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Smart Flood Monitoring System via IoT Platform for Early Warning of Road Closures Against Flood Events

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Abstract

Floods constitute a recurrent natural disaster impacting Malaysia and various global regions annually. This project concentrates on conceiving and executing an Internet of Things (IoT)-based smart flood monitoring system, with the objective of furnishing early warnings and notifications about road closures during flood events. Presently, authorities resort to manual methods, such as employing stakes to assess water levels on roads. However, this project aspires to institute a more effective system, obviating the necessity for manual measurements, allowing authorities to receive water depth warnings promptly. The principal goal is to harness IoT technology, specifically through the Blynk application, to formulate a user-friendly approach for authorities to monitor potential flood-prone road areas. For this purpose, the system relies on vital data, notably water levels, to discern increases during flood events. The Smart Flood Monitoring System through an IoT Platform for Early Warning of Road Closures Against Flood Events utilizes electronic components, particularly the Ultrasonic sensor and Durian UNO embedded controller, to emulate traditional measurement techniques. The Ultrasonic sensor assesses the flood level, transmitting data to the Durian UNO. The Durian UNO plays a pivotal role, incorporating an integrated Wi-Fi module (ESP-01) for data transmission to the Blynk application, facilitating real-time flood level monitoring. The project also encompasses a user-friendly prototype to enhance device usability. Testing encompasses both indoor and outdoor water level detection. The results indicate that the ultrasonic sensor method accurately measures flooded road water levels with a precision of 96.65%. This system empowers authorities to promptly announce vehicle restrictions or road closures in response to flooding.

1. Introduction

Floods are a common natural phenomenon in Malaysia, occurring almost yearly during the monsoon season. Malaysia experiences strong and consistent rainfall from October to March each year, resulting in flooding as a natural consequence of these cyclical monsoons [1]. When floods occur, they can cause significant loss of life, damage to properties worth millions of Ringgits, and destruction of agricultural and animal operations [2]. For instance, severe flooding in Kelantan recently devastated 11,099 hectares of agricultural land, affecting 6,309 farmers, breeders, and fishers, according to Datuk Seri Ismail Sabri Yaakob, the Minister of Agriculture and Argo-

Based Industry [3]. In Batu Pahat, Johor, there was a recent flood incident. According to a March 4, 2023 article in Berita Harian, eight highways in the Batu Pahat region were closed to all vehicles due to worsening floods [4]. Unfortunately, despite the availability of technology, there seems to be a lack of interest in implementing an early warning system for flooded road situations. In this scenario, the worker routinely visits the flood-affected area to conduct measurements. The manual measurement process involves the worker physically assessing and recording the water level at the site. This traditional approach, while providing on-the-ground data, may have limitations in terms of efficiency and real-time monitoring capabilities. One major drawback is the lack of an efficient water level monitoring mechanism. The existing system does not possess the capability to continuously monitor the water levels in real time. Another limitation is the absence of immediate notification to the local authorities when the water level rises. The current process involves manual measurements by workers, resulting in delays and inefficiencies in announcing road closures due to rising water levels. Additionally, during flood events, there are challenges related to limited communication systems and electricity availability. These constraints further hinder the effective dissemination of warnings and updates about road closures. To address these shortcomings, there is a crucial need to develop an early warning system that can overcome the weaknesses of the existing system. The goal is to provide the local authorities, such as JKR, with a reliable and timely notification system for road closures caused by rising water levels. The system should be capable of real-time water level monitoring, immediate communication of alerts, and functioning under limited communication and power availability conditions. By implementing such a system, authorities can make prompt and informed decisions regarding road closures without the need for manual measurements, saving time and resources. The concept of the Internet of Things (IoT) is not unfamiliar in Malaysia, as it allows users to control various devices and objects. Building upon this concept, a device can be designed to assist authorities in monitoring the water level of flooded roads using a smartphone, providing real-time information and alerts based on user preferences. This initiative endeavors to confront these challenges through the creation of a prototype that is both user-friendly and economically efficient, utilizing Internet of Things (IoT) technology. The objectives of the project include developing a simple smart flood monitoring system aimed at offering real-time guidance on road closures to admin, implementing a simple monitoring system that can be customized based on users' preferences and abilities. The aim is to analyze its accuracy, usability and reliability by conducting indoor and outdoor testing.

