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IoT-Based Early Warning System for Flood Disasters Using Predictive Method Approaches

Peringatan Dini Bencana Banjir Berbasis Iot Menggunakan Pendekatan Metode Prediktif

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ABSTRACT

Floods are among the natural disasters that can cause substantial damage, particularly in tourist locations with high visitor traffic. This paper proposes the implementation of an IoT-based predictive method for early flood disaster warnings in tourist areas. The proposed system utilizes IoT sensors to monitor environmental conditions in real-time and employs machine learning-based predictive models to forecast the likelihood of flooding. By continuously collecting and analyzing data such as rainfall, river water levels, and soil moisture, the system can predict potential flood events with a relatively high degree of accuracy. The research involved developing and testing the system in a controlled environment to evaluate its performance. The results demonstrated that the system could provide timely early warnings, allowing tourist site managers to take necessary preventive measures to protect visitors and infrastructure. The implementation of such a system can significantly reduce the impact of floods by providing actionable information well in advance of potential disasters. This early warning capability is crucial in tourist areas where rapid response is necessary to ensure the safety and well-being of visitors. Overall, the study highlights the effectiveness of combining IoT technology with predictive analytics in disaster management and risk mitigation. The result of this research is an IoT-based flood detection application using the Predictive Method approach that will warn users if there is an unnatural water flow or a flood disaster will occur.

Keywords : Flood, IoT, predictive models

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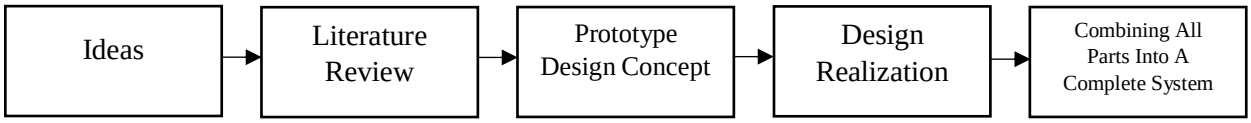
1. INTRODUCTION

There has been a global climate change in Indonesia, one of the impacts being the irregularity of seasons marked by the phenomena of El Nino (prolonged dry season) and La Nina, which brings continuous rain [1]. Floods occur due to the overflow of river water as a result of the river's inability to contain rainwater. The delay in flood disaster warnings and evacuations by city and regional governments causes losses within the community. This also affects the growth of urban land and infrastructure, leading to a decline in environmental quality. To provide information about the onset of floods, a system is needed to deliver early warnings to the public, enabling them to better prepare for flood disasters [2].

Technological developments that can be utilized to access electronic equipment such as implementing IoT-based flood disaster early warning using a predictive method approach can be operated online via android [3]. Of the various natural disasters that occur in Indonesia, flooding is a natural disaster that quite often hits various cities in Indonesia. Therefore, this research implements the concept of the Internet of Things on a flood monitoring system [4]. The purpose of this research is to implement a flood detection system to reduce material losses caused by disasters and prevent casualties and present IoT (Internet of Thing) based water capacity information [5].

2. METHOD

This study employs an experimental method to test the author's hypothesis on the use of ultrasonic sensors for water level measurement and utilizes the IoT Firebase platform to develop an Early Warning System. The research process was conducted systematically, we starting from.



The system design is in Figure 1.

