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Solar-Powered Flood Early Monitoring System with IoT Technology in Parit Raja

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Abstract

Flooding is a recurring natural disaster that causes significant damage to infrastructure and poses risks to human lives. This study introduces a solar-powered flood early warning system designed to enhance flood monitoring and management in Parit Raja. The system integrates ultrasonic sensors, water flow sensors, temperature and humidity sensors, and a raindrop sensor with a microcontroller for real-time data collection. Solar panels provide continuous, eco-friendly power, while IoT technologies, including the Blynk application and ESP8266 Wi-Fi module, enable remote monitoring and timely alerts. Testing confirmed the system's ability to accurately detect water levels and environmental conditions, ensuring reliable performance even under variable weather. The results demonstrate the system's potential to minimize flood-related risks, reduce property damage, and support proactive response efforts in flood-prone regions. This innovation represents a sustainable and scalable solution for effective flood monitoring and management.

1. Introduction

The recurring occurrence of floods in Malaysia has resulted in significant financial and societal losses for both the government and the populace. The year 2023 saw Malaysia incurring losses amounting to RM 800 million because of floods. Among the 14 Malaysian states that have been impacted by the flooding, Johor, a southern state, has been identified as the most severely affected [1]. The occurrence of floods in Malaysia can be attributed to its geographical location, wherein cyclical monsoon seasons are followed by heavy and regular rainfall from approximately May to September and October to March [2]. Empirical evidence suggests that anthropogenic activities have also played a significant role in exacerbating this calamity. These activities include the proliferation of suboptimal sewage systems, unregulated urbanization, and uncontrolled waste management practices [3].

As is commonly understood, flooding is an unavoidable natural phenomenon. However, it is feasible to mitigate the negative impact of flooding through the implementation of a warning or river monitoring system. In numerous instances, the onset of flooding in specific regions results in insufficient time for inhabitants to evacuate, thereby resulting in property damage [4].

Numerous flood monitoring and warning systems have been developed to facilitate water level monitoring; nevertheless, most of these designs have relied on conventional power sources, such as batteries or alternating current energy [5-10], which possess inherent limitations in terms of reliability and necessitate regular maintenance. To address these concerns, there is a growing emphasis on the integration of environmentally friendly components in the system design to aid in the preservation of the ecosystem.

This study focuses on developing an early flood warning system powered by green energy that is capable of integrating a connection between the proposed system and the user for remote monitoring using IoT applications. The expected functionality of the system allows continuous and real-time water level monitoring contributing to flood control efforts in an environmentally friendly manner.

2. Methodology

The study focuses on several key scopes. Firstly, the developed system is employed with an ultrasonic sensor, water flow sensor, humidity sensor, temperature sensor, and raindrop sensor integrated with Durian Uno V3. Subsequently, the developed system will be powered up by solar energy. The device is linked to the user via Arduino and Blynk software installed on mobile apps and the Blynk website. Finally, the device's performance will be tested at Taman Universiti, Parit Raja to ensure the user receives accurate data from the ultrasonic sensor, water flow sensor, temperature, and humidity sensor as well as raindrop sensor.

Fig. 1 depicts the complete block diagram of the proposed study. The hardware configuration incorporates a variety of sensors, including an ultrasonic sensor, a water flow sensor, a humidity sensor, and a temperature sensor. Furthermore, the utilisation of solar panel technology is employed to provide energy to the device, thereby enhancing its reliability while encouraging a more environmentally sustainable system. The main goal of Blynk software development is to establish a connection between the user and the device through the utilisation of IoT technologies. The system subsequently employs the buzzer to effectively notify nearby residents.

