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IJIE

http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

Development of a Wireless Monitoring System to Monitor River Water Levels in Real Time

Siti Norshafika Mohd Zain[1], Muhammad Rusydi Muhammad Razif[1*], Dalila Misman[1], Abdul Hafidz Yusoff[2], Mohd Sofiyan Sulaiman[3], Muslim Abdullah Zaik[4], Nizzal Syafiq Bostaman[4], Muhammad Noorazlan Abd Azis[5]

[1]Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, Pagoh, Muar, Johor, 84600, MALAYSIA

[2]Gold Rare Earth and Material Technopreneurship Centre (GREAT),
Faculty of Bioengineering and Technology (FBET), Universiti Malaysia Kelantan, Jeli, Kelantan, 17600, MALAYSIA

[3]Faculty of Ocean Engineering Technology and Informatics,
Universiti Malaysia Terengganu, Kuala Nerus, Terengganu, 21030, MALAYSIA

[4]Technerve Technology Solutions Sdn. Bhd.,
Bandar Baru Bangi, Selangor, 43650, MALAYSIA

[5]Faculty of Science and Mathematics,
Universiti Pendidikan Sultan Idris, Tanjung Malim, Perak, 35900, MALAYSIA

*Corresponding Author

DOI: https://doi.org/10.30880/ijie.2023.15.03.026
Received 21 June 2023; Accepted 17 July 2023; Available online 2 October 2023

Abstract: This wireless monitoring system is developed to alert and warn the resident regarding the upcoming flood. Due to the floods that occur every year, especially during the monsoon season, the loss and damage done by this disaster are uncontrollable. When the water level rise-up above the safe ground, it may hit the communication substation, as well as the power tower. In most cases, many residents are not alert with their surroundings because there is no alert system that can remind them regarding to the issues that will arise. By not preparing themselves for the upcoming nature disaster, it could endanger themselves and destroy their property. Thus, this project focus on monitoring a real-time river water level system for flood prediction purposes which utilize three devices connected together in a centralized system. By having this system, people will be notified about the current situation and the water level of the river near to them via Internet of Things (IoT) such as Blynk application. ESP32 and ESP32-Cam are used as the main microcontroller to control the system. The sensor used to detect the water level at the river is TF Mini Lidar and ultrasonic sensor for the water level detection of the rain gauge. The ESP32-cam are used to monitor the surrounding area at the river. The combination of these three systems is used to monitor and predict the flood occurrence.

Keywords: Water level, rain gauge, wireless, IoT, Blynk

**Corresponding author: rusydi@uthm.edu.my*

1. Introduction

Flooding is one of the most serious natural disasters in the world [1]. Floods usually occur when heavy rain pours continuously for days during the monsoon season. The geographical structure of the land, the duration and the intensity of the rain influence the flood. The floods' occurrence affected almost all the residents and destroyed their properties. In 1926 a major flood occurred in Kelantan including the Besut district in Terengganu which resulted in the destruction of hundreds of square kilometers of lowland forest. The flood affected almost the entire area of the Malaysian Peninsula and caused severe damage, so it was considered as the greatest flood in human memory [2]. In addition to the severe flood in Kelantan in 1926, monsoon floods are actually an annual natural disaster in Malaysia, with severe floods occurring in 1996, 2000, 2006, 2010, 2011, 2014 and 2021 [3-4]. Due to the flood, the people and the government faced huge losses and the economy of the people was affected [5]. Thus, this proves that flood disasters are enormously dangerous and should be taken seriously.

There are several flood detection technologies invented by other researchers over the world. One of them comes from Siva Kumar Subramaniam *et al.* [6]. The researchers developed a warning and alert system in real time to monitor the flood areas using radio frequency (RF) receiver and real time information via SMS. It uses contractive and non-contractive sensors as the water detection. Sensors used can locate flood areas from 100 meters in radius and prediction messages will be sent whenever there are changes in level and they use programmable logic controller (PLC) connected to Global System for Mobile Communication (GSM) modem to perform the communication at the monitoring station.

