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A Flash Flood Warning System Using Solar Powered Node MCU

Irfan Yahaya[1] and Ahmad Nazrul Rosli[1, 2, *]
[1]*Faculty of Science and Technology, Universiti Sains Islam Malaysia, 71800 Bandar Baru Nilai, Negeri Sembilan, Malaysia.*
[2]*Energy Materials Consortium (EMC), Faculty of Science and Technology, Universiti Sains Islam Malaysia, 71800, Nilai, Negeri Sembilan, Malaysia.*
[*]*Corresponding author*: anazrul84@usim.edu.my, *ORCiD*: 0000-0002-8834-8567
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Abstract **— Flash flood disasters are natural phenomena in Malaysia that can occur anytime and anywhere. For safety precautions, a notification message should be sent to the people early to avoid any losses of property or life. This system is designed as an earlier flood alert system that can detect water levels using an ultrasonic sensor. The objectives of this research are to develop a system that can be aware of the water level of flood to the user and send a notification to people about the flood's condition through the mobile application. NodeMCU, an ultrasonic sensor, and solar technology developed the system. This project focuses on monitoring water levels, using Wi-Fi as a medium to send warning notifications to people through mobile phones, and the accuracy of ultrasonic sensors using and without pipes. This prototype can send short warning notifications to Blynk apps. The average percentage error of the water level distance from the ultrasonic sensor with pipe was lower than without pipe, which was 2.55% and 3.11%, respectively. This system improved the notification message-sending method and detection of the ultrasonic sensor.**

Keywords—Flood, IoT, Ultrasonic Sensor, Flood detection system.

I. INTRODUCTION

Malaysia experiences annual floods due to its tropical climate, characterized by high rainfall, high temperatures, humidity, monsoon seasons, and the impacts of climate change. These floods affect all states in the country. In 2012, the Department of Irrigation and Drainage Malaysia (JPS) reported that 10.1% of the area in Malaysia is at risk of being affected by floods, which cover around 33,298 kilometre square [1]. There are two types of floods: monsoon floods that usually hit Malaysia's east coast and flash floods that mostly happen on the west coast of Malaysia and major cities [2]. The monsoon flood season occurs at the end of the year and is characterized by prolonged rainfall over several days, which can overwhelm the river's water capacity.

Flash floods happen when heavy rainfall persists for several hours. Poorly maintained drainage systems, construction activities, and unplanned development contribute to an increased risk of flooding in certain areas. This disaster affects not only the communities but also government agencies. The impact of floods extends to businesses, lives, housing, and educational programs. In 2014 only, the government lost RM2.85 billion due to floods in 8 states, with 25 deaths and half a million people evacuated [3]. A total of RM14.09 billion was lost by the government from 2014 until 2023, with two significant floods in 2014 (Kelantan, Terengganu, and Pahang) and 2021 (Selangor, Kuala Lumpur, and Pahang) [2, 3].

The government initiated the National Flood Forecasting and Warning Program (PRAB) to prepare a long-term plan for mitigating these problems, including improving drainage, upgrading warning systems, and preparing reports for the government. The program uses the latest technology, including IoT, databases, and forecasting simulations, to help the government manage floods [3]. While the government works to enhance information delivery and early warning systems, many areas remain at risk of floods, particularly flash floods [4, 5].

The warning system is designed to alert users about impending dangers and provide essential information. It prepares individuals to respond quickly and effectively to avoid potential threats. Various types of disaster warning systems, such as tsunami and fire warning systems, play a crucial role in informing

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people about possible disasters and risks [6-8]. Using the flood warning system provides users with information and awareness about flash floods in specific areas, allowing them to prepare and avoid getting trapped. Various methods have been utilized to detect floods, including the use of an ultrasonic sensor connected to an Arduino [9], Raspberry Pi, and NodeMCU with the Blynk application [10, 11]. Additionally, Twilio Cloud Communications APIs have been employed for sending SMS notifications [12], while a photodiode sensor is used for detecting infrared radiation [13].

However, several challenges have been identified. For instance, the photodiode encounters detection issues with transparent objects. There are also limitations regarding coverage, which extends only up to 50 meters between the mobile phone and the NodeMCU [11] and the high cost associated with subscribing to telecommunications services [12].