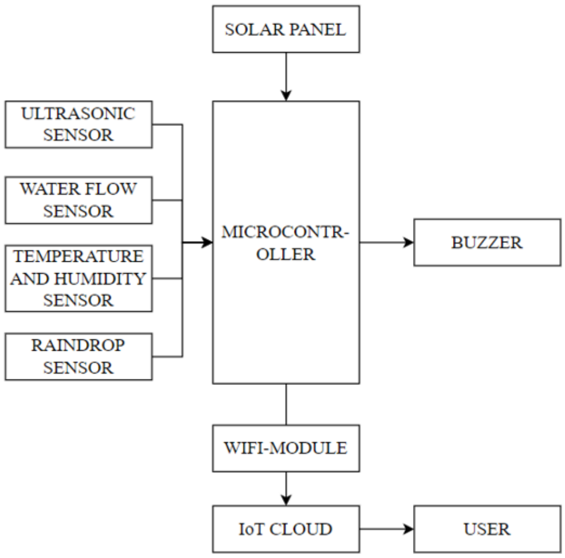

Fig. 1 *Block diagram of Solar -Solar-powered flood Early Warning System with IoT Technology*

The system's operational functionality relies on the data collected from the sensors, which is subsequently used to make informed decisions. The flowchart depicted in Fig. 2 provides a comprehensive outline of the sequential procedures involved in detecting an early flood. The sensors will collect and analyse the data, which will then be presented on the Blynk application placed on the user's mobile device.

2.1 Hardware Design and Simulation

Figure 3 illustrates the schematic design of the proposed system, where the Durian Uno V3 microcontroller functions as the main control unit. Key components include an ultrasonic sensor connected to digital I/O ports 12 and 13 to measure water levels in centimetres (cm), and a water flow sensor with three wires: ground (black), 5V input (red), and signal (yellow), the latter connected to digital pin 2.

The DHT-11 sensor, for temperature and humidity measurement, is linked to analogue pin A0, while the raindrop sensor connects to analogue pin A2, utilizing its analogue (A0), digital (D0), ground, and VCC pins. A buzzer is connected via digital pin 7 to alert residents in flood-prone areas. All sensor data is transmitted to the Blynk platform through a Wi-Fi module (ESP8266) embedded in the microcontroller, enabling real-time monitoring and notifications.

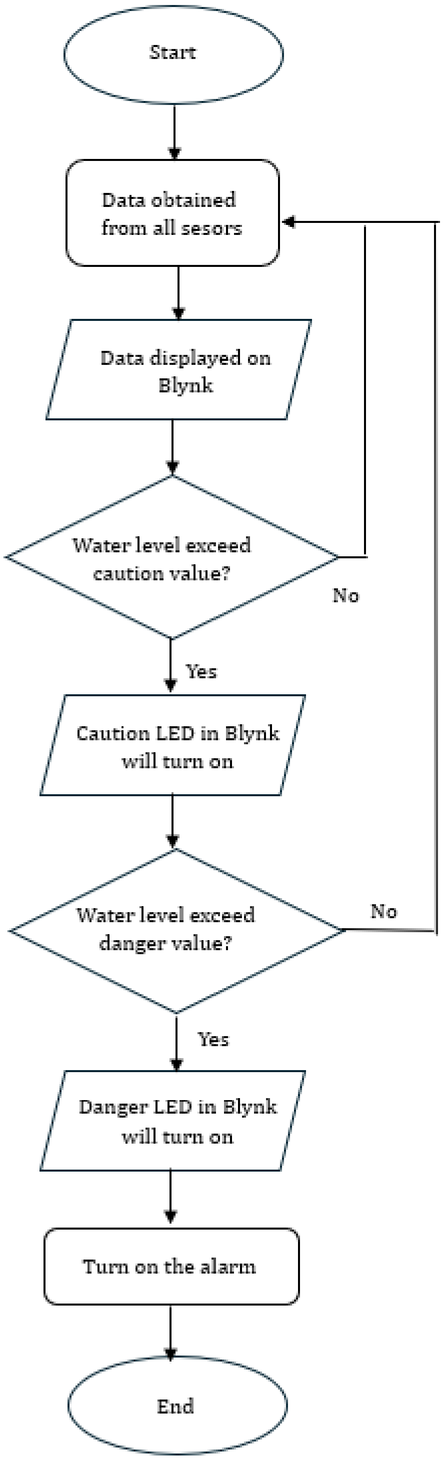

Fig. 2 *The general flowchart of the system*

2.2 Solar System Design

The Durian UNO V3 microcontroller is powered by a solar system comprising a solar panel, a charge controller, and a rechargeable battery. The solar panel collects sunlight, while the charge controller regulates battery charging, ensuring efficient energy flow. The rechargeable battery serves as a backup power source, enabling the Arduino Uno to operate autonomously even in the absence of sunlight. Figure 4 illustrates the system's configuration.