In 2018, Melisa Acosta-Coll *et al.* [7], presented an idea to develop a Web application that allows people to get effective and fast information as fast as every 5 minutes. This research group has designed an early warning system (EWS) consisting of risk identification and mapping. The main part of the system is equipped with a water level sensor, a water velocity sensor and a rain gauge. The main part of the system is powered by a photovoltaic system. Web and mobile applications have been implemented in all projects to provide alerts. To make it more efficient, more detectors are needed to cover the entire community at risk.

Project proposed by Amirah Hasbullah *et al.* [8] in 2019, stated that in Malaysia flash floods most often occur in urban areas, where vehicles are mostly parked. A flood warning system based on a water level sensor and an Internet of Things (IoT) system has been developed. The HC-RS04 has been placed at two different levels of water: 0.05 m and 0.09 m. When water enters this level range, the light emitting diode (LED) will turn on, triggering the buzzer, which will inform both the owner and the local authority, and all of the water level information displays in the Blynk application.

The demand for IoT has grown rapidly to facilitate the communication and control of gadgets and systems in various human daily activities [9-10]. The main requirements of IoT today are related to the provision of efficient connections to ensure reliable remote communication and data transmission in wireless environments [11]. One of the application areas of IoT is the Internet of smart environment (IOsE). The IOsE covers air pollution monitoring, forest fire detection, protecting wildlife, water quality, weather monitoring and river flood. Thus, for this project, the IOsE used is for river floods. It can be used to monitor the water level of rivers, dams and reservoirs in rainy days as discussed by Keyur K Patel *et al.* [12].

The ESP32 are small, affordable, and powerful Wi-Fi modules that are suitable for DIY projects in the field of Internet of Things (IoT) [13-15]. This module combined with Wi-Fi and Bluetooth wireless capabilities and comes with GPIOs, support for a variety of protocols like SPI, 12C, UART, and more [16]. This device enables diverse users to experience and understand programming where it allows user to plug ESP32 into computer for programming without FTDI programmer [17]. This camera module is suitable to be used as a surveillance camera where the streaming can be monitored in real time. The advantages of using ESP32 cam is to carry a small vision system within robotic arms that could operate wirelessly with robotic arms with the aid of IoT. Thus, they use an ESP32 camera to stream the video and remote the location [18].

Floods must be predicted via live update to determine the absolute behavior of the river because pre-collected data can be wrong anytime as the water-level can change at any moment due to the unpredictable climate change. Thus, an ultrasonic sensor is used and placed to detect any changes in the water level [19]. Ultrasonic sensor emitting ultrasonic sound waves which travels faster than the speed of audible sound to measure the distance of a target object and convert the reflected sound into an electrical signal. This sensor is commonly used for distance measuring applications like level control, and it can detect most metal and non-metal, transparent or opaque, and liquid items [8]. This sort of sensor is being used by other researchers to combat the flood issue as mention in [20] which is quite similar with this project.

2. Methodology

Fig.1 illustrates the block diagram of the overall project system. This system is a combination of three processes which are related to rain gauge, water level and camera. The ESP32 is the main microcontroller that is attached with the other sensors and electronic components for this project. Rain gauge is used to measure the intensity of the rainfall where ultrasonic sensor will measure the water level inside the rain gauge while water level system is used to monitor the water level of the river from the bridge using the TFmini Plus LiDAR Module. As for the camera, it is used to capture live stream of situation at the river area. The output from these three devices will be uploaded to the Blynk app to be displayed to users to monitor the condition of the river model in one monitoring center.

