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FloWMS: Flood Rapid Warning and Monitoring System

Muhammad Hazizan Kadir[1,2], Radzi Ambar[1,*], Mohd Helmy Abd Wahab[1], Khalid Isa[1], Herdawatie Abdul Kadir[1], Dedi Suryadi[3], Muhammad Mahadi Abdul Jamil[1]

[1] Department of Electronic Engineering, Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400 Batu Pahat, Johor, Malaysia
[2] Ipex Global Manufacturing (M) Sdn Bhd, No 1, Jalan Teknologi, Taman Teknologi, Taman Nusa Perintis 2, 79200 Iskandar Puteri, Johor, Malaysia
[3] Department of Mechanical Engineering, University of Bengkulu, Sumatera, Bengkulu 38371, Indonesia

ABSTRACT

Flood Rapid Monitoring and Warning System (FloWMS) is a portable and cost-effective system designed to be applied in areas potentially affected by floods. The objective of this project is to assist the authorities in monitoring river water levels at specific locations and serve as a warning system to notify people of dangerous water level situations. The system comprises of an ultrasonic sensor used to measure the differences between the initial water level and the current water level. It also includes three float sensors that provide information on three water levels, corresponding to three warning messages: ALERT, BEWARE, DANGER. The uniqueness of the system is the incorporation of a flow rate sensor, which can measure the velocity of the water flow. To deliver warnings, the system utilizes the Short Message System (SMS) through a GSM SIM900A module. The product is equipped with LEDs that indicate the status of water level, as well as a water level alarm buzzer that informs people of the dangerous water levels. The proposed system aims to rapidly monitor abnormal changes in water levels and flow, enabling early detection of potential floods. The system demonstrated effective real-time data collection, analysis and warning messages, highlighting its effectiveness as an emergency flood monitoring and warning system.

Keywords:

Flood warning; monitoring system; Float sensors; Flow rate sensors; GSM SIM900A; Microcontroller

1. Introduction

Floods inflict the heaviest financial burden compared to other natural disasters causing immense economic devastation on a global scale [1-10]. Based on the United Nations (UN), floods cause the most fatalities compared to any other type of disaster [11]. In Malaysia, floods are among the most frequent disasters, particularly during the year-end monsoon season. These events can inflict devastating consequences, leading to fatalities and substantial property losses [12-15]. While low-lying areas near rivers are especially susceptible, flooding can also disrupt cities and metropolitan areas like Kuala Lumpur and Pulau Pinang. The recent tragedy in Shah Alam resulted in at least 16 deaths, with thousands temporarily displaced due to inadequate drainage systems that could not

* *Corresponding author.*
E-mail address: aradzi@uthm.edu.my

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handle the excess rainwater [16]. It is increasingly evident that human activities play a significant role in the frequency and severity of floods. Unchecked development, construction encroaching on rivers and widespread deforestation disrupt the delicate ecological balance. For example, forests act as natural sponges, playing a crucial role in absorbing rainwater and regulating water flow. The intensification of flood risks can be attributed to deforestation that results in increased rainwater runoff and overloaded drainage systems. Thus, addressing these human-induced factors is vital to mitigating the impact of floods and safeguarding communities against future disasters.

Floods due to natural phenomena can be broadly classified into three distinct categories based on their cause and characteristics [17]:

i. Flash floods are triggered by brief yet rapid and intense rainfall, commonly in mountainous and sharply sloped watershed areas. Flash floods are often accompanied by additional hazards such as mudflows and rockslides.
ii. In contrast, river floods occur due to prolonged periods of heavy rainfall, leading to rivers overflowing their banks and flooding adjacent areas. This process is gradual and continues for an extended period.
iii. Coastal floods result from severe meteorological conditions that elevate water levels in vast water bodies, caused by a blend of low atmospheric pressure and powerful winds. These incidents typically happen in proximity to oceans, seas or expansive lakes.

A flash flood is a rapid flood that happens within 6-7 hours after heavy rainfall and often within 2 hours of the onset of high-intensity rain [17]. It is best defined as a swift rise in river water levels, extending beyond the river's banks. Therefore, it is most likely to appear at the river's edge. Flash floods may develop when multiple thunderstorms strike the same location. They are less likely to occur when storms move quickly, as the rain spreads out over a larger region. Flash floods can also occur even without recent rain, for example, when levees or dams break or when water is suddenly released by debris. Since flash floods are triggered when water and debris flow down from hillside areas, estimating flash flood occurrence can be achieved rapidly by measuring the rainwater flow rate in the surrounding hillside area. Therefore, an abnormal or sudden increase in water flow can serve as an early warning of an impending flash flood.

This project focuses on developing a Flood Rapid Monitoring and Warning System (FloWMS), a portable and cost-effective rapid flood monitoring system designed to monitor water levels and flows periodically, particularly along riverbanks. The proposed portable flood monitoring system can be deployed at rivers to monitor sudden increases in water levels or areas prone to frequent excessive water overflow. In the system design, water level measurement is achieved by measuring discharged water, typically using float and ultrasonic sensors. Flash floods resulting from sudden heavy rainfall in hillside areas can be estimated by measuring water velocity using flow rate sensors. FloWMS employs a multi-level approach to flood level determination by categorizing water levels as low, medium, high and highest. This categorization provides in-depth information into flood conditions at various stages for effective monitoring and early warning.

The rest of this paper is structured as follows. Section 2 describes some previous related works. Section 3 introduces the materials and methods, and experimental data and analyses are explained in Section 4. Section 5 concludes the study with conclusions and recommendations.

2. Related Works

Flood monitoring and warning systems play a crucial role in mitigating the impacts of floods by enabling early detection and timely transmission of alerts to the public and local authorities. The existing literature discusses various technologies and approaches for flood monitoring and warning, ranging from traditional flood systems to modern Internet of Things (IoT)-based solutions. For instance, a study introduced the Flood Alert Notification System (FANoS) which utilizes a water level sensor to detect three (3) water level conditions: ALERT, BEWARE, and DANGER [18]. The system employs a siren unit, LED notifications and a GSM module to send SMS alerts to notify the public about the flood situation. The integration of a solar panel as the main power supply ensures cost-effectiveness and ease of maintenance.