2. Research Methods

For the prototype to achieve success, the ultrasonic sensor must accurately measure the height of the water level. The controller of the system which is Durian Uno is integrated with the ESP8266, is required to be connected to the battery for proper functioning. The Durian Uno is designed to acquire data from ultrasonic sensors for the purpose of monitoring water levels. Subsequently, the Durian Uno will transmit this data to the Blynk platform utilizing the ESP-01 module. The collected data will be transmitted to the Blynk application, and administrators will receive updated warnings through Gmail. Consequently, this system empowers users to monitor the data effectively, as illustrated in Fig. 1.

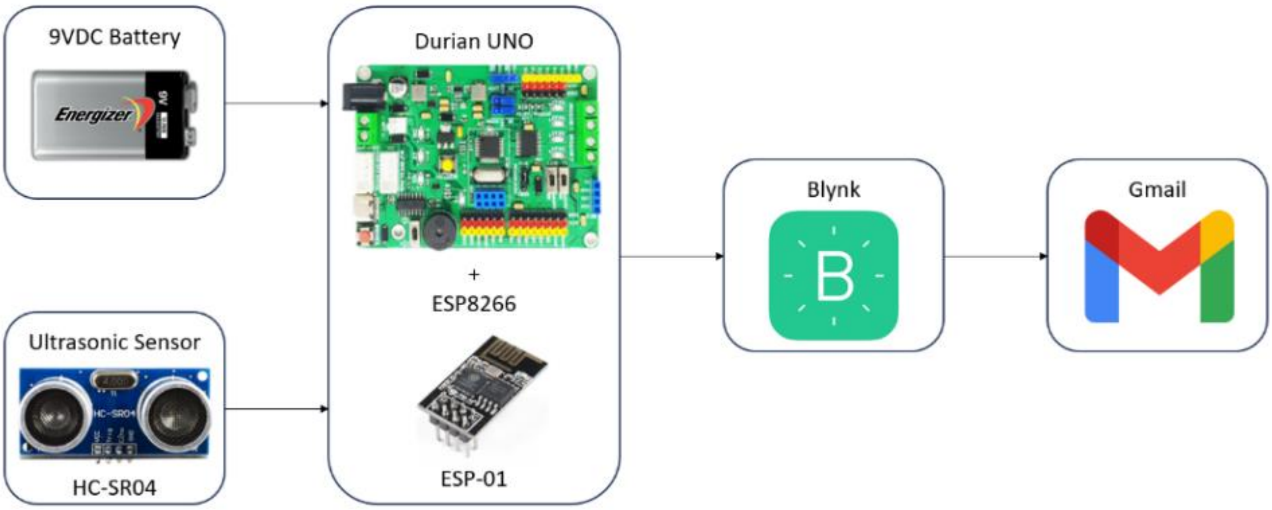

Fig. 1 *Block diagram of the road closure's early warning*

Fig. 2 illustrates the conceptual framework of a Smart Flood Monitoring System designed to provide early warnings for road closures. This innovative system utilizes the Blynk platform to send notifications directly to users' Gmail accounts. The integration of Blynk with the monitoring system enhances its communication capabilities, ensuring that timely alerts reach users, enabling them to take proactive measures in response to

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potential flooding events. In this context, the Blynk platform acts as a bridge between the smart flood monitoring system and end-users, facilitating the transmission of critical information through Gmail notifications. The concept is rooted in leveraging the power of real-time data and advanced communication channels to enhance the effectiveness of early warning systems.

