\sum_{i=1}^{n} a_i} \tag{3}$$

Description:

- $WA =$ weighted average value
- a_i = *a i-th* predicate
- z_i = *i-th* consequent

3. Results and Discussion

3.1 System Implementation

The form of the prototype can be seen in the following figure which consists of ultrasonic sensor, water flow, LCD I2C, servo motor, red, yellow, green LED, buzzer, ESP32. All components are arranged and combined in a simple aquarium.

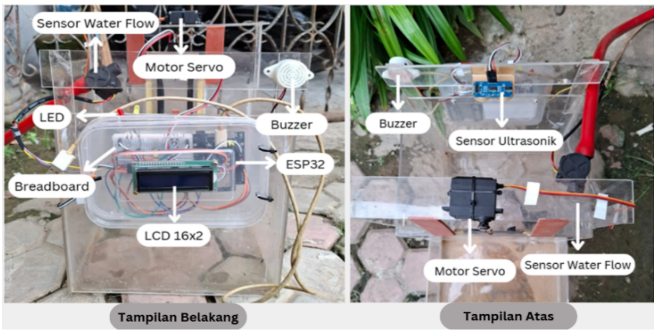


Fig 3 Tool Prototype

Once the device is connected to the prototype aquarium, the next step is to build a PHP-based Website to monitor data in real-time, including water level, water discharge, and sluice status based on the Sugeno Fuzzy Logic method. The ESP32 is programmed to read the data from the sensors, process it with fuzzy logic, and control the servo motor that opens or closes the floodgates. Buzzers and LEDs are activated as early warnings, while the ESP32 functions as a control center to monitor and control the flood system automatically. The Web display can be seen in the picture below.

To ensure the continuity of the system's functioning in conditions without internet connectivity, a fallback mechanism is implemented. The system is equipped with local data storage that allows data collection to continue even when there is no connection. In addition, alternative communication channels such as SMS are used to send alerts to users when the internet is unavailable.

https://doi.org/10.31849/digitalzone.v15i2. *23356*

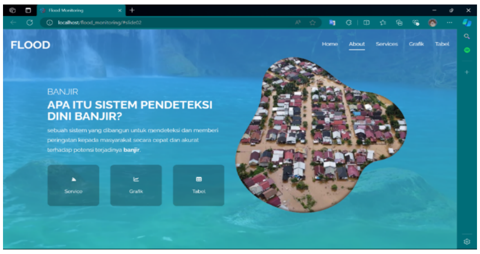
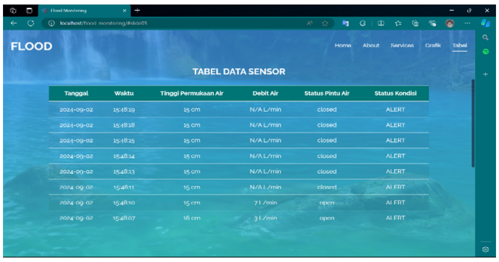


Fig 4 About Page

Fig 5 Grafik Page



Tanggal	Waktu	Tinggi Permukaan Air	Debit Air	Status Pintu Air	Status Kondisi
2024-09-02	15:48:19	15 cm	N/A L/min	closed	ALERT
2024-09-02	15:48:18	15 cm	N/A L/min	closed	ALERT
2024-09-02	15:48:15	15 cm	N/A L/min	closed	ALERT
2024-09-02	15:48:14	15 cm	N/A L/min	closed	ALERT
2024-09-02	15:48:13	15 cm	N/A L/min	closed	ALERT
2024-09-02	15:48:11	15 cm	N/A L/min	closed	ALERT
2024-09-02	15:48:10	15 cm	7 L/min	open	ALERT
2024-09-02	15:48:07	16 cm	3 L/min	open	ALERT

Fig 6 Table Page

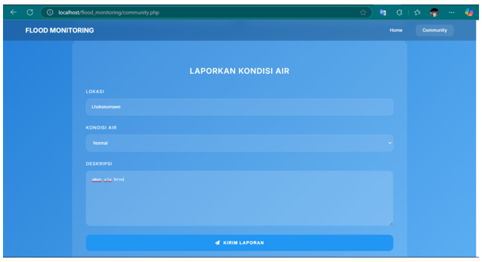


Fig 7 Community Page

The images above present different sections of the flood monitoring website, showcasing visual elements that help users easily understand the displayed information. These visuals clearly represent system operations and real-time sensor data. Furthermore, the "Community Page" enables local residents to submit water condition reports directly to the server, fostering community engagement and ensuring timely updates.