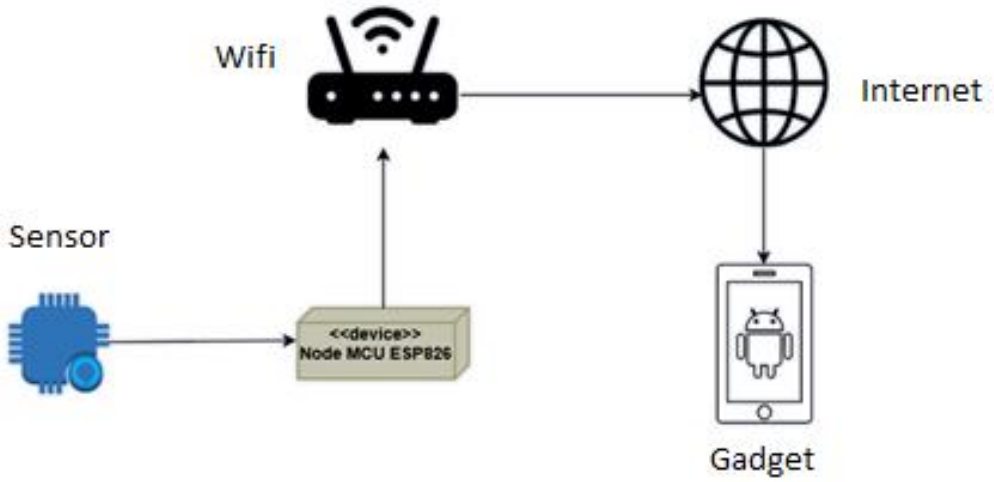


Figure 2. IoT Flood Early Warning System Block Diagram

The Firebase platform serves as a data center, where data stored in Firebase can be accessed in parallel by multiple devices simultaneously. Each device has different access rights; the alerting device and the monitoring web browser only have access rights to read the data, while the device that measures the water level is given access rights to read and modify the data. The main components in this research include:

a. Water Level Reader Hardware

The hardware to read the water level consists of an ESP8266 microcontroller that is already integrated in the board (Wemos D1 mini). As for the water level sensor, a JSN-SR04T type ultrasonic sensor is used, which is a waterproof ultrasonic sensor.

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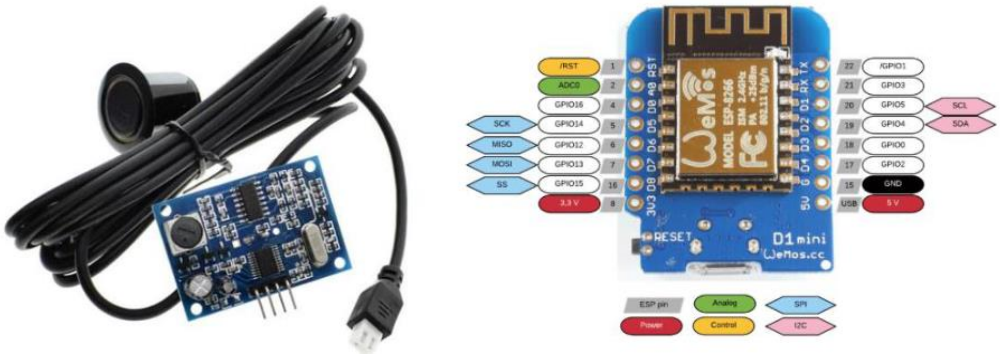


Figure 3. (a) JSN-SR04T Module, (b) Wemos D1Mini ESP8266

The JSN-SR04T module works by sending ultrasonic waves after receiving a trigger with a pulse width of at least 100 µS. After the ultrasonic module sends waves, the echo pin will turn High and return to Low after receiving wave feedback or after 38 ms. Since the working principle used is the reflection of waves, the formula used to measure distance with an ultrasonic sensor is as follows:

$$Distance = \frac{High\ Pulse\ Width * Sound\ Propagation\ Speed)}{2}$$

According to the datasheet, the JSN-SR04T sensor can measure distances up to 600 cm with an accuracy of ±1 cm and a reading resolution of 1 mm. In order to function, the ESP8266 microcontroller needs to be programmed. The program that must be embedded in this microcontroller board includes the JSN-SR04T reading algorithm to obtain water level data and the algorithm for sending the data to Firebase Realtime Database via the internet network. Programming is done using the Arduino IDE software with the C programming language. With Arduino IDE, using ESP8266 becomes very easy, including working with the ESP8266 onboard processor, so it does not require an additional downloader device. The ESP8266 microcontroller requires two digital pins to communicate with the JSN-SR04T: one pin as an output to provide a trigger signal, and another pin to read the echo signal which is a pulse signal. This pulse width is converted into the distance between the sensor and the water surface using the formula already mentioned. To convert distance into water level, normal distance data is required as a comparison constant. The calculation principle is inversely proportional, where the closer the distance between the sensor and the water surface, the higher the water surface. The calculation of the increase in water level can be done with the following formula:

water level rise = (normal constant - sensor reading distance)