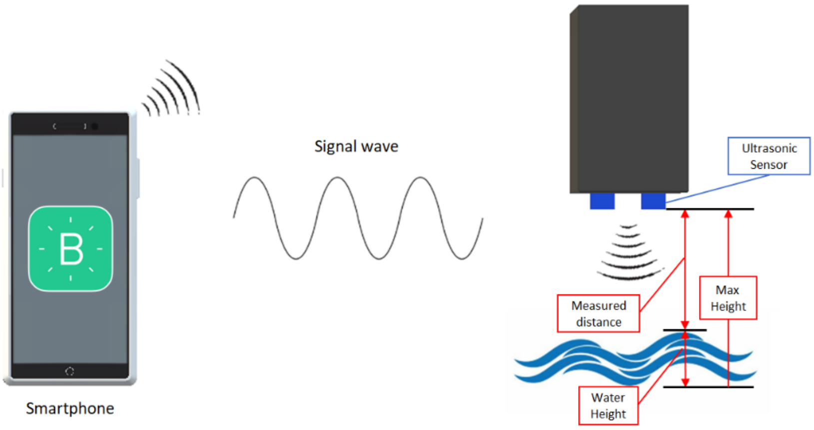


Fig. 2 *Block diagram of the road closure's early warning*

This section delineates the flowchart of Smart Flood Monitoring System via IoT Platform for Early Warning of Road Closures Against Flood Events. The project encompasses two distinct flowcharts: the comprehensive project flowchart and the Blynk process flowchart. Fig. 3 depicts the Blynk process flowchart. Once the device establishes a successful connection to the Blynk database, the Ultrasonic sensor will read the water level using the "duration_us" command as programmed. Subsequently, all the acquired data will be transmitted to the Blynk application. It is important to note that the display unit for the data is in centimeters, as specified in the programming under "distance_cm."

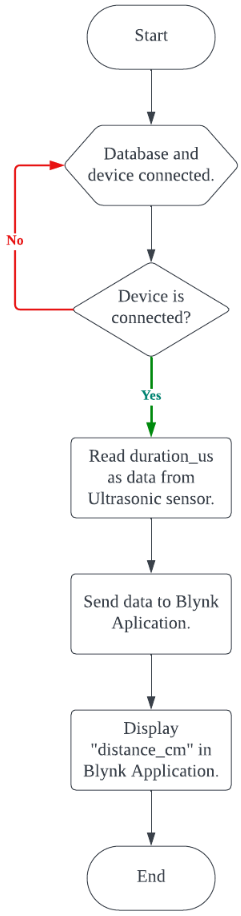


Fig. 3 *Blynk process flowchart*

Fig. 4 illustrates the complete flowchart of the project; the initial stage involves measuring the water level using an ultrasonic sensor. This stage divides the water level into three conditions. The first condition checks if the water level is below 35cm; if so, the system will measure the water level again as it is at a safe water level. If the water level does not meet the first condition, it proceeds to the second condition, checking if the water level is between 36cm to 74cm. In this case, a warning sign stating "Only heavy vehicles can pass through" will be sent to Gmail via the Blynk platform. If the water level does not meet the second condition, it then checks the third condition, verifying if the water level is above 75cm. If so, a warning sign stating "Road closed for all vehicles" will be sent to Gmail via the Blynk platform. If the water level measured by the ultrasonic sensor does not meet any of the three conditions, the sensor must repeatedly measure the water level until it obtains a valid reading.