3.2 System Testing

In the System Monitoring Test Results section, we will explain the test results related to system monitoring, which includes the sensors and features used. The tests include ultrasonic sensors, water flow sensors, buzzers, LEDs, and servo motors to control the floodgates, as well as data transmission to the server. The results provide an overview of the accuracy and reliability of the sensors in monitoring important parameters for early flood detection. To overcome possible internet failures, a fallback mechanism has been designed using temporary local storage. The data will be synchronized back to the server once the internet connection is restored, so that monitoring continuity is maintained.

a. Ultrasonic Sensor Testing

The sensor will measure the resulting distance when placed at a predetermined height, which is 30 cm (low), 17 cm (medium), and 10 cm (high).

Table 1 Ultrasonic sensor testing

No	Status	Date	Time	High Water Level (cm)	Testing		
					Average	Std Dev	*Error* (%)
1	High	2024-09-10	17:21:21	10 cm	9,99	0,16	-0,10
2	Medium	2024-09-10	17:21:22	12 cm	11,98	0,21	0,17
3	Medium	2024-09-10	17:21:23	12 cm	12,01	0,21	-0,08
4	Medium	2024-09-10	17:21:24	12 cm	12,08	0,18	-0,67
5	Medium	2024-09-10	17:21:25	13 cm	12,99	0,16	0,08
6	Medium	2024-09-10	17:21:26	13 cm	12,99	0,16	-0,08
7	Medium	2024-09-10	17:21:27	12 cm	12,03	0,14	-0,25
8	Medium	2024-09-10	17:21:28	12 cm	11,97	0,14	-0,25
9	Medium	2024-09-10	17:21:29	12 cm	12,03	0,18	0,25
10	Medium	2024-09-10	17:21:30	12 cm	12,07	0,18	-0,58
Overall average				12,01			

The test is performed ten times. If the average error is small and consistent, the sensor is judged to be accurate; otherwise, recalibration or sensor replacement is required.

b. Water Flow Sensor Testing
The measured water discharge is 1.5 l/min (low), 2.5 l/min (medium), and 4 l/min (high). As the water flows, the impeller sensor rotates according to the flow speed, generating electrical pulses sent to the ESP32.
Table 2 Water Flow Sensor Testing

No	Status	Date	Time	Water Discharge (L/min)	Testing		
					Average	Std Dev	*Error* (%)
1	Medium	2024-09-10	17:21:21	3,20	3,20	0,01	-0,06
2	Low	2024-09-10	17:21:22	1,86	1,86	0,01	-0,11
3	High	2024-09-10	17:21:23	9,33	9,33	0,01	-0,02
4	Medium	2024-09-10	17:21:24	3,47	3,47	0,01	-0,06
5	Low	2024-09-10	17:21:25	2,27	2,27	0,01	-0,09
6	Medium	2024-09-10	17:21:26	2,80	2,80	0,01	-0,07
7	High	2024-09-10	17:21:27	4,93	4,93	0,01	-0,04
8	Medium	2024-09-10	17:21:28	3,73	3,73	0,01	-0,05
9	Medium	2024-09-10	17:21:29	3,06	3,06	0,01	-0,07
10	High	2024-09-10	17:21:30	4,53	4,53	0,01	-0,04
Overall average					-0,06 %		

After calibration is performed, a retest is performed to ensure that the average error decreases and the consistency of the results increases. If after calibration the average error is still small and consistent, the sensor is considered accurate and can be used reliably.

c. Motor Servo Testing
The results of the servo motor tests that have been carried out are listed in the table below.
Table 3 Motor Servo Testing

No	Position Servo	Water Gate Status	Water Discharge (L/min)	High Water Level (cm)
1	90°	Half Open	3,20 L/m	10 cm
2	90°	Half Open	1,86 L/m	12 cm
3	180°	Open	9,33 L/m	12 cm
4	90°	Half Open	3,47 L/m	12 cm
5	90°	Half Open	2,27 L/m	13 cm
6	90°	Half Open	2,8 L/m	13 cm
7	180°	Open	4,93 L/m	12 cm
8	90°	Half Open	3,73 L/m	12 cm
9	90°	Half Open	3,06 L/m	12 cm
10	180°	Open	4,53 L/m	12 cm