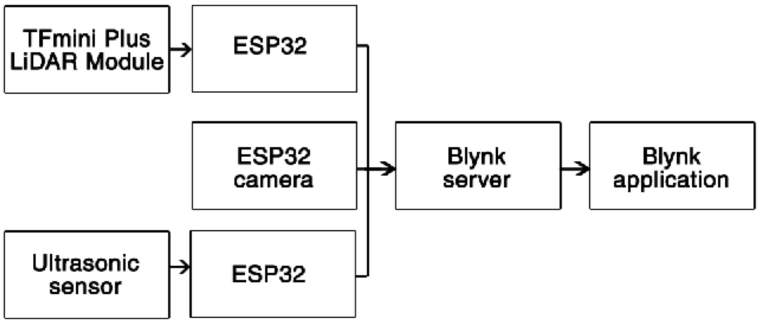

Fig. 1 - Block diagram of the overall system

The ESP32 performs as the controller to process data captured from sensors and transmit wirelessly to the Blynk application for display purposes of the project system. TFmini Plus LiDAR Module will be attached to the ESP32 powered by a 5V power supply to monitor the water level of the river. ESP32 camera module also will be attached to the bridge to monitor the situation around the river. Next, an ultrasonic sensor will be attached to another ESP32 to measure the raindrop level inside the rain gauge to determine the amount of rainfall from time to time.

All the data collected from the three devices will then be connected and uploaded to the Blynk server and then will be displayed in the Blynk application. The purpose of using this combination is to get the solid validation from the three sources to determine the flood's occurrence where the result is more accurate and specific. The output data from the TFmini Plus LiDAR Module measure the river water level in centimeters (cm) while the ultrasound sensor measures the water level inside the rain gauge in the unit of millimeters (mm). The camera footage captures the image from the river surroundings in real time. All these processed outputs will be automatically uploaded to the Blynk server and displayed in Blynk application.

The Blynk interface displays the output from the water level of the river and the rain gauge via liquid crystal display (LCD). The system has been set to state the current water level distance level and warning message. Next, both of the output data from water level system and rain gauge system will be displayed in the SuperChart widget in Blynk application which consist of distance versus time in graph type. The distance will be shown simultaneously with the time to show the difference in water level. The third system output which is the camera module will be displayed in the type of video stream It will automatically update the current situation at the river area in real time.

Fig. 2 illustrates the workflow of the water level. Sensors sense the river water level. Data collected by ESP32, and the output will transmit wirelessly to Blynk application in real time. The shorter the distance the higher the chance of flood occurrence. When the distance between the sensor and the water surface is reduced from 35 to 25 centimeters, the ESP32 will process the data and send it to the Blynk and a notification pop up showing “Stay Alert! River Water Level is rising! Kindly be prepare for evacuation” to inform the resident regarding the upcoming hazard. When the water level keeps on rising and the distance between the sensor and the river surface reduced to less than 25 centimeters, the ESP32 will process the data and send it to the and the notification of “Dangerous!! Evacuate immediately!” will pop up to make sure all the residents near the river to evacuate as soon as possible.

Fig. 3 illustrates the workflow of the rain gauge which will determine the amount of the rainfall from time to time. The ultrasonic sensor attached to the ESP32 will measure the water level inside the rain gauge. The ESP32 will be programmed to detect any rain drop level changes inside the rain gauge, then the data will be uploaded to the Blynk automatically. If the changes are low, it means that the amount of the rainfall is small and if the changes are high, the rain is heavy and could be dangerous. The data will be uploaded to the Blynk application in graphs in real time. A ESP32-Cam will be programmed to display a live streaming to monitor the situation on the Blynk application. For this project, all the data collected from all devices will be shown in the Blynk app to provide strong predictions of flood events.