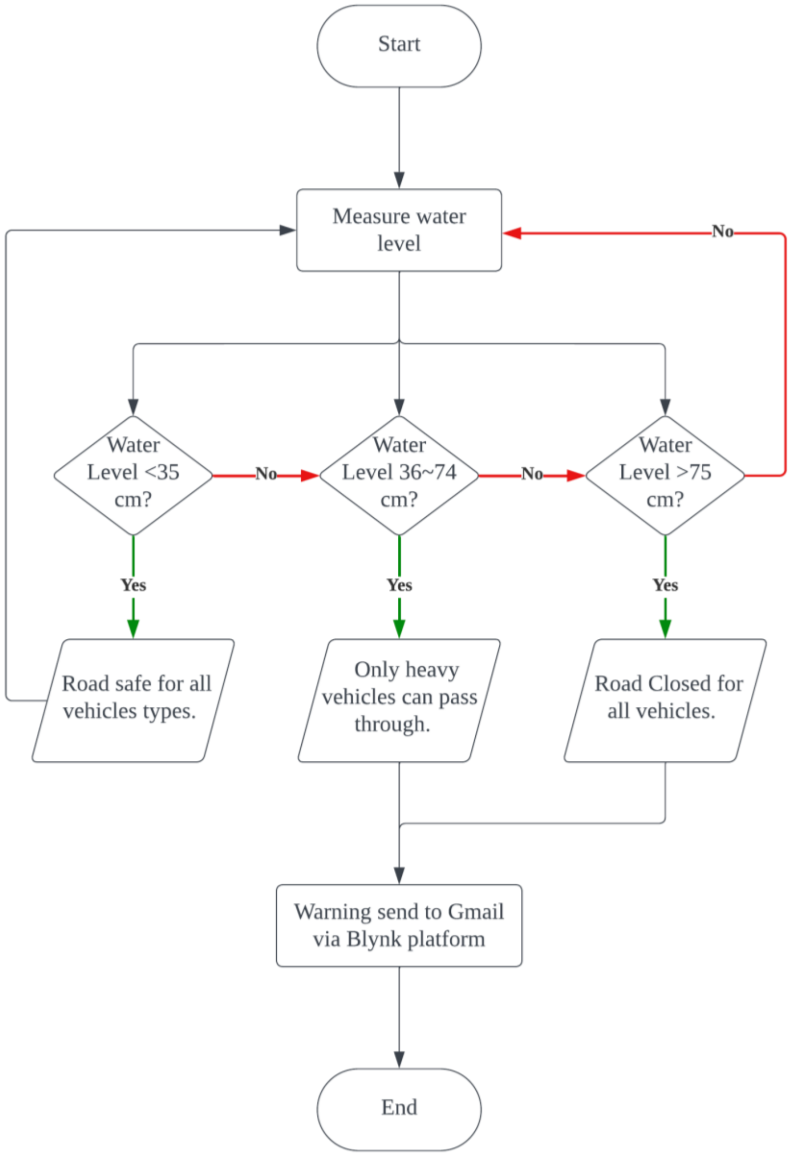


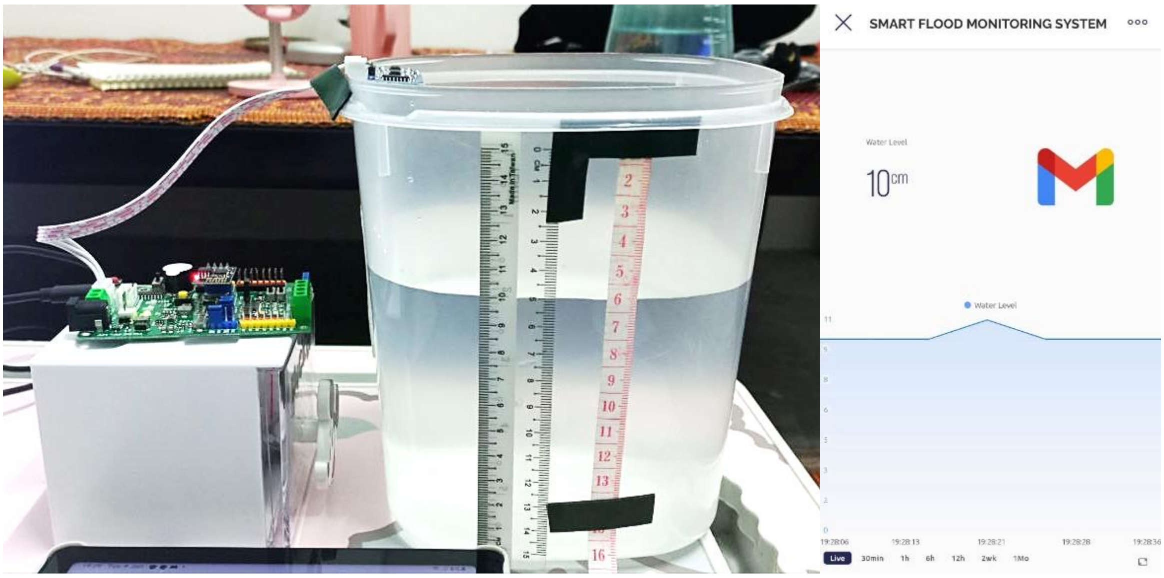
Fig. 4 *The flowchart of overall system*