Tests were conducted ten times with a one-second interval between each test in real-time to ensure that the servo motor provided consistent and accurate results in regulating the floodgates.

d. System Control Testing Using Sugeno Fuzzy Logic Method
A system control test applying Sugeno's Fuzzy Logic method for sluice gate operation in a flood early detection system. The results of this test will provide an overview of the performance and reliability of the process in responding to changes in environmental conditions automatically and efficiently while emphasizing the importance of smart technology in improving flood risk management systems to protect the public.

https://doi.org/10.31849/digitalzone.v15i2. 23356

Determination of Input Parameters:
Water surface height: 18
Water discharge: 3,5

1. Finding Membership Degrees:
Membership Degree of Water Level Height:

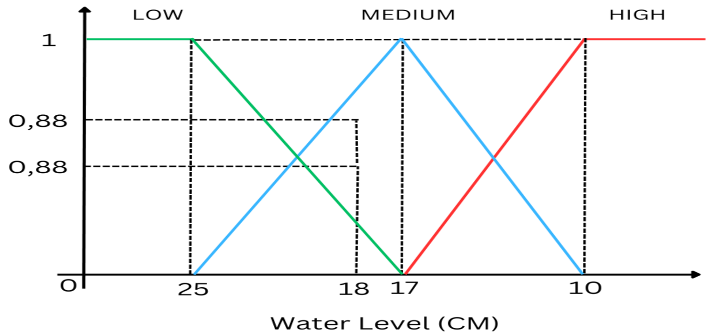


Fig 8 Membership Degree of Water Level Height

Low membership value

$$\mu Rendah(x)\begin{cases} 1, & x \leq 10 \\ \dfrac{25-x}{25-17} & 10 < x \leq 17 \\ 0, & x > 25 \end{cases}$$

Description:

- x is the water surface height value in cm
- For a water surface height of 18 cm, the formula used is $\boxed{\frac{25-x}{25-17}}$ because the value is between 17 and 25

$$\mu Rendah(18)\,\frac{25-18}{25-17} = 0{,}875$$

Medium membership value

$$\mu Sedang(x)\begin{cases} \dfrac{x-10}{7} & 10 < x \leq 17 \\ \dfrac{25-x}{25-17} & 20 < x \leq 25 \\ 0, & x > 25 \end{cases}$$

Description:

- x is the water surface height value in cm
- For a water surface height of 18 cm, the formula used is $\boxed{\frac{25-x}{25-17}}$ because the value is between 17 and 25

$$\mu Sedang(18)\,\frac{25-18}{25-17} = \frac{7}{8} = 0{,}875$$

High membership value

$$\mu Tinggi(x)\begin{cases} 0, & x \leq 17 \\ \dfrac{x-17}{10-17} & 17 < x \leq 25 \\ 1, & x \leq 10 \end{cases}$$

Description:

- x is the water surface height value in cm

- For a water surface height of 18 cm, the formula used is $\boxed{\frac{x-17}{10-17}}$ because the value is between 17 and 25

$$\mu Tinggi(18)\ \frac{18-17}{10-17} = \frac{1}{-7} = 0{,}00$$

Membership Degree of Water Discharge:

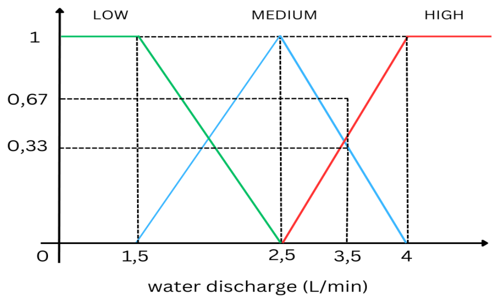


Fig 9 Membership Degree of Water Discharge

Low membership value

$$\mu Rendah(x) \begin{cases} 1, & x \le 1{,}5 \\ \dfrac{2{,}5-x}{2{,}5-1{,}5} & 1{,}5 < x \le 2{,}5 \\ 0, & x > 2{,}5 \end{cases}$$