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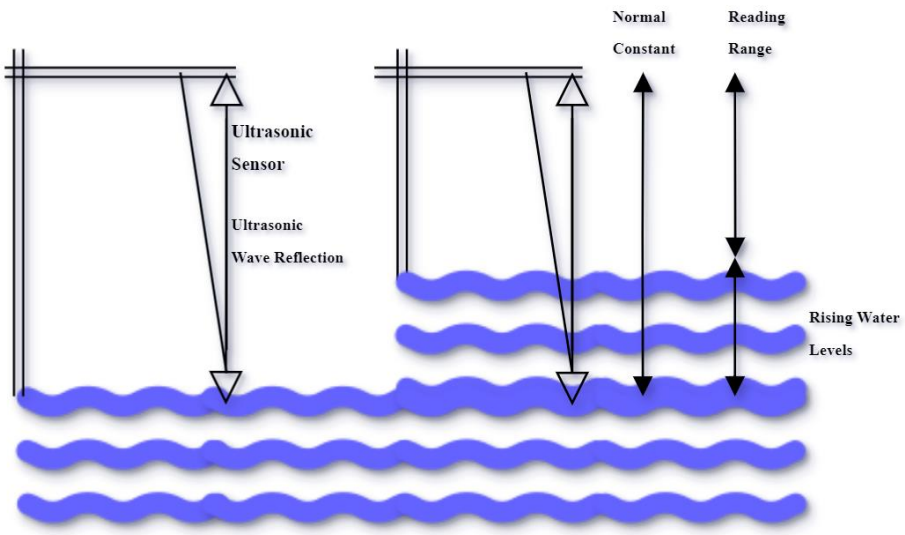


Figure 4. Illustration of Water Level Rise Reading

By setting the time interval of the sensor reading, data on changes in water level can be obtained at any time. In this research, the time interval used is one minute, so the data obtained is the change in water level per minute. With this time interval, the data is also sent to the Firebase Realtime Database. To send data to the Realtime Database, the ESP8266 requires internet access, so an internet provider access point is needed. In this research, an access point from MiFi is used as an internet service provider. ESP8266 already has a WiFi interface integrated in the chip, so it does not require additional devices for communication with MiFi.

The program needs to be made so that the ESP8266 activates its internal WiFi in station mode by adjusting the SSID and password so that it can connect to the access point. The interface between the ESP8266 and the JSN-SR04T sensor module can be seen in Figure 4. In the figure, pin D4 is used as an output from the ESP8266 board to generate a trigger signal to JSN-SR04T, while pin D3 is used to read the echo signal from JSN-SR04T.

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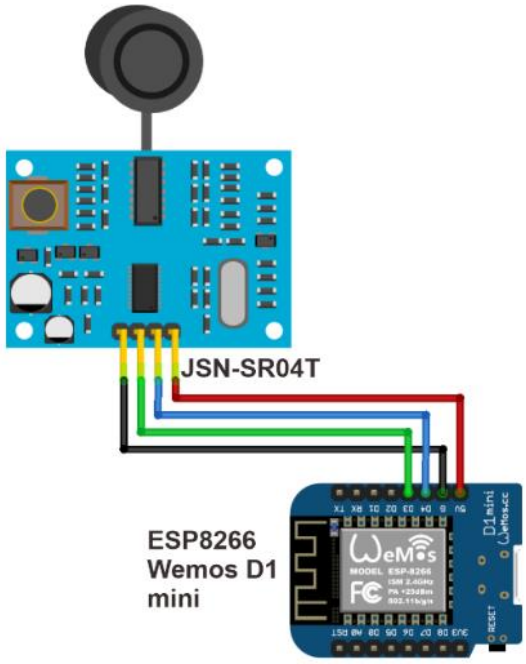