In this project, we propose a flood detection system designed for individual users and residential communities. The system will be powered by solar panels and connected via Wi-Fi. Its primary purpose is to provide early notifications about potential floods, particularly in areas prone to flooding or at risk of experiencing flash floods. Although the government offers various warning systems, such as water level alerts for rivers, early warnings based on weather forecasts, and the use of social media, these measures often do not cover many regions susceptible to flooding. Our system aims to bridge this gap and ensure that communities receive timely alerts to enhance their safety and preparedness.

Many studies have utilized the GSM mode due to its reliability and the fact that it operates without concerns regarding the distance between the consumer and the system. However, we focus on the Wi-Fi system, as we target a small urban community. According to a report by the Malaysian Communications and Multimedia Commission (MCMC) in 2019, the number of fixed broadband users increased by 10%, reaching 2.95 million [14]. This system consumes less than 1 MB per month, making using a SIM card for each NodeMCU system economically unfeasible. Further research can be conducted on the effective distance of the Wi-Fi signal, as well as the battery life and solar operation time of the NodeMCU system.

II. PROPOSED SYSTEM

A. System Design

This project uses NodeMCU as the microcontroller, ultrasonic sensor as the sensor to detect and measure the distance of flood in a particular level, solar panel as the source energy to recharge the battery and Wi-Fi as the medium to send the signal and information to the Blynk server and the mobile apps (Blynk) in the user's mobile phone. The solar panel will charge the battery, which is controlled by the charger controller connected to the microcontroller. This project will be held in a container with water flow as the artificial flood to test the effectiveness of this prototype. The NodeMCU has widely used the Arduino system for processing information from the ultrasonic sensor [15, 16]. This system will measure the water level to detect any increase that could lead to a flood. The ultrasonic sensor system has been tested directly on the water, and the improvement of this sensor by putting a pipe in it has improved its accuracy. Figure 1 shows the node circuit with an ultrasonic sensor.

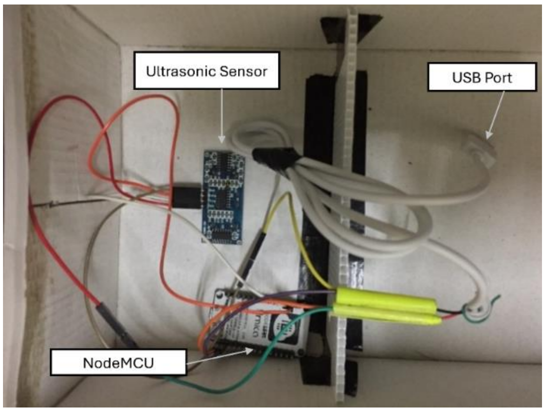

Fig. 1. Ultrasonic sensor connected with NodeMCU and USB.

The project utilizes an ultrasonic sensor to monitor water levels during a flood. This flash flood warning system is based on three key concepts: input, process, and output, as illustrated in Fig. 2 [17]. The input is obtained from the ultrasonic sensor to detect the increase in the water level. Next, the processed concept is when collecting data and signals from the sensor that will be processed using NodeMCU. Then, the output will be sent to the mobile phone application through Wi-Fi to the user through the Blynk application. This device will give early warning to the users that flash floods in that area.

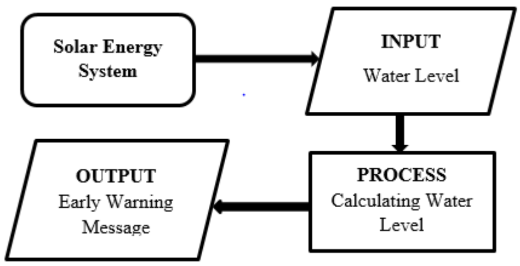

Fig. 2. Flowchart of flash flood warning system.

This system is powered by a rechargeable battery that charges from a solar panel. The solar panel collects sunlight and converts it into electrical energy. The solar system used in this device is low-cost, maintainable, and environmentally friendly [18]. Figure 3 shows the solar panel connections of this system.

B. Notification Message by Using NodeMCU

The NodeMCU will be connected to all nearby mobile phones. Still, the device needs a specific mobile application (Blynk) to connect with the Flood Detector to send the message and information to the nearby device. Figure 4 is a flowchart of information transfer between the NodeMCU and the mobile phone through Wi-Fi.