Water discharge = 3.5 L/min. Because 3.5 is above 2.5, the membership value is 0. Moderate Membership Value

$$\mu Sedang(x) \begin{cases} \dfrac{x-1{,}5}{2{,}5-1{,}5} & 1{,}5 < x \le 2{,}5 \\ \dfrac{4{,}0-x}{4{,}0-2{,}5} & 2{,}5 < x \le 4{,}0 \\ 0, & x > 4{,}0 \end{cases}$$

Description:

- is the water discharge value in L/min
- for a water discharge of 3.5 L/min, the formula used is $\boxed{\frac{4{,}0-x}{4{,}0-2{,}5}}$ Because the value is between 2.5 and 4.0

$$\mu Sedang(3{,}5)\ \frac{4{,}0-3{,}5}{4{,}0-2{,}5} = \frac{0{,}5}{1{,}5} = 0{,}33$$

High membership value

$$\mu Tinggi(x) \begin{cases} 0, & x \le 2{,}5 \\ \dfrac{x-2{,}5}{4{,}0-2{,}5} & 2{,}5 < x \le 4{,}0 \\ 1, & x > 4{,}0 \end{cases}$$

Description:

- x is the water discharge value in L/min
- for a water discharge of 3.5 L/min, the formula used is $\boxed{\frac{x-2{,}5}{4{,}0-2{,}5}}$ Because the value is between 2.5 and 4.0

$$\mu Tinggi(3{,}5)\ \frac{3{,}5-2{,}5}{4{,}0-2{,}5} = \frac{1}{1{,}5} = 0{,}67$$

2. Finding Inference using Sugeno Fuzzy Logic

[R1] If the water level is low and the water discharge is low, the sluice gate output = 0 (closed).

$\boxed{\alpha - \text{predicate}_1 = \mu_{Rendah}(x) \cap \mu_{Rendah}(x)}$

= min ($\boxed{\mu_{Rendah}(18) \cap \mu_{Rendah}(3{,}5))}$

= min (0,88;0)

= 0

Value of $\boxed{z_1 = 0}$

[R2] If the water level is low and the water discharge is moderate, then the sluice gate output = 0 (closed).

$\boxed{\alpha - \text{predicate}_2 = \mu_{Rendah}(x) \cap \mu_{Sedang}(x)}$

= min ($\boxed{\mu_{Rendah}(18) \cap \mu_{Sedang}(3{,}5))}$

= min (0,88;0,33)

= 0,33

Value of $\boxed{z_2 = 0}$

[R3] If the water level is low and the water discharge is high, then the sluice gate output = 0.5 (half open).

$\boxed{\alpha - \text{predicate}_3 = \mu_{Rendah}(x) \cap \mu_{Tinggi}(x)}$

= min ($\boxed{\mu_{Rendah}(18) \cap \mu_{Tinggi}(3{,}5))}$

= min (0,88;0,67)

= 0,67

Value of $\boxed{z_3 = 0{,}5}$

[R4] If the water level is medium and the water discharge is low, then the sluice gate output = 0 (closed)

$\boxed{\alpha - \text{predicate}_4 = \mu_{Sedang}(x) \cap \mu_{Rendah}(x)}$

= min ($\boxed{\mu_{Sedang}(18) \cap \mu_{Rendah}(3{,}5))}$

= min (0,88;0)

= 0

Value of $\boxed{z_4 = 0}$

[R5] If the water level is medium and the water discharge is medium, the sluice gate output = 0.5 (half open)

$\boxed{\alpha - \text{predicate}_5 = \mu_{Sedang}(x) \cap \mu_{Sedang}(x)}$

= min ($\boxed{\mu_{Sedang}(18) \cap \mu_{Sedang}(3{,}5))}$

= min (0,88;0,33)

= 0,33

Value of $\boxed{z_5 = 0{,}5}$

[R6] If the water level is medium and the water discharge is high, the sluice gate output *is* 1 (open).

$\boxed{\alpha - \text{predicate}_6 = \mu_{Sedang}(x) \cap \mu_{Tinggi}(x)}$

= min ($\boxed{\mu_{Rendah}(18) \cap \mu_{Tinggi}(3{,}5))}$

= min (0.88;0,67)

= 0,67

Value of $\boxed{z_6 = 1}$

[R7] If the water level is high and the water discharge is low, the sluice gate output is 0.5 (half open).