Figure 5. Ultrasonic circuit with ESP8266

b. Arduino IDE Configuration

Open the Arduino IDE application then click Tools> Board> NodeMCU 1.0 (ESP-12E Module) Next create a new sketch. Click File > New. Or you can also press the CTRL + N keys on the keyboard simultaneously. Sketch to connect esp8266 is no different from the basic principles of Arduino programming. Consists of declaration, initialization and looping sections. In the declaration this section is stored from line 1 to 7. It starts by calling the ESP8266Wifi preprocessor file. Then proceed to create ssid and password constants. Finally, an int wifiStatus variable is created to store connection status data that will be used in lines 23 and 30. Initialization is in lines 9 to 27 First, set the data transfer speed.

```
#include <ESP8266WiFi.h>
//ssid and password data
const char* ssid     = "ogo";
const char* password = "jangand11s1";

// Create a wifiStatus variable to store wifi status data
int wifiStatus;

void setup() {

Serial.begin(115200);
delay(200);

// Boasting a connected status label with the name Wifi
Serial.println();
Serial.println();
Serial.print("Connected to Wifi : ");
Serial.println(ssid);

WiFi.begin(ssid, password);

//if WiFI.the value status is not the same with WL_CONNECTED
while (WiFi.status() != WL_CONNECTED) {
  delay(500);
  Serial.print(".");
  }
}

```

Figure 6. sketch arduino

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c. Alerting Hardware

The hardware for the alerts requires a microprocessor connected to the internet. The author uses ESP8266 to read data from Firebase Realtime Database. For audio playback, an MP3 player module equipped with an amplifier and horn-type speaker is used. The MP3 player module was chosen so that it can provide varied alerts with recorded sound. This module supports asynchronous serial communication with a baudrate of 9600, parity bit: none, and flowcontrol: none [9]. The main parts of this alert circuit are the ESP8266 and DF Player Mini as the audio file player. The audio output uses a standard 3.5mm jack to be compatible with different types of amplifiers. The amplifier is not the main part so that it can be adapted to the needs at the installation site. In the test, the author used active speakers. This alert device works by reading the rate of change and water level from a realtime database. If the water level approaches the critical level and the rate of change is still increasing, the microprocessor will play an MP3 file accordingly. This research divides three critical conditions with an estimated time of 30 minutes, 15 minutes, and 5 minutes before the water overflows.

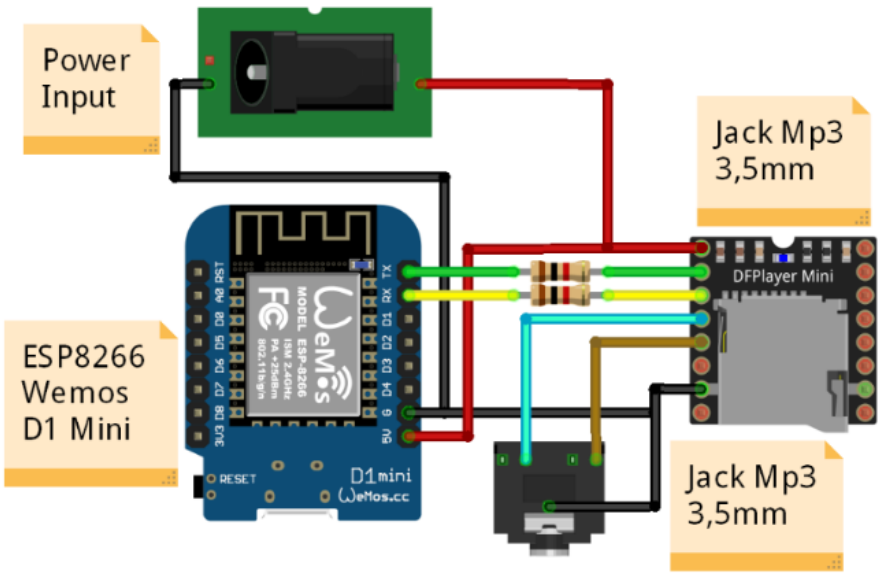


Figure 7. Warning Main Circuit

3. RESULT AND DISCUSSION

In this study, we used simple linear regression to predict the water level based on rainfall. The calculation steps of the model are described as follows:

A. Data Gathering

Rainfall (X) and water level (Y) data were collected for one year. Suppose the data obtained is as follows:

X (Rainfall in millimeters): [10, 20, 30, 40, 50]

Y (Water level In millimeters): [15, 25, 35, 45, 55]

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1. Calculation of model parameters:

   - Average rainfall (X): (10 + 20 + 30 +40 + 50) / 5 = 30
   - Average water level (Ỹ): (15 + 25 + 35 + 45 + 55) / 5 = 35