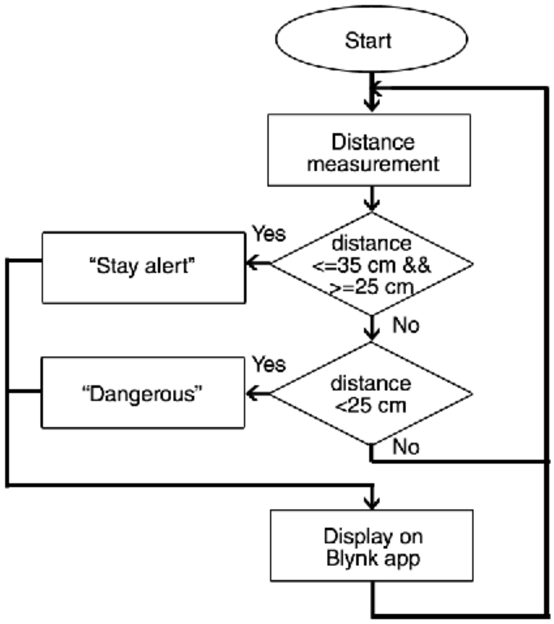

Fig. 2 - Water level flowchart workflow

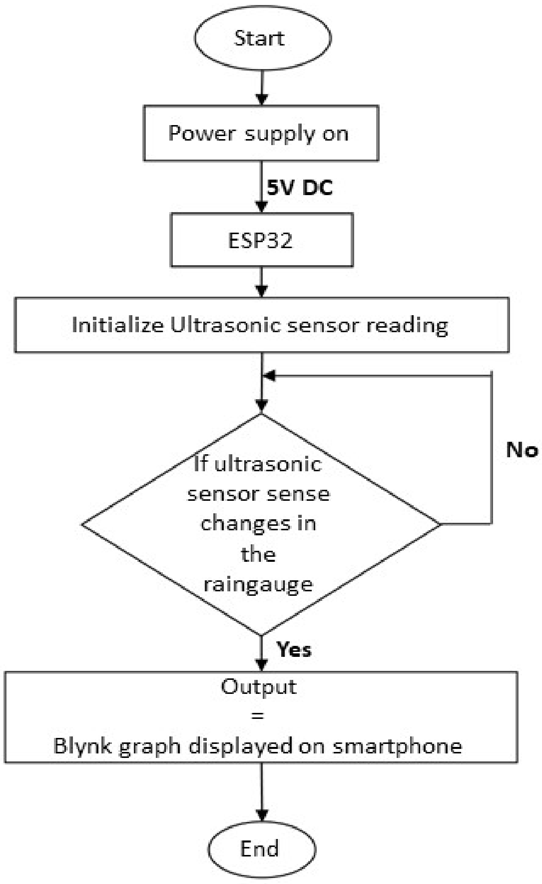

Fig. 3 - Rain gauge system workflow

3. Results and Discussion

Table 1 shows the calibration process of the rain gauge where the data of the rain intensity was collected roughly on the rainy days per hour each. The calibration process was run by classifying the rain intensity into three criteria which are heavy, moderate and low. The data was taken three times for each type of rain and the average rain intensity was calculated to be used in the overall testing process.

Table 1 - Rain intensity measurement

Time taken	Rain Intensity	Average (ml)
1 hour	heavy	84.3
1 hour	moderate	47.3
1 hour	low	21.3

After the initial test is completed, the hardware now is ready to be installed and tested. Fig. 4 shows the hardware setup for the automated river water level monitoring system using Blynk.

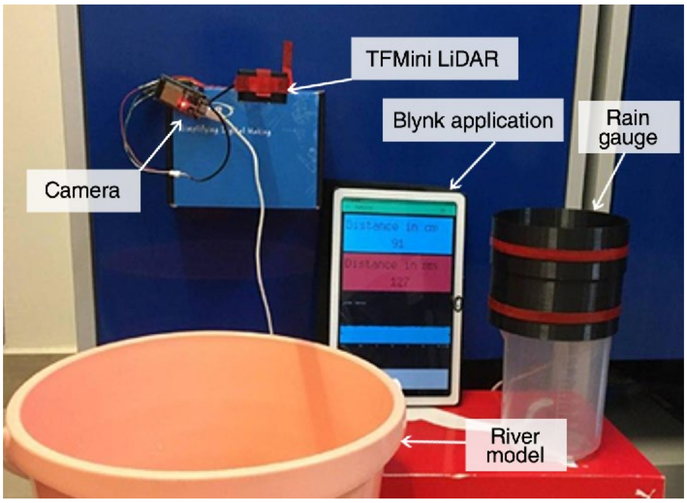

Fig. 4 - Hardware setup

The overall test started by pouring water into the empty rain gauge to indicate that it was raining heavily, moderate or low in the testing. The test was then proceeded by pouring water inside the empty bucket following the rain intensity represent that the river water level was rising which caused by the rain towards the river. The approximate value of water volume added into the bucket and rain gauge is as shown in Table 2.

Table 2 - Water volume added into the bucket and rain gauge

Rain intensity	Water level (ml)	Rain gauge (ml)
Heavy	400	84.3
Moderate	800	47.3
Low	1200	21.3

The time taken for the entire testing is for 10 minutes, where each 1 minute represents 1 day. Water will be added to the bucket and rain gauge container gradually. Fig. 5 shows graph plotted for 10 minutes of testing.