$\boxed{\alpha - \text{predicate}_7 = \mu_{Tinggi}(x) \cap \mu_{Rendah}(x)}$

= min ($\boxed{\mu_{Tinggi}(18) \cap \mu_{Rendah}(3{,}5))}$

= min (0,0;0)

= 0

Value of $\boxed{z_7 = 0{,}5}$

[R8] If the water level is high and the discharge is moderate, the sluice gate output *is* 1 (open).

$\boxed{\alpha - \text{predicate}_8 = \mu_{Tinggi}(x) \cap \mu_{Sedang}(x)}$

$= \min\left(\mu_{Tinggi}(18) \cap \mu_{Sedang}(3{,}5)\right)$
$= \min(0{,}0;0{,}33)$
$= 0{,}0$

Value of $z_8 = 1$

[R9] If the water level is high and the water discharge is high, the sluice gate output *is* 1 (open).

$\alpha - \text{predicate}_9 = \mu_{Tinggi}(x) \cap \mu_{Tinggi}(x)$
$= \min\left(\mu_{Tinggi}(18) \cap \mu_{Tinggi}(3{,}5)\right)$
$= \min(0{,}0;0{,}67)$
$= 0{,}0$

Value of $z_9 = 1$

3. Searching for *defuzzification* with the *weighted average* method *Defuzzification of the* sluice gate output:

$$WA = \frac{\sum_{i=1}^{n} apredikat_i \, z_i}{\sum_{i=1}^{n} apredikat_i}$$

Total *Fuzzy Logic Sugeno* rules

$$z = \frac{(0{,}33\,.\,0) + (0{,}33\,.\,0{,}0) + (0{,}67\,.\,0{,}5) + (0{,}67\,.\,1) + (0{,}33\,.\,0{,}5) + (0{,}67\,.\,1)}{0{,}33 + 0{,}67 + 0{,}33 + 0{,}67}$$

$$z = \frac{0 + 0{,}335 + 0{,}165 + 0{,}67}{2{,}0}$$

$$z = \frac{1{,}17}{2{,}0} = 0{,}585$$

With a water level of 18 and a water discharge of 3.5, the result of the Fuzzy Logic Sugeno calculation for sluice control is 0.585, which means the sluice will be in the "half-open" position.

Calculation results of zero-order Sugeno fuzzy logic for sluice control in the system:

Fig 10 Calculation of Sugeno Fuzzy Logic on the System

The figure shows that the calculations produced by the system and manual for the Fuzzy Logic Sugeno method obtained identical results.

The system was also tested using Mamdani fuzzy logic and artificial neural networks for comparison.

Table 4 Comparison of Data Processing Methods

Method	Accuracy (%)	Execution Time	Notes
Sugeno	95	10	Stable, suitable for real-time
Mamdani	97	20	More accurate, but slower
Artificial Neural Network	98	50	Very accurate, but requires more resources

https://doi.org/10.31849/digitalzone.v15i2. 23356

Sugeno remains the best choice for real-time applications as it is able to maintain a balance between accuracy and execution time. However, Mamdani can be applied to systems that are less dependent on time sensitivity.

e. Testing the Entire System

The picture of the overall system testing on the flood detection prototype can be seen in the following figure:

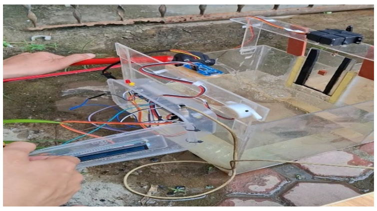


Fig 11 Testing the Entire Tool

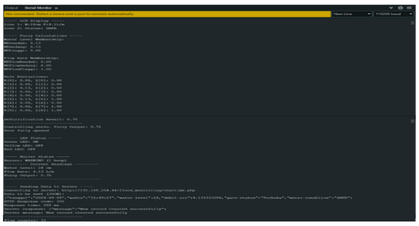


Fig 12 Testing the Entire System

In the testing phase of the flood control and monitoring system with floodgates, the authors used two approaches to ensure system reliability. First, direct manipulation of the water level and floodgate status was performed to test the system's response, which is important to verify the system's ability to respond quickly and accurately to changing conditions. In addition, the internet-connected test results displayed data from sensors and other devices, with Sugeno Fuzzy Logic controlling the movement of the floodgates. Once the data is read and displayed on the serial monitor, it is sent to the database. However, if there is an internet interruption, the data may fail to be saved.