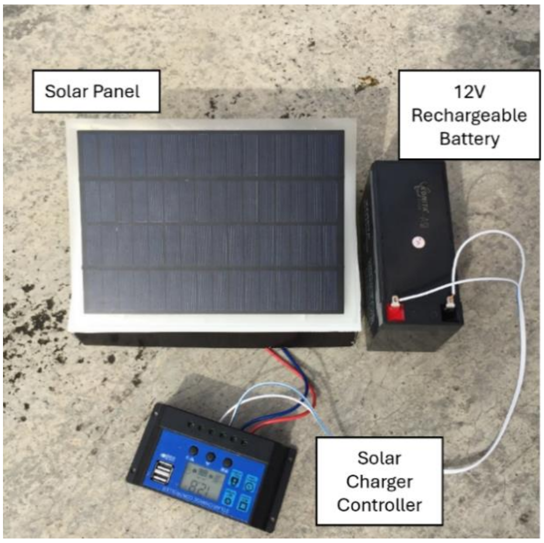

Fig. 3. Solar system with solar panel, 12V battery and solar charger controller.

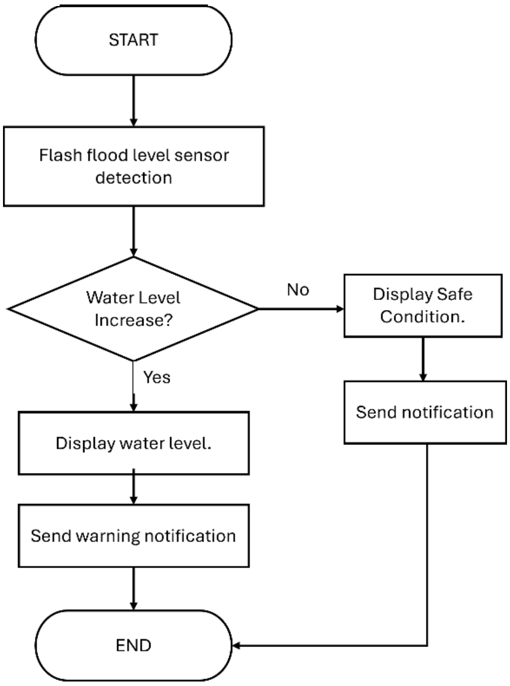

Fig. 4. Flowchart information transfer between the Wi-Fi Module and the Mobile Phone.

This Flash Flood Detector System will send a notification to everybody connected with the Wi-Fi from this device by using Blynk as a platform to show the information and notification. Each mobile phone must have the Blynk application to access the notification system. The application will be provided to the users through a link to download the mobile application. When the water level increases, the sensor will get triggered; the data will be sent to the microcontroller. Then, the system will send a notification to the users that the water level has reached a certain water level condition.

III. RESULTS AND DISCUSSION

This system has been developed using NodeMCU, an ultrasonic sensor powered by solar energy. The system was tested with and without a pipe to measure the water level and found that measuring using a pipe gives a better result. The actual system and design are shown in Fig. 5. This system is connected to the Blynk app to show the notification reflex to the water level. The signal and notification appear when the water level reaches a certain level (that has been set), as shown in Fig. 6.

This system was tested to measure the water level using an ultrasonic sensor only and compared with the system that connects with the pipe. Table I compares these two methods. Both methods show a good agreement with the actual water level measurement. It shows that the system-compile ultrasonic sensor and NodeMCU are working well. However, using the pipe, most results are near the exact measurement except for levels 20 and 25 cm. The data will be sent to the Blynk app, and a notification will pop up when the water level increases to a dangerous level.

Figure 7 shows that the distances taken from the ultrasonic sensor using a pipe are more accurate than the distance from the ultrasonic sensor without a pipe compared to the actual distance of the water level. At 20 cm to 25 cm, the ultrasonic sensor without a pipe shows more precise readings than with a pipe. When taking readings, the ultrasonic sensor was suspected to have some schematic or human error.

Fig. 5. A Flash Flood Warning System with a solar panel at the top and a pipe with the ultrasonic sensor at the bottom.