3. Result and Discussion

Upon the conclusion of the project, it underwent testing. Successful achievement was noted in the wireless communication and transmission of data between Durian UNO and Ultrasonic sensor. The sensed data were displayed through the Blynk application and concurrently recorded in the database developed within the Blynk application. This prototype underwent testing in two distinct locations, and the ensuing results are deliberated upon in the subsequent sections.

3.1 Hardware and Software Testing

Following the completion of software testing, the next step is proceeded with hardware and software testing. The purpose of this testing phase is to verify the integrity of the connections among all components, ensuring a seamless transition from input to output. Additionally, it aims to ascertain that the Blynk application effectively displays the data captured by the prototype. Fig. 5 illustrates the testing involving a container with height of 16cm filled with water.



(a) (b)

Fig. 5 *(a) Testing conducted with container filled with water and (b) Height of water level*

3.2 Blynk Application

Fig. 6 shows the Blynk interface displayed on a smartphone, and Fig. 7 showcasing the integration of a warning system through Gmail.

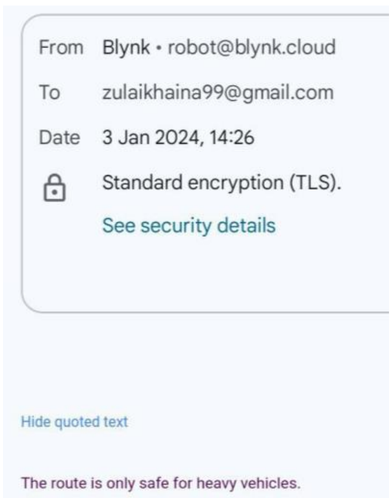


Fig. 6 *Blynk Interface on Smartphone*

Fig. 7 *Warning received via Gmail*

The visual representation captures the user interface on the mobile device, emphasizing the interaction with the Blynk platform. This setup not only allows for real-time monitoring and control through the smartphone but also incorporates a warning mechanism via Gmail, providing a comprehensive and user-friendly solution for communication and alerting in the depicted system. The reading of data sense from the ultrasonic sensor from Durian UNO in Blynk application platform. Table 1 shows, three modes of integration of this system which is safe, warning and danger.

Table 1 *Summary of the system*

Measurement (cm)	Level	Alert
0-35	Safe: The route is safe for all types of vehicles.	Off
>35 and <74	Warning: The route is only safe for heavy vehicles.	On
>75	Danger: The route is closed to all types of vehicles.	On

3.3 Test Rig

To test the effectiveness and the accuracy of this prototype, there were two types of work which have been conducted. Details of the work will be explained below. The indoor experiment was conducted in particular house at Taman Maju Bistari, Parit Raja, Johor. The prototype of the water tank was placed in the bathroom. Then, the first hardware will be hang-on above the prototype. The second hardware (act as control unit) was placed in the living room. For the outdoor experiment, it was conducted at Taman Maju Bistari's drainage canal (parit). The first hardware is put in the canal, while the second hardware (acting as the control unit) was placed near the canal.

3.3.1 Indoor Water Level Detection

For the indoor experiment, the water level testing is tabulated in Table 2. Table 2 presents the outcomes of ultrasonic sensor testing, detailing measurements (M) alongside corresponding water levels in centimeters for both the ultrasonic sensor and manual readings. The success percentage reflects the accuracy of the ultrasonic sensor, with minimal errors observed. The largest discrepancy is found in Measurement 3 (M3) with a 9.09% error, while Measurement 6 (M6) boasts the smallest error at 0.99%. The overall average error across all measurements is 3.35%, indicating a high level of precision in the ultrasonic sensor readings. The average success rate stands at 96.65%, affirming the reliability and effectiveness of the ultrasonic sensor in accurately gauging water levels.