Similarly, another research introduced the Flood Detection and Warning System (FLoWS), that helps monitor flood occurrences [19]. FLoWS provide information related to flood situations, preparation plans and updates to local authorities and the public. It employs an Arduino UNO microcontroller for data processing and a GSM module for remote SMS alerts on water levels. Three (3) float sensors provide ALERT, BEWARE, and DANGER conditions, while an ultrasonic sensor ensures accurate readings. Additionally, a flow rate sensor detects flash floods rapidly. The electronic system powered by a 7.4V battery, is enclosed in a waterproof box mounted on a 2.1-meter vertical stainless-steel structure for river deployment. Three (3) LEDs indicate water levels, an embedded LCD displays sensor readings and a buzzer alert nearby people.

Another innovative approach describes a real-time flood monitoring and prevention system utilizing IoT sensors that serve the information received from the flood situation to the local authorities and the public [20]. The system comprises a miniature model with interconnected IoT sensors, a mobile app for user interaction and a server with a database. The IoT sensor hardware includes a water flow sensor to monitor water volume, a water level sensor for flood detection and a stepper motor simulating a road barrier. This approach shows great potential for enhancing flood preparedness and response while contributing to improved disaster management strategies.

Moreover, Zhang *et al.*, proposed a flood monitoring system employing Geographic Information System (GIS) technology, regional growth algorithm and Gaofen series satellite data for swift extraction of flood information [21]. The integration of these technologies allows for timely and precise determination of flood ranges which significantly enhances flood monitoring capabilities.

In contrast, government-managed flood management systems typically integrate flood monitoring, forecasting and warning systems to provide essential data for flood management. In Malaysia, the Department of Irrigation and Drainage operates government-managed flood management systems that integrate flood monitoring, forecasting and warning systems to provide essential data for flood management. These systems are stationed in Operations and Flood Monitoring Rooms across the country, receive real-time data and facilitate faster information transmission compared to the traditional Short Messaging System (SMS). This online system directly receives data which enables smooth handling of operations, forecasting and flood monitoring. It outperforms the SMS method by ensuring quicker access to critical information. Specifically, the system operates based on predefined programming in the flood monitoring master that triggers alerts and warnings when the water level reaches critical thresholds (alert level, warning, and danger). Additionally, if rainfall exceeds 60mm, the system activates to respond promptly to potential flood events. This comprehensive approach is commonly known as the Telemetry System. The integration of real-time data, faster information transmission and proactive alert mechanisms makes the Telemetry System a valuable tool in flood monitoring and management. By providing timely and accurate data, this system aids in reducing the impact of floods and enhances disaster preparedness and response efforts.

Despite the advantages of existing flood monitoring systems challenges persist. The high cost of installing fixed monitoring stations limits their deployment to specific locations. Furthermore, the rapid rise of water levels leaves little time for population evacuation. Therefore, there is a need for the development of a rapid, low-cost flood monitoring and warning system to address these issues effectively. In this study, the development of a flood rapid monitoring and warning system (FloWMS) is presented. The proposed FloWMS aims to address the limitations of existing flood monitoring systems offering a cost-effective, rapid and reliable solution for flood detection and early warning. By providing real-time data and timely alerts, FloWMS can assist in flood management efforts by reducing the impact of floods on communities and infrastructure. FloWMS consists of an Arduino UNO microcontroller to efficiently process sensor data accompanied by a GSM module for remote SMS alerts regarding water levels. Three (3) float sensors are employed to determine three (3) distinct water level conditions: ALERT, BEWARE and DANGER. Furthermore, an ultrasonic sensor ensures precise water level readings, while a flow rate sensor enables rapid detection of flash floods.

3. Methodology

3.1 Overview of FloWMS

Figure 1 illustrates the block diagram detailing the complete Flood Rapid Monitoring and Warning System (FloWMS) system. The input components consist of an ultrasonic sensor and three (3) units of float sensors designed to record and collect data on water level for precise monitoring. Additionally, a water flow sensor is integrated to measure water velocity that provides information about the speed and volume of moving water to predict flood dynamics. These components are integrated via the Arduino UNO microcontroller that processes and manages the incoming data from all sensors. On the output side, three (3) LED units serve as indicators for the float sensors, distinguishing between ALERT, BEWARE and DANGER water level conditions. This visual feedback mechanism is important for quickly informing the current flood risk status. Furthermore, an LCD screen is used to display the collected data in real-time. To enhance warning capabilities, a buzzer is utilized as an alarm specifically activated when the water level reaches the third float sensor, indicating a DANGER level. Additionally, to alert the responsible personnel promptly, a GSM SIM900A module is used to send SMS notifications if the water level reaches BEWARE or DANGER levels. This ensures timely responses to potential flood situations, thereby minimizing risks and facilitating effective flood management. By integrating these technologies, FloWMS not only improves the accuracy and reliability of flood monitoring but also enhances the system's overall responsiveness.