   Slope (b) is calculated with :

   $$b = \frac{\Sigma(X-X)(Y-\ddot{Y})}{\Sigma(X-X)2}$$

   $$b = \frac{(10-30)(15-35) + (20-30)(25-35) + (30-30)(35-35) + (40-30)(45)}{(10-30)2 + (20-30)2 + (30-30)2 + (40-30)2 + (50}$$

   $$b = \frac{(20)(-20) + (10)(-10) + (0)(0) + (10)(10) + (20)(20)}{(20)2 + (16) + (0)2 + (10)2 + (20)2}$$

   $$b = \frac{-400 + (-100) + 0 + 100 + 400}{400 + 100 + 0 + 100 + 400} = \frac{0}{1000} = 0$$

   intercept (α) can be calculated with :

   $\alpha = \bar{Y} - b\ddot{X}$

   $\alpha = 35 - 0 \times 30 = 35$

   thus the linear regression equation is:

   $Y = 35 + 0 \times X = 35$

2. Model Evaluation: The model is evaluated using Mean Squared Error (MSE) to measure its accuracy. Suppose the test data is as follows :

   - X (Rainfall in millimeters): [15, 25, 35, 45, 55]
   - Y (Water level In centimeters): [20, 30, 40, 50, 60]

   Predicted water level (Y') is calculated with the regression model that has been built:

   - Y' (Predicted Water Level in centimeters): [35, 35, 35, 35, 35]

   MSE is calculated by:

   $$\frac{\Sigma(Y - Y)\hat{}2}{n}$$

   $$MSE = \frac{(35-20)2 + (35-30)\hat{}2 + (35-40)2 + (35-50)\hat{}2 + (35-60)\hat{}2}{5}$$

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$$MSE = \frac{225 + 25 + 25 + 225 + 625}{5} = \frac{1125}{5} = 225$$

B. Result Display

The following is a display of the results of the application that has been made, where in this section will be explained about the displays that exist in the design of an internet of thinks (IoT)-based flood disaster early warning system so that the results of its implementation can be seen in accordance with the results of the program that has been made. The following are the views that exist in the trial using the Arduino IDE :

1. Tool Set Display

The miniature flood early warning display that will be made is a schematic of the network that will be made IoT shown in Figure 7.

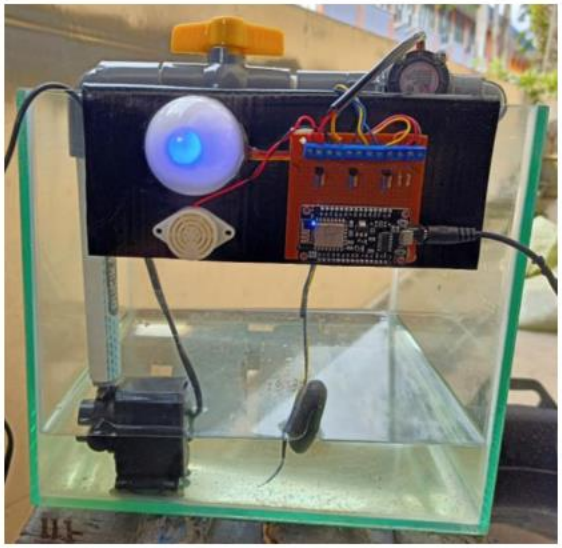


Figure 8. Tool Set Display

2. Application Display

The following is the appearance of the flood early warning application that has been made, shown in Figure 8.

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Figure 9. Application Display

3. Discussion

In building this internet of things (IOT)-based flood disaster early warning system design, the author uses arduino and wifi (IOT) and Arduino IDE as the connecting software. The commands in the program that the author made are also quite easy to understand because the admin only needs to click the buttons that are already available.

The above reasons can be a goal to increase work effectiveness and can further maximize the resources involved in designing an internet of things (IOT)-based flood disaster early warning system.

4. System Testing

System testing is a test where the admin sets up the internet. With this test, the data entered will match the conditions that have been created. The test of the system aims to ensure that the system is in a ready-to-use condition.

a) Safe Water Condition Display (Safe water level condition, Slow water speed)

The early warning display for flood disasters that will be created is the Safe Water Condition Display (Safe water level condition, Slow water speed). If the water conditions are safe, the flood disaster early warning in the application will show that the water level status is in a safe condition, as well as the water speed status will show the status of slow water conditions.