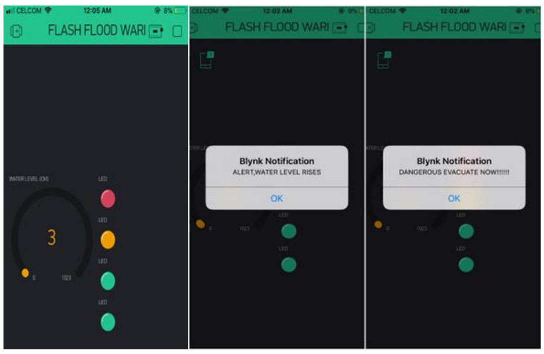

Fig. 6. Water level indicator with virtual LED and notification sent through Blynk apps.

Table I. The comparison of water level measurement using the Flood Detector System.

Real Water Level (cm)	Water Level Measured by Ultrasonic Sensor with Pipe (cm)	Water Level Measured by Ultrasonic Sensor without Pipe (cm)
5	5.2	5.4
10	10.5	10.7
15	15.7	15.9
20	21.2	20.3
25	25.8	25.5
30	30.3	30.6
35	35.3	36.0
40	40.0	41.6

The data from Table I are plotted in the graph in Fig. 7.

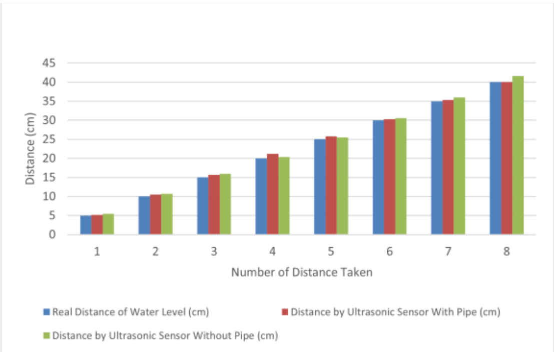

Fig. 7. Histogram of comparison water level between exact distance and ultrasonic sensor with pipe and without pipe.

Table II. Water level distance percentage error.

Real Water Level (cm)	Percentage Error: Measured by Ultrasonic Sensor with Pipe (%)	Percentage Error: Measured by Ultrasonic Sensor without Pipe (%)
5	4.0	8.0
10	5.0	7.0
15	4.7	6.0
20	6.0	1.5
25	3.2	2.0
30	1.0	2.0
35	0.9	2.9
40	0.0	4.0

The percentage error of electronic sensors with and without pipe can be calculated using the Eq. (1) below.

$$\left|\frac{\text{Approximate Value} - \text{Exact Value}}{\text{Exact Value}}\right| \times 100 \qquad (1)$$

The error of the distance from the ultrasonic sensor with the pipe is lower than without the pipe. This shows that using a pipe will give a more precise reading due to better echo, and the wave does not spread out by distance when using a pipe, resulting in a more accurate distance measurement at Table II.

IV. CONCLUSION

A flash flood warning system powered by solar energy and utilizing a NodeMCU is proposed to provide users with early warnings and information about potential flash floods in the area where the device is installed. The system uses solar energy to recharge a battery, which powers the microcontroller. An ultrasonic sensor detects rising water levels or flood levels. Notifications about flood conditions in the target area are transmitted to users via Wi-Fi through an app called Blynk. Data is collected by the ultrasonic sensor, both with and without a pipe, to compare the measurements against the actual water level.

The experiment uses a controlled setup where the range of water levels monitored is between 5 centimetres and 40 centimetres. This allows for easier experimentation and data collection. Results indicate that measurements taken with the pipe are more accurate than those taken without it. The average percentage error for the ultrasonic sensor with the pipe is 2.55%, while the average error without the pipe is 3.11%. This small percentage error is unlikely to impact the efficiency of the ultrasonic sensor when used in real-world conditions.

The Blynk app shows the virtual image and notification to the user, which is the water level distance from the water surface of the device, then an LED virtual image to show the condition of the flood condition, green LED for safe conditions, yellow LED for alert condition and red LED for dangerous condition. Then, the notification icon from the Blynk shows the warning message to the user about the flood condition, whether it is safe, alert for water level rises or dangerous conditions ready for immediate evacuation. The notification message will pop up on the phone screen, even when the phone is in the lock screen mood. This app can be shared with several people as long as they have a Wi-Fi connection.

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