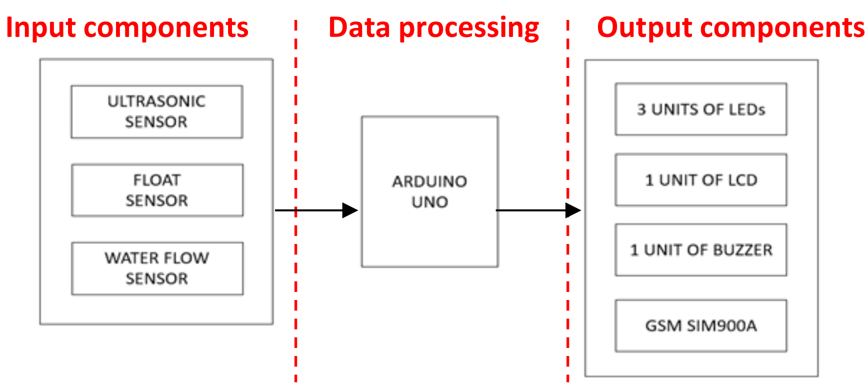


Fig. 1. Block Diagram for FloWMS

3.2 Water Level Measurement

Figure 2 shows the flowchart for measuring the water level. When the prototype is turned ON, all sensors are initialized, and the measurement process starts. As the water level rises and reaches the first float sensor (Level 1), the green LED is activated, and the LCD displays the corresponding water level value. This provides an initial indication of the rising water level. Subsequently, when the water level reaches the second float sensor (Level 2), the yellow LED turns ON, and the LCD continues to display the water level value. At this point, the system triggers the GSM module to send an SMS alert to the user's phone, cautioning them about the escalating water level with the message "BEWARE OF THE WATER LEVEL". This alert serves as an early warning to stay vigilant. As the water level further rises and reaches the third float sensor (Level 3), the red LED is illuminated, and the buzzer starts to sound continuously. Simultaneously, the LCD updates to display the current water level value. Moreover, the system activates the GSM SIM900A module to send a critical SMS to the specified phone with the message "DANGER!! PLEASE EVACUATE TO HIGHER GROUND." This urgent alert urges individuals to take immediate action and seek safety. Based on this flowchart, the prototype effectively monitors water levels and communicates crucial information to users in real-time. The combination of LEDs, LCD, GSM module and buzzer ensures comprehensive and timely warnings, facilitating proactive responses to potential flood hazards.

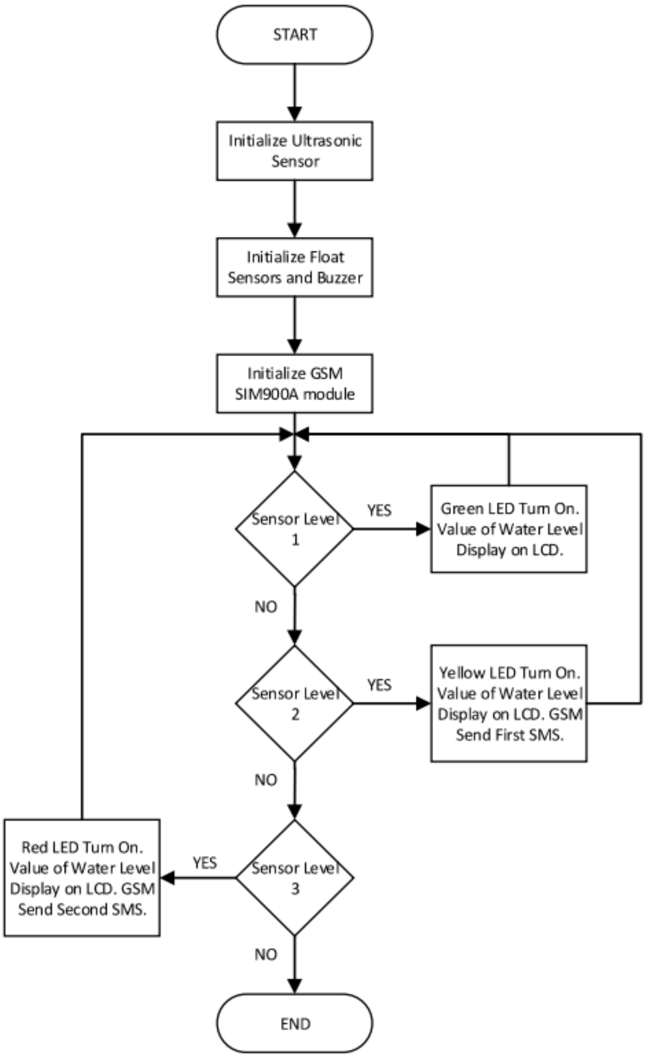


Fig. 2. Flowchart for Transmitting SMS

In the design of FloWMS, water level measurement is achieved using both ultrasonic and float sensors. The ultrasonic sensor emits ultrasound at a frequency of 40 kHz, which travels through the air and bounces back to the module upon encountering an object or obstruction. The distance is then determined based on the speed of sound and the time taken for the sound wave to travel. To initiate the measurement, the trigger pin is set to a high state for 10 seconds, generating an 8-cycle sound burst that travels at the speed of sound and is subsequently received by the Echo pin. The duration of the sound wave's travel, measured in microseconds, is output via the Echo pin. Thus, the ultrasonic sensor provides the water level value, or distance measurement, between the sensor and the water's surface. On the other hand, the float sensor is responsible for capturing and detecting data as the water level rises. In the proposed prototype, three (3) units of float sensors are utilized to record and collect water level data effectively. The system utilizes three (3) units of LEDs that indicate the current water level situation (ALERT, BEWARE or DANGER) to show the water level information to the users. An LCD is used to display precise water level value obtained from the sensors. Additionally, the system incorporates a GSM SIM900A module that receives data from the Arduino, including information about the rising water level. If the water level reaches a critical condition (BEWARE or DANGER), an SMS alert is sent to the users, while a buzzer sounds to signify the dangerous water level. By integrating both ultrasonic and float sensors, FloWMS provides accurate and reliable water level measurements.

3.3 Water Flow Measurement

Figure 3 shows the flowchart of water flow measurement. When the device is turned ON, all sensors are initialized for data collection.