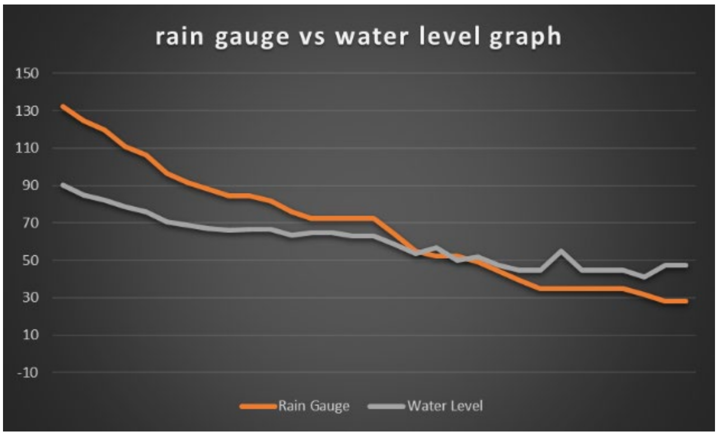

Fig. 5 - Graph of rain gauge system and water level system

Fig. 6 shows the result of the overall system displayed in the Blynk application. Based on the figure, it successfully shows the current distance tested for the rain gauge system and water level system via digital LCD widgets. Graph plotted in the app below the LCD widget is used to show data obtained from sensors that detect water levels and rain gauge. From the graph, it shows that both readings are directly proportional and it has been verified by the live streaming present at the bottom of the Blynk app. As shown in the graph, the distance between rain gauge and water level are getting lower and shorter, means the rain does not stop because the water level in the rain gauge is increasing and the water level in the river is also increasing. Hence, the possibility of flooding is high.

Fig. 6 - The overall data collection displayed in Blynk application

Fig. 7 shows a notification that pops up when the water level in the river rises and the distance between the water river surface and the sensor is between 35 cm and 25 cm. The notification shows an early warning sign for the resident to be prepared for the upcoming hazard and to stay alert. Meanwhile, Fig. 8 shows the notification pops up for the resident to evacuate immediately as the water level in the river is starting to exceed the dangerous level and there is a high possibility that flooding will occur in their residential areas.

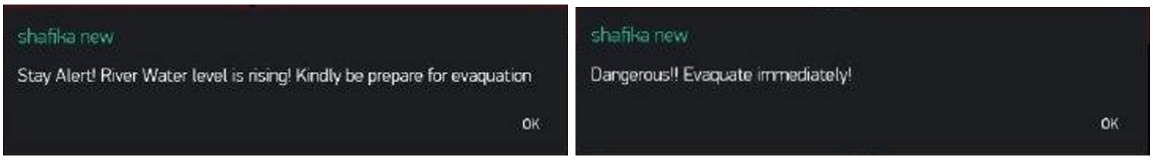

Fig. 7 - Notification pop up for (a) early warning; (b) evacuation

4. Conclusion

Based on the results presented, the wireless monitoring system to monitor river water levels in real time are ready to be used in real life. The hardware chosen are compatible and could operate successfully where the wireless controller, sensors and camera are suitable for the project. The results show that the Blynk application can clearly see and monitor the condition of the river water level and the sensor can provide current readings of the river water level. Thus, the people do not need to endanger themselves to measure the water level or go to the river to view and analyze the situation manually to alert the others regarding the flood's disaster. The people near the flood area will be notified with the incident data via Blynk application.

There are some suggestions for future improvements that can be made which is to develop a protective box for electronic equipment to be safer from changing weather conditions including in rainy conditions. Additionally, it is recommended to use a waterproof sensor for the rain gauge system as it is most likely to come into contact with water.

Acknowledgements

This research was supported by Universiti Tun Hussein Onn Malaysia (UTHM) through UTHM Contract Grant (vot H872) and Universiti Malaysia Kelantan (UMK) through Matching Grant (vot R/MTCH/A1300/00692A/003/ 2021/00947).

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