Table 5 Overall System

Date	Time	High Water Level (cm)	Water Discharge (L/min)	Water Gate Status	Status data
2024-09-10	17:19:01	25 cm	2,26 L/m	Closed	Successful
2024-09-10	17:19:02	26 cm	4,7 L/m	Closed	Successful
2024-09-10	17:19:03	25 cm	2,93 L/m	Closed	Successful
2024-09-10	17:19:04	25 cm	1,87 L/m	Closed	Successful
2024-09-10	17:19:05	-	-	-	Failed
2024-09-10	17:19:06	-	-	-	Failed
2024-09-10	17:19:07	-	-	-	Failed
2024-09-10	17:19:08	-	-	-	Failed
2024-09-10	17:19:09	-	-	-	Failed
2024-09-10	17:19:10	24 cm	14,26 L/m	Open	Successful
2024-09-10	17:19:11	24 cm	3,2 L/m	Half Open	Successful
2024-09-10	17:19:12	24 cm	2,54 L/m	Half Open	Successful
2024-09-10	17:19:13	24 cm	2 L/m	Closed	Successful
2024-09-10	17:19:14	22 cm	4,40 L/m	Open	Successful
2024-09-10	17:19:15	23 cm	4,7 L/m	Open	Successful
2024-09-10	17:19:16	24 cm	3,7 L/m	Half Open	Successful
2024-09-10	17:19:17	24 cm	2,27 L/m	Closed	Successful
2024-09-10	17:19:18	24 cm	4,13 L/m	Open	Successful
2024-09-10	17:19:19	23 cm	5,86 L/m	Open	Successful
2024-09-10	17:19:20	24 cm	3,47 L/m	Half Open	Successful
2024-09-10	17:19:21	23 cm	3,47 L/m	Half Open	Successful
2024-09-10	17:19:22	22 cm	4,4 L/m	Open	Successful
2024-09-10	17:19:23	23 cm	2,4 L/m	Closed	Successful
2024-09-10	17:19:24	22 cm	6,93 L/m	Open	Successful
2024-09-10	17:19:25	22 cm	2,9 L/m	Half Open	Successful

The results of these tests, through parameter adjustments and real-time continuous monitoring, are reflected in tables that record changes in water levels, floodgate status, and flood conditions, along with the system's response to these changes. This test provides a thorough understanding of the performance of the designed flood monitoring and control system. It proves that the system can maintain safety and efficiency in flood control accurately and reliably.

4. Conclusion

The system is designed to monitor critical parameters in real-time, such as water levels and flow rates, to detect potential flooding. With continuous monitoring, the system is able to provide fast and accurate information, enabling early preventive measures to reduce the risk of flooding. The application of Sugeno's Fuzzy Logic method proves effective in processing complex sensor data into simple decisions and generating precise automatic control. Test results show that this method can accurately detect changes in water conditions, allowing the system to automatically adjust floodgates when significant changes occur indicating a flood threat. Furthermore, the system has the potential to be applied on a larger scale, such as large river networks or urban infrastructure, with further development involving integration into national or regional flood monitoring systems to support overall disaster preparedness. Local community participation is also an important element, where education and training on the use of the system and preventive measures can improve flood preparedness. Future research could focus on developing systems to deal with more complex environmental conditions or diverse flood scenarios.

References

[1] Saskia Eka Cahyani, Tatang Rohana, And Santi Arum Puspita Lestari, "Implementation Of Fuzzy Logic In Rice Field Irrigation System To Improve Water Use Efficiency Based On Iot," *INFOTECH J. Inform. Teknol.*, Vol. 4, No. 1, Pp. 37–46, 2023, https://doi.org/10.37373/Infotech.V4i1.496.

[2] A. R. S. Rosida, "Prototype Of Flood Early Warning System Based On Iot-Based River Elevation (Case Study: Gedebage District)," Pp. 13–56, 2021.

[3] A. Diriyana *Et Al.*, "Water Level Monitoring And Flood Early Warning Using Microcontroller With Iot Based Ultrasonic Sensor," *J. Tek. Inform. C.I.T*, Vol. 11, No. 1, Pp. 22–28, 2019.