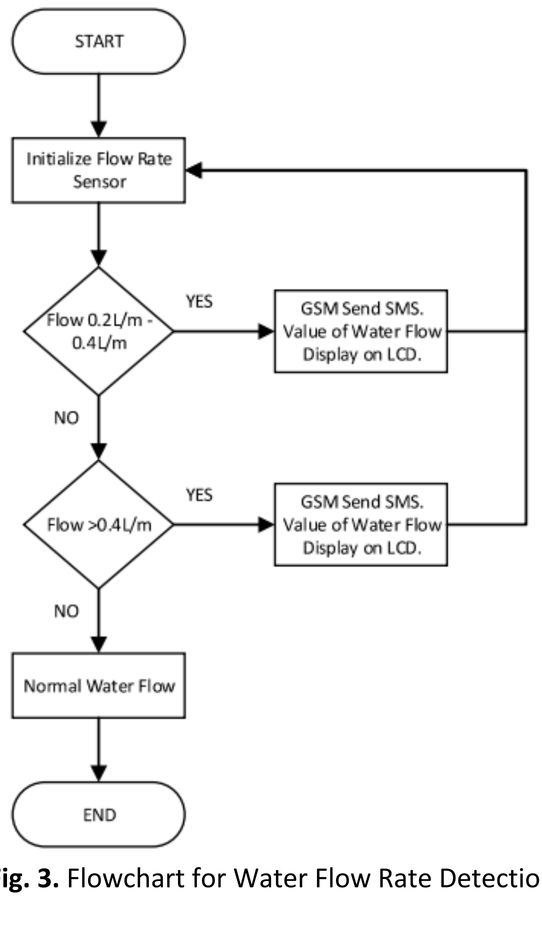


Fig. 3. Flowchart for Water Flow Rate Detection

The flow rate sensor continuously records the flow reading and displays it on the LCD. If the recorded value falls between 0.2L/m and 0.4L/m, the GSM SIM900A module triggers an SMS message to be sent to the user, stating: "WATER FLOW STATUS – BEWARE." This alert warns users about a moderate flow rate, prompting them to remain cautious. In the case where the flow rate sensor detects a reading exceeding 0.4L/m, the GSM SIM900A module sends another SMS message: "WATER FLOW STATUS – DANGER!!". This critical warning signals a high flow rate, indicating a potentially hazardous situation. However, if the sensor records a flow reading below 0.2L/m, the GSM SIM900A module remains inactive, indicating normal water flow condition. Based on these measurements, users can effectively identify water flow conditions in rivers or drains. The system enables rapid monitoring of dangerous flood conditions, allowing individuals to take appropriate precautions and respond swiftly to potential flood risks.

3.4 Circuit Design

Figure 4 presents the circuit design for the proposed FloWMS, as illustrated using Fritzing software. As shown in the figure, the system incorporates three (3) types of sensors: ultrasonic, float and flow rate. At the heart of this prototype is an Arduino UNO microcontroller, responsible for processing data from all the sensors. The LCD serves as a display, showing readings from both the flow rate and float sensors, providing valuable water level information to users. Meanwhile, three (3) LEDs act as indicators for different water levels: ALERT, BEWARE and DANGER. These LEDs visually communicate the severity of the water level conditions. To ensure timely warnings to users, a GSM SIM900A module is integrated into the system. The module sends warning SMS messages to users, alerting them to potential flood situations. Additionally, a buzzer is utilized as an audible alarm, activating when water levels reach dangerous thresholds (BEWARE and DANGER). This audible alert enhances the system's effectiveness by providing another layer of notification to users.

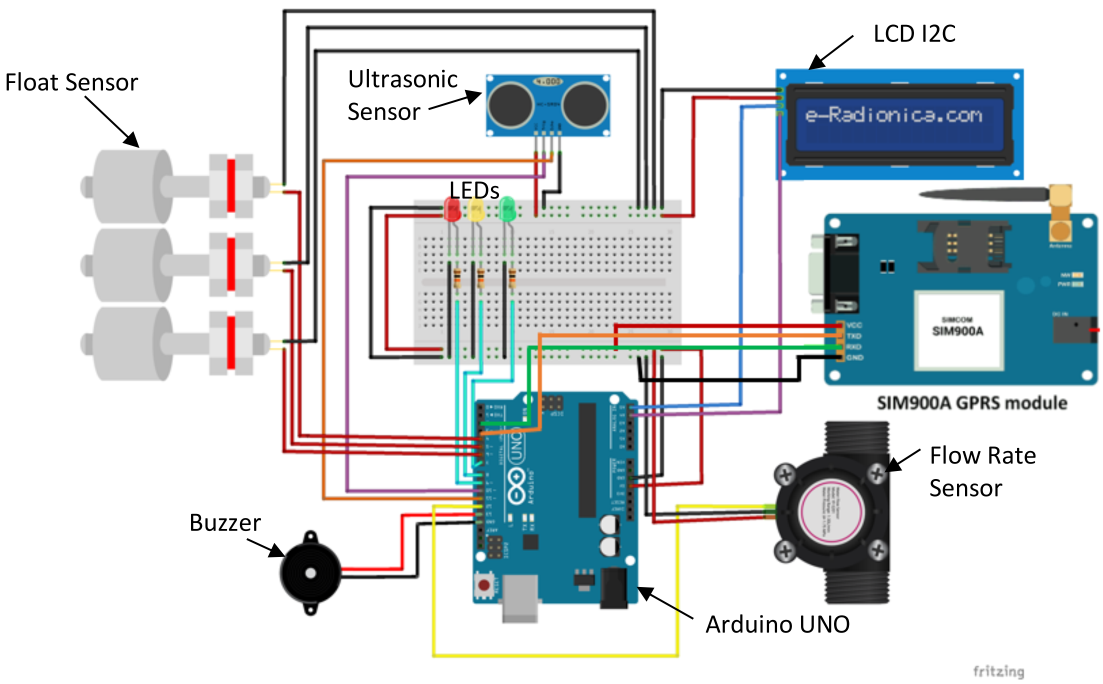


Fig. 4. Circuit Design of FloWMS

3.5 Hardware Design

Figure 5 shows the front and back views of the waterproof box of the developed prototype. Figure 5 (left figure) shows the front external view of the waterproof box that houses most of the electronic circuits. As depicted, an LCD is positioned at the centre of the box to show the sensors readings and water levels. Below the LCD, a buzzer produces a warning alarm sound to alert nearby people. The front panel also shows the positions of three (3) LEDs that display three different water levels: green for low, yellow for medium and red for high. Figure 5 (right figure) shows the rear view of the waterproof box. The box is attached to a 2.1-meter-long vertical stainless-steel tripod stand that can be positioned in deep rivers. The figure demonstrates the method of securing the box to the upper end of the tripod stand using heavy-duty cable ties.