Table 2 *Comparison between Ultrasonic sensor reading and manual measurement*

Measurement (M)	Ultrasonic sensor, cm	Manual, cm	Percentage difference, %
M1	9	9.1	1.09
M2	7	7.4	5.41
M3	5	5.5	9.09
M4	4	4.3	6.98
M5	3	3.3	9.09
M6	10	10.1	0.99
M7	12	12.3	2.44
M8	8	8.1	1.23
M9	11	11.2	1.79
M10	6	6.3	4.76
Total	75	77.6	3.35

3.3.2 Outdoor Water Level Detection

For the outdoor experiment, it was conducted at Taman Maju Bistari's drainage canal. The Water Level Acquisition System is put in the canal, while the Control Unit was placed near the canal. Referring to Fig. 8 is the set-up of the experiment where the level of water in the canal is tested to see the validity and the measurement using ultrasonic sensor and Blynk applications. Based on the results obtained in Fig. 9, the values are around 29.75 cm to 36cm. The graph is shown in Fig. 9 where it is keep changing. The trend of the graph reflected to the surface of water which influenced by rubbish or other materials appear in the lake.

(a) **(b)**

Fig. 8 *(a) Water Level Acquisition System and (b) Control Unit*

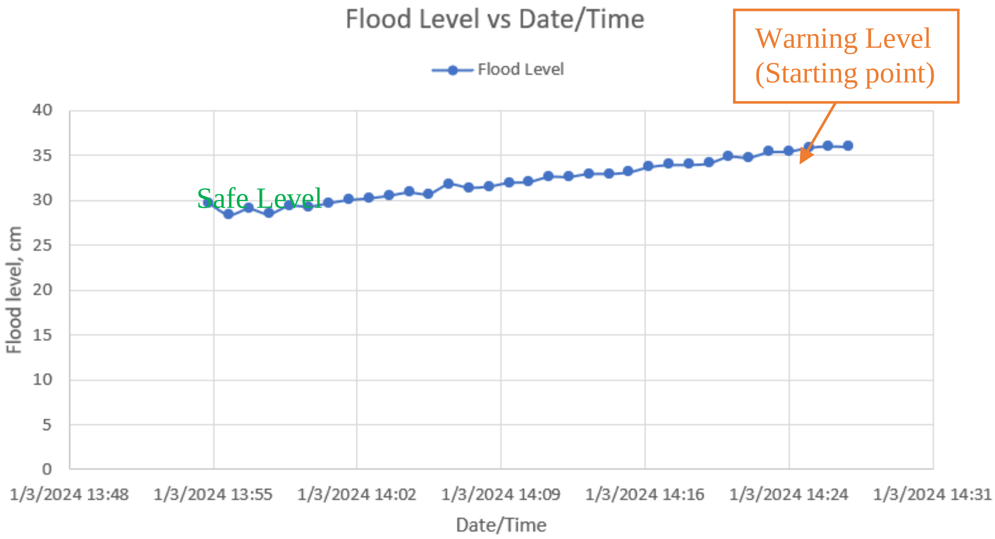


Fig. 9 *Graph of flood level*

4. Conclusion

The project culminates with success in attaining its objectives, contributing to the enhancement of knowledge in electrical design and device communication. The Internet of Things (IoT) proves instrumental in enabling users to monitor floods and provides real-time guidance on road closures. Suggestions for future enhancements encompass exploring strategies for leveraging multiple sensors to enhance the precision of water level readings. Additionally, the proposal involves integrating cloud-based data processing for dynamic routing during flood conditions and facilitating real-time updates on maps. A collaborative effort with experts is recommended to develop a more robust and effective monitoring and alerting system.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Zulaikha;* ***data collection:*** *Zulaikha;* ***analysis and interpretation of results:*** *Zulaikha;* ***draft manuscript preparation:*** *Zulaikha and Farhana. All authors reviewed the results and approved the final version of the manuscript.*

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