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b) Alert Water Condition Display (Safe water level condition, Fast water speed)

The early warning display for flood disasters that will be created is the Safe Water Condition Display (Safe water level condition, Fast water speed) The early warning display for flood disasters that will be created is the Safe Water Condition Display (Safe water level condition, Fast water speed

c) Alert Water Condition Display (Alert water level condition, Slow water speed)

The early warning display for flood disasters that will be created is the Safe Water Condition Display (Alert water level condition, slow water speed). Display of the flood disaster early warning application that will be created is a schematic of the network that will create IoT Water Condition Display Safe (Alert water level condition, Slow water speed).

d) Alert Water Condition Display (Alert water level condition, Fast water speed)

The The early warning display for flood disasters that will be created is Display of alert water conditions (alert water level conditions, water speed fast). Display of the flood disaster early warning application that will be created is a schematic of the network that will create IoT Water Condition Display alert (Alert water level condition, Fast water speed).

e) Alert Water Condition Display (Dangerous water level condition, Slow water speed)

The early warning display for flood disasters that will be created is Display of alert water conditions (Dangerous water level conditions, water speed fast) dangerous water level conditions , (Dangerous water level condition slow water speed)

f) Display of dangerous water conditions (dangerous water level conditions, speed fast water)

The early warning display for flood disasters that will be created is The display of dangerous water conditions (dangerous water level conditions, fast water speed). The display of the flood disaster early warning application that will be created is a schematic of the network that will be created IoT. The display of dangerous water conditions (dangerous water level conditions, fast water speed).

The following are the results of application testing of the system The following is the coding of the internet of things (IoT)-based flood disaster early warning system tool using the internet :

Table 1. Application Testing

Testing	State Of Water Level	State Of Water Velocity	Water conditions	Alarm	Water Height (cm)	Led Color	Notification
1	Safe	Slow	Safe	off	**10**	Blue	Not Appear
2	Safe	Fast	Alert	off	**20**	Green	Not Appear
3	Alert	Slow	Alert	off	**30**	Green	Not Appear
4	Alert	Fast	Alert	off	**40**	Yellow	Not Appear
5	Danger	Slow	Danger	on	**50**	Red	Appears
6	Danger	Fast	Danger	on	**60**	Red	Appears

5. System Test Results

After testing the system, the results can be concluded

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What is obtained is:

a. Performance becomes more interesting
b. The wifi internet capture system becomes a link between wifi and the system
c. The system can maximize Android
d. Reduce response time
e. And also avoid overload or accumulation of traffic which makes the network down

6. Advantages and Disadvantages of the System The advantages of the system to be designed are:
   a. With this system, the need for an early warning system for flood disasters has been fulfilled with the internet network
   b. The design of an internet of things (IoT) based flood disaster early warning system is very easy to use and the results are more effective and efficient.
   c. Minimal delays or traffic buildup so the network runs smoothly
   d. It is very easy to apply to all internet networks now.

   The shortcomings of the currently designed system are:

   a. This networked early warning system for flood disasters is difficult for ordinary people to understand.
   b. If the system created is not always updated according to new knowledge, then the system cannot provide the best solution.

1. CONCLUSION

Based on the discussion above, we can draw several conclusions, including the following:

1. The design of a Flood Disaster Early Warning system based on the internet of things (IoT) is very precise in its application, namely Flood Disaster Early Warning.

2. The design of the Internet of Things (IoT)-based Flood Disaster Early Warning system is very simple, so that application users can understand and use this application easily.

3. The results of designing an early warning system for flood disasters based on the internet of things (IoT) have provided quite satisfactory results because they have used methods that suit the needs of systems that use the internet of things.

4. Designing a Flood Disaster Early Warning system based on the internet of things (IoT) can produce the right solution for automatic Flood Disaster Early Warning with the internet of things.

2. SUGGESTION

For development more continue with planning system warning early disaster flooding at the location tour based on the internet of things (IoT), mak can given some suggestions as following :

1. The design of an early warning system for flood disasters based on the internet of things (IoT) should be further developed so that it can be even better

2. The design of an early warning system for flood disasters based on the internet of things (IoT) was developed so that it can be more useful for everyone.

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3. It is best to always update regularly according to developments in science, which of course affects the system in identifying text similarities, so that the results are optimal.

4. For future development of this system, it is hoped that we can build a system that has more detailed knowledge data.

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