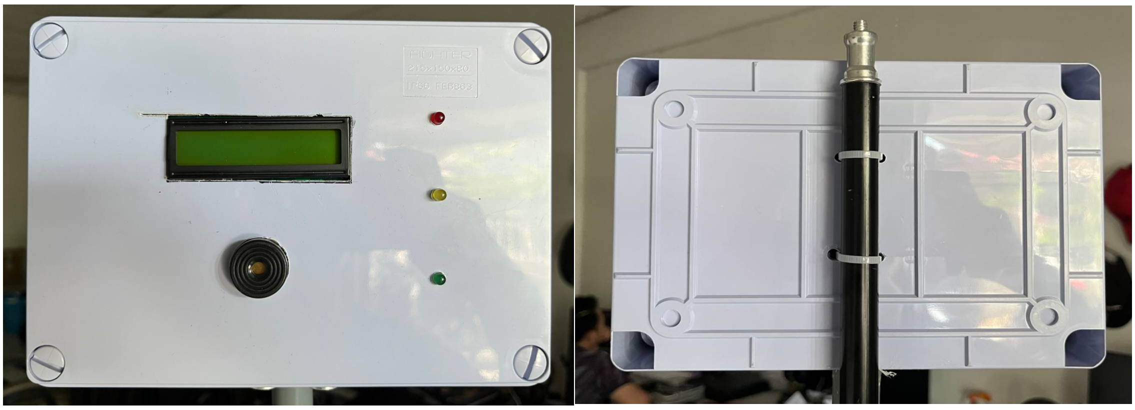


Fig. 5. Views of the waterproof box. Front view (left), back view (right)

The prototype design incorporates several components to ensure its functionality and durability. A 1.6 meters long PVC tube is attached to the lower part of the box, through which all the wires from the float and flow rate sensors are routed and connected to the Arduino UNO inside the waterproof box. Special attention has been given to the connection between the PVC tube and the waterproof box to maintain the waterproof integrity of the system. This connection is sealed with epoxy glue, a durable and water-resistant adhesive to ensure no water can infiltrate the box and damage its sensitive electronics. Watertight sealing is a crucial design consideration, as the prototype is intended for use in environments where water exposure is inevitable, such as rivers or other water bodies.

Figure 6 shows the view of the lower part of the box. The placement of an ultrasonic sensor is clearly depicted in the figure. The purpose of the ultrasonic sensor is to accurately measure the distance between the sensor and the water surface that allows the prototype to monitor water levels with precision and reliability. Notably, the sensor's positioning ensures that there are no obstacles in its path that could potentially interfere with the accuracy of the readings. The PVC tube plays an important role in FloWMS design. It serves as the platform for installing three (3) float sensors at different locations along the tube.

Fig. 6. Lower view of the waterproof box

Each float sensor is connected to an L-shaped tube, as shown in Figure 7. The figure shows an example of the attachment method for the float sensor. The wires connecting the float sensors to the Arduino UNO microcontroller are safely contained within the PVC tube for proper organization and protection.

Fig. 7. Float sensor attachment method

Figure 8 shows the primary circuit stored inside the waterproof box. The figure shows the placement of the Arduino UNO microcontroller and GSM module in the upper half of the box. Additionally, the wires for the buzzer, LCD and LEDs are neatly arranged and connected. The Arduino UNO acts as the central hub that facilitates communication between all the sensors. The wires connecting the Arduino UNO to the other sensors are routed through the PVC tube.

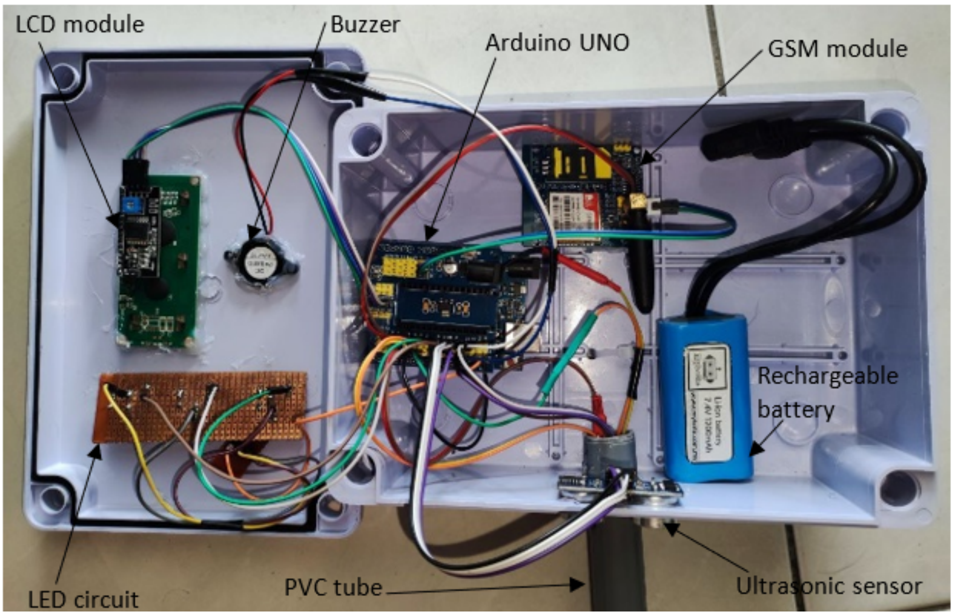


Fig. 8. Internal view of the waterproof box

Figure 9 shows the method of installing the flow rate sensor. The sensor is positioned at the bottom of the tripod stand. The flow rate sensor is securely attached to the lower float sensor at Level 1. Heavy-duty cable ties are used to ensure the stability of the sensor, even under conditions of fast-flowing water for accurate and reliable flow rate measurements.