[4] Sabaruddin, A. Al Hafiz, And D. H. Pane, "Implementation Of Internet Of Things (Iot) Based Fuzzy Method For Flood Early Warning," *J. Sist. Komput. Triguna Dharma (JURSIK TGD)*, Vol. 1, No. 1, P. 26, 2022, https://doi.org/10.53513/Jursik.V1i1.4805.

[5] M. Z. Arifin, E. Utami, And E. Pramono, "Design Of Flood Early Detection System Using DTMF Transmission Technique Based On 433 Mhz RF Module And Arduino," *J. Teknol. Inf. Dan Komun.*, Vol. 8, No. 2, 2020.

[6] R. Dias Valentin, M. Ayu Desmita, And A. Alawiyah, "Microcontroller Based Ultrasonic Sensor Implementation For Flood Early Warning System," *Jimel*, Vol. 2, No. 2, Pp. 2723–598, 2021.

[7] J. N. Kusteja And D. N. P. Pratamawari, "1s Analysis Of Evolutionary Trends In Arithmetic Network Architecture 1 . 1," Vol. 2, No. 4, Pp. 48–59, 2022.

[8] Dimas Maulana Hakim, Tri Hastono, And Yanuar Arifia Ranggana, "Application Of Sugeno Fuzzy Logic In Predicting The Amount Of Income Commission At Toko Karunia Ijo In Malang," *J. Publ. Ilmu Komput. Dan Multimed.*, Vol. 3, No. 1, Pp. 90–104, 2024, https://doi.org/10.55606/Jupikom.V3i1.2583.

[9] Yendrizal, "Implementation Of Artificial Intelligence For Company Employee Recruitment With Sugeno Fuzzy Concepts," Vol. 08, No. 340, Pp. 161–170, 2023.

[10] R. Risdiandi, "Analysis Of How Ultrasonic Sensors Work Using Arduino Uno Microcontroller To Design An Automatic Flood Detection Tool," *OSF Prepr. January*, Vol. 1, No. January 2020, P. 1, 2021, https://doi.org/10.13140/RG.2.2.24386.61123.

[11] R. T. Adek, M. Ula, And B. Bustami, "Efficient Hygro-Thermal And Ammonia Control In Day-Old Chick Brooding Box Using Internet Of Things And Tsukamoto Fuzzy Controller," *IOP Conf. Ser. Earth Environ. Sci.*, Vol. 1356, No. 1, 2024, https://doi.org/10.1088/1755-

1315/1356/1/012119.
[12] V. Pravalika And C. Rajendra Prasad, "Internet Of Things Based Home Monitoring And Device Control Using Esp32," *Int. J. Recent Technol. Eng.*, Vol. 8, No. 1 Special Issue 4, Pp. 58–62, 2019.
[13] M. Ula, M. Muliani, R. T. Adek, And B. Bustami, "Optimizing Water Condition In Tropical Brackish Water Aquaponics: A Novel Internet Of Things And Machine Learning Approach," *IOP Conf. Ser. Earth Environ. Sci.*, Vol. 1356, No. 1, 2024, https://doi.org/10.1088/1755-1315/1356/1/012055.
[14] Siswanto, Ikin Rojikin, And Windu Gata, "Utilization Of DHT-22 Temperature Sensor, HC-SR04 Ultrasonic To Control Pool With Email Notification," *J. RESTI (Rekayasa Sist. Dan Teknol. Informasi)*, Vol. 3, No. 3, Pp. 544–551, 2019, Doi: 10.29207/Resti.V3i3.1334.
[15] Habibullah Akbar, Diah Aryani, And Muhamad Bahrul Ulum, "Urban Area Flood Detection Based On Digital Image Convolutional Neural Network (Vgg19)," *J. Tek. Mesin, Elektro Dan Ilmu Komput.*, Vol. 2, No. 3, Pp. 82–91, 2022,https://doi.org/10.55606/Teknik.V2i3.798.
[16] A. Saputra, "USING ARDUINO UNO," Vol. 2, No. 3, Pp. 1–12, 2022.
[17] H. Hafidz, "Automatic Design Of Product Separator Conveyor Based On Color Based On Arduino Nano At Pt. Jonan Indonesia," *J. Vocat. Educ.*, Vol. 1, No. 1, 2022.