Overall, the design of this prototype demonstrates a robust approach to tackle water level and flow rate measurements in challenging environments. The combination of the PVC tube for wire routing, the waterproof box with its securely sealed connections and the strategically placed ultrasonic sensor showcases a comprehensive solution for gathering accurate water-related data.

Fig. 9. Flow Rate Sensor Attachment Method

4. Experimental Steps and Results

4.1 FloWMS Field Test

This section presents the initial findings on the development of a rapid flood monitoring and warning system, known as FloWMS. Figure 10 shows the fully assembled hardware prototype that demonstrates the successful integration of all the sensors used in the system. One of the primary objectives of this study was to verify the functionality and effectiveness of the developed FloWMS. Comprehensive field tests were conducted at a predetermined location replicating diverse environmental conditions and potential flood scenarios. These real-world tests allowed the authors to assess the system's performance in real-time monitoring and accurately measuring water levels and flow rates. Throughout the field tests, detail records were maintained, documenting the data collected from all the sensors. This included continuous readings of water levels and flow rate differences. By capturing this detailed information, the system's performance under different conditions was able to be analysed and evaluated.

Fig. 10. FloWMS prototype

4.2 Experimental Setup

The current system is still in the prototype development phase for testing. The experiment aims to assess the basic functionality of the system in detecting water level rise through floating and scanning the water surface, as well as measuring the water flow rate. The experiment was conducted following the setup outlined below:

i. Two river locations at Universiti Tun Hussein Onn Malaysia (UTHM) were selected as the testing sites, named Site A and Site B.
ii. First, FloWMS was positioned at Site A for testing, as shown in Figures 11(a).
iii. Then, FloWMS was turned ON, and the movement of the water in the river was observed. Additionally, the LCD readings that show the water flow rate and the distance of the ultrasonic sensor from the water surface were recorded manually. Furthermore, the notification received on the user's phone from the GSM SIM900A module was also recorded.
iv. Data collection involved manual recording of the values displayed on the LCD every 30 minutes for a duration of three (3) hours, from 4.00 PM to 7.00 PM.
v. The recorded data were plotted on graphs to visualize and analyse the water levels and water flow readings.
vi. Steps 3 to 5 were repeated by positioning FloWMS at Site B for testing, as shown in Figure 11(b).

These experimental steps are aimed to evaluate the system's performance under real-world conditions and assess its ability to accurately detect water level changes and monitor water flow rates. The chosen sites at UTHM provided a suitable environment to simulate various water conditions and validate the system's functionality. The manual recording of data allowed for a detailed analysis of the system's performance over the specified period. It is important to note that the current system is still in the prototype development process, and this experiment serves as a crucial step in assessing its capabilities and identifying areas for further improvement. The results obtained from this testing phase will inform subsequent refinements and enhancements to the FloWMS, ultimately advancing its potential as an effective flood monitoring and warning system.

(a) Site A (b) Site B

Fig. 11. Two sites for testing FloWMS at UTHM

4.3 Experimental Results

Figure 12 illustrates the experimental results obtained from Site A showing the river water level and water flow rate measurements. Initially, the water level in the river was classified as Level 2, indicating a "BEWARE" condition. Simultaneously, the system activated the GSM module to send "BEWARE OF THE WATER LEVEL" warning SMS messages to the user's phone. Additionally, the yellow LED was triggered, providing a visual indicator of the water level. The initial ultrasonic reading at this point was 30 cm, as depicted in Figure 12(a). Subsequently, data recording commenced for three (3) hours to continuously monitor changes in water level and flow. During the experiment, the water level gradually decreased, and by 7.00 PM, the reading had reached 25 cm. This downward trend in water level is evident in Figure 12(a).

Figure 12(b) presents the experimental results for the water flow rate at Site A. The figure displays an increasing trend in the water flow rate towards the end of the experiment. The measurements started at approximately 0.21 L/m and ended at 0.38 L/m. The recorded water flow rate values were consistently between 0.2 L/m and 0.4 L/m. In response to these readings, the GSM module sent "WATER FLOW STATUS – BEWARE" SMS messages to the user every 30 minutes.

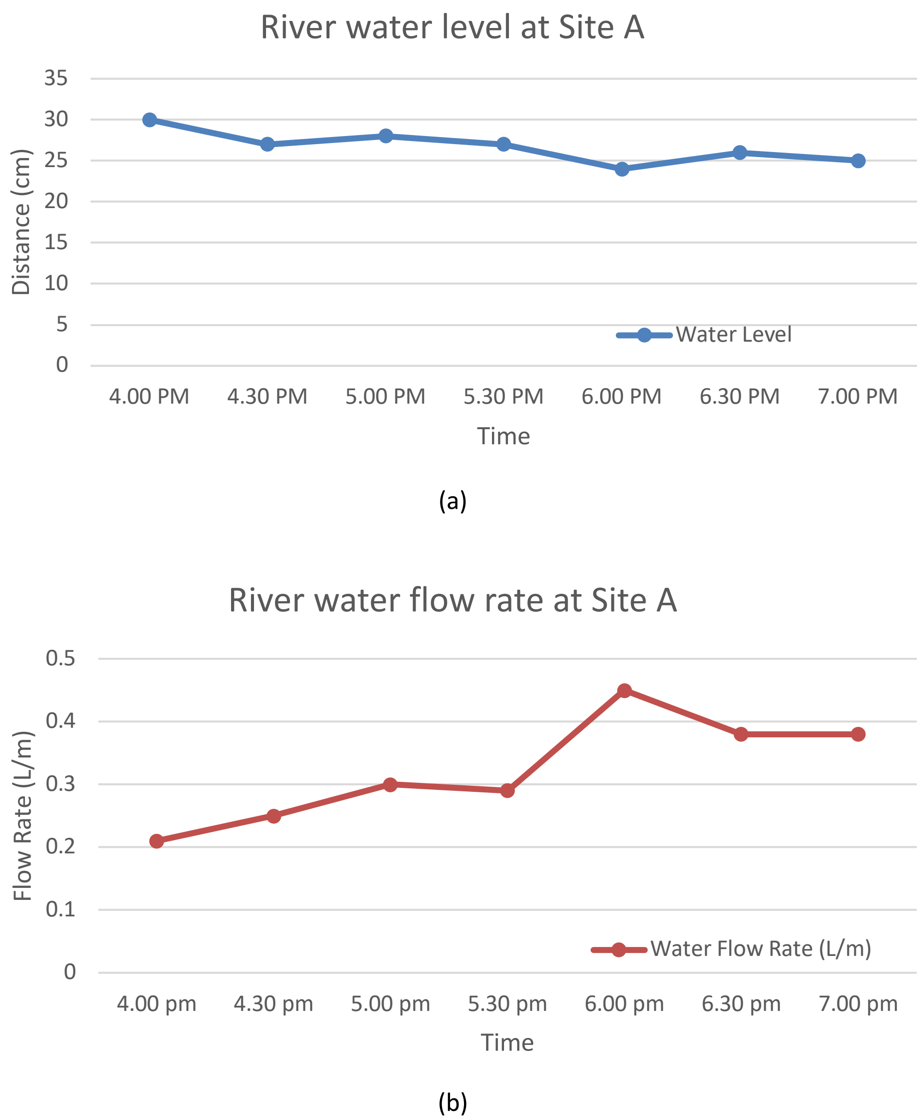


Fig. 12. Experiment results for Site A: (a) water level and (b) water flow rate

Table 1 provides a simplified tabulated form of the water level and flow rate data. The data collection by FloWMS commenced at 4.00 PM, with the river water level at 30 cm and the flow rate at 0.21 L/m. At 6.00 PM, the water flow significantly increased, reaching its highest reading at 0.45 L/m, while the distance between the ultrasonic sensor and the water surface was measured at 24 cm.

Table 1
River water level and flow conditions at Site A

Time	Water level (cm)	Water flow rate (L/m)
4.00 PM	30	0.21
4.30 PM	27	0.25
5.00 PM	28	0.30
5.30 PM	27	0.29
6.00 PM	24	0.45
6.30 PM	26	0.38
7.00 PM	25	0.38

Consequently, the GSM module initiated the transmission of warning SMS messages concerning the water level and flow condition, as shown in Figure 13.

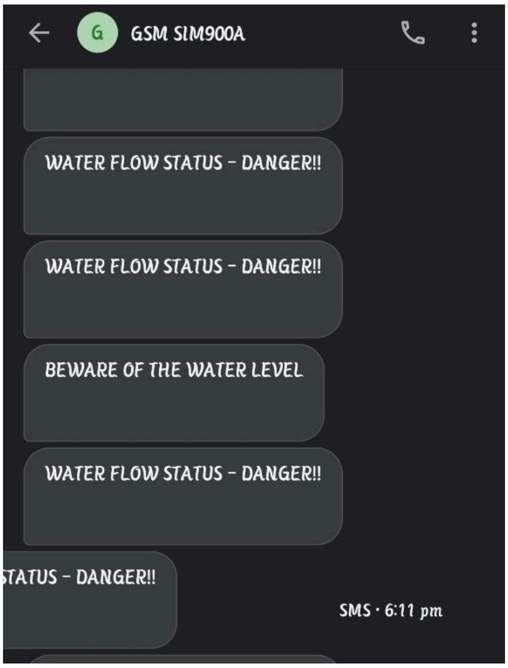
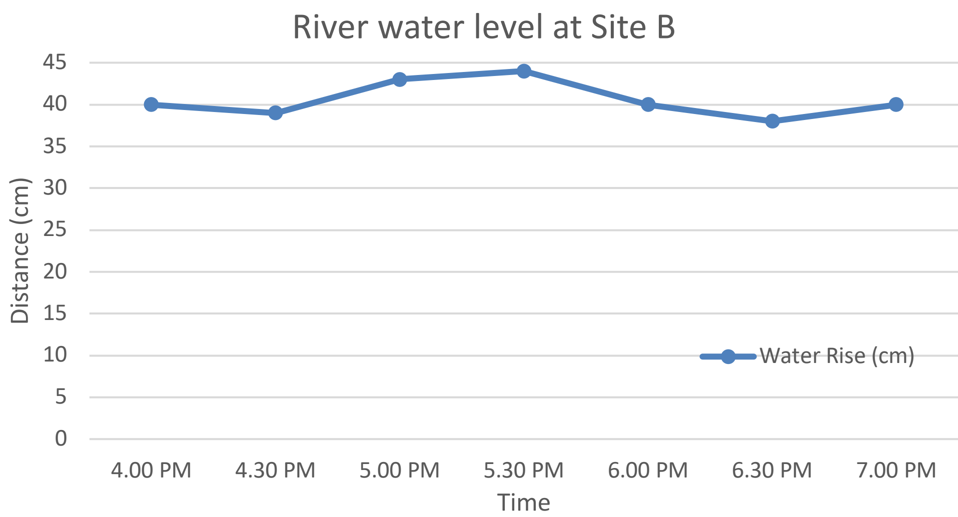
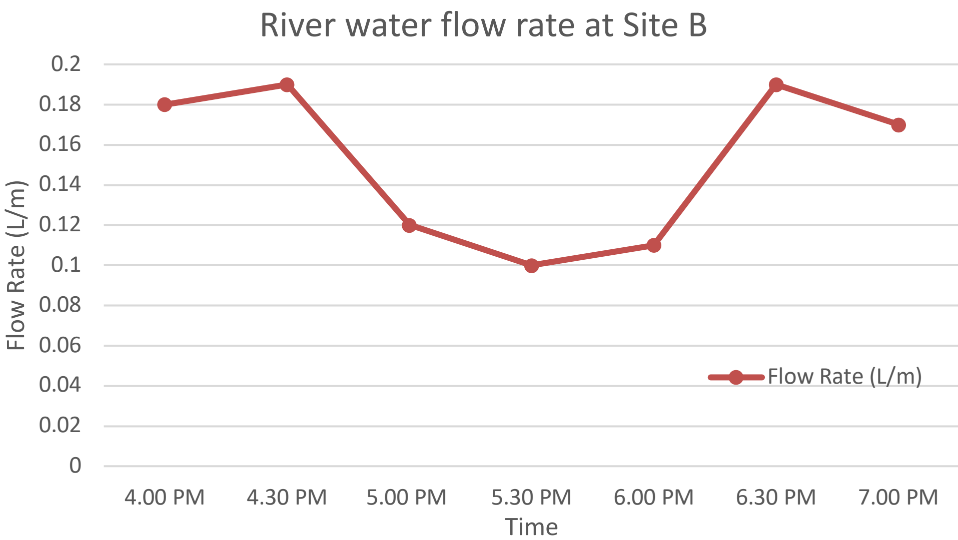


Fig. 13. Warning SMS messages received from FloWMS via GSM

Figure 14 shows the experimental results obtained from Site B showing the river water level and water flow rate measurements. Initially, the water level in the river was classified as Level 1, indicating "ALERT" condition. Simultaneously, the green LED was triggered, providing a visual indicator of the water level. The initial ultrasonic reading at this point was 40 cm, as depicted in Figure 14(a). Subsequently, data recording commenced for three (3) hours to continuously monitor changes in water level and flow. During the experiment, the water level fluctuated between 35 cm to 45 cm, as shown in Figure 14(a). Figure 14(b) presents the experimental results for the water flow rate at Site B. The figure displays a decreasing water flow rate trend during the middle of experiment, followed by an increasing trend in the water flow rate towards the end of the experiment. The measurements started at approximately 0.18 L/m and ended at 0.17 L/m. The recorded water flow rate values were consistently between 0.1 L/m and 0.19 L/m, which is well below the threshold for the alert water flow rate status. Thus, the GSM module did not send any water flow rate alert SMS messages to the user.



(a)



(b)

Fig. 14. Experiment results for Site B: (a) water level and (b) water flow rate

Table 2 provides a simplified tabulated form of the water level and flow rate data at Site B. The data collection by FloWMS commenced at 4.00 PM, with the river water level at 40 cm and the flow rate at 0.18 L/m. At 4.30 PM and 6.30 PM, the water flow significantly increased, reaching its highest readings at 0.19 L/m, while the distance between the ultrasonic sensor and the water surface was measured at 39 cm and 38 cm, respectively. At 5.30 PM, the water flow was at its lowest reading at 0.10 L/m. However, the water level was at its highest reading at 44 cm. The final reading was at 7.00 PM, where the river water level was at 40 cm, and the water flow rate was 0.17 L/m. The GSM module did not initiate the transmission of warning SMS messages concerning the water level and flow condition. However, the green LED was triggered, indicating only alert condition.

Table 2
River water level and flow conditions at Site B

Time	Water level (cm)	Water flow rate (L/m)
4.00 PM	40	0.18
4.30 PM	39	0.19
5.00 PM	43	0.12
5.30 PM	44	0.10
6.00 PM	40	0.11
6.30 PM	38	0.19
7.00 PM	40	0.17

The successful integration of real-time data collection, analysis and warning message transmission in the FloWMS exemplifies its efficiency as a rapid flood monitoring and warning system. These results emphasize the system's capability to provide timely and accurate flood alerts that enable users to take appropriate precautions and actions to ensure their safety and mitigate potential flood-related damages. Further investigations and improvements can be explored based on these results to enhance the system's performance and adaptability in diverse geographical locations and environmental conditions.

5. Conclusions

In this project, a Flood Rapid Monitoring and Warning System (FloWMS) prototype capable of measuring river water level rise and flow rate has been proposed. The system design utilized an ultrasonic sensor to measure the actual water level, along with three (3) float sensors based on the buoy concept to detect water level rise. Field experiments were performed to verify the functionality of the integrated FloWMS. The performance of the system was evaluated at two test sites and the recorded data allowed a detailed study of water level variations and flows. Experimental results showed a drop in water level at Site A and fluctuating water levels at Site B. On the other hand, the water flow rate at Site A showed an increasing trend, while the flow rate at Site B fluctuated between a decreasing and increasing trend. Furthermore, the GSM module successfully sent warning SMS messages to users based on water level and flow conditions. The system performed excellently according to the intended design objectives. The FloWMS effectively detected rising water levels and promptly sent messages for evacuation or flood preparation. The buzzer and light indicators effectively informed the surrounding area about the flood situation on the test sites. Furthermore, the flow rate sensor triggered the GSM module, notifying users about the water flow situation, whether it posed a danger or required vigilance.

In conclusion, FloWMS demonstrated effective real-time data collection, analysis and warning message communication, and demonstrated its effectiveness as an emergency flood monitoring warning system. The system is expected to assist authorities and communities in early flood preparations. Timely detection of floods allows households and road users to take preventive measures, preserving valuable property and potentially saving lives. The prototype's cost-effectiveness and ease of height adjustment make it suitable for deployment in flood-prone areas, where water levels frequently rise. However, further field tests should be conducted to validate the FloWMS's performance in diverse environmental conditions and geographical locations. It is essential to continuously develop and improve the system's accuracy and reliability. Therefore, collaborating with hydrologists and weather experts can enhance the system's predictive capabilities and early flood warning accuracy. Additional future works include enhancements to the system's user interface and mobile application that can facilitate easy access to flood warnings and real-time data for users. Furthermore, to ensure long-term sustainability, research and development efforts will also focus on enhancing power efficiency and utilizing renewable energy sources to power the system to reduce its environmental impact. By implementing these recommendations and continually refining the prototype, a more resilient and proactive approach to flood management can be achieved.

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