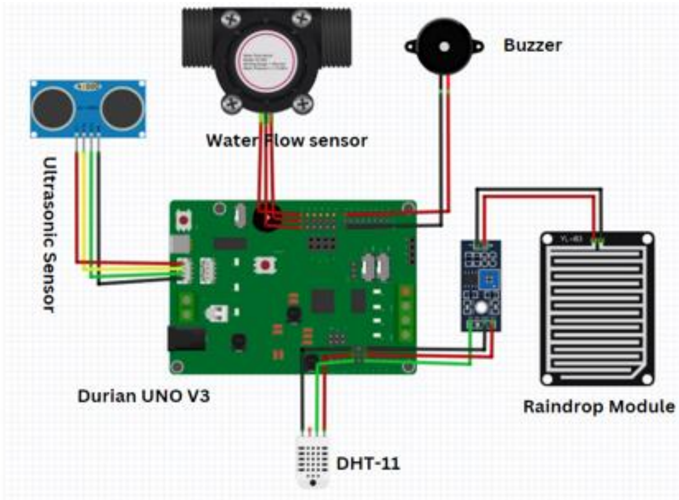

Fig. 3 *Schematic diagram of proposed design using Fritzing Software*

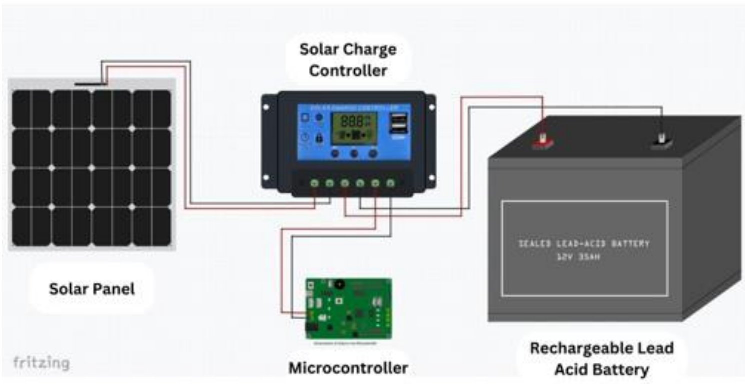

Fig. 4 *Schematic diagram of solar system design using Fritzing Software*

2.3 Interface Design

This section details the interface design implemented to monitor and control the alarm system, with a specific focus on the alarms situated in the junction box of the system. The interface will be created by employing the Blynk official website as well as the Blynk application deployed on mobile devices.

To integrate additional elements into the layout, including gauges, displays, and controls, the Blynk developer mode can be accessed. Establish a logical progression and user-friendly configuration for these elements, prioritising simplicity, and coherence. The Blynk application provides users with the ability to customise the visual elements, captions, and colours to suit their tastes. To facilitate the transmission of sensor data to the gadget for display or control purposes, it is vital to establish a data stream. Following this, the data stream for each corresponding sensor will be designated as V1, V2, and so forth within the Arduino IDE programming interface. The mobile device interface of a consumer is illustrated in Figure 5. Furthermore, the interface development process on the Blynk website is comparable to that of the mobile application. The interface development process on the Blynk website is comparable to that of the mobile application. Fig. 6 illustrates the user interface that was developed for the authorised website.

3. Results And Discussion

This section provides an overview of the finalized results obtained from the project simulation and discussion on the implications and significance of the findings.

3.1 Project Design Prototype

The design comprises an adjustable sign stand poster, a weatherproof junction box, and a PVC water pipe clamp. The comprehensive system architecture depicted in Fig. 7 illustrates the front and back views, respectively. Figures 8 and 9 depict the junction box, illustrating the installation of all the sensors from a top view and a bottom view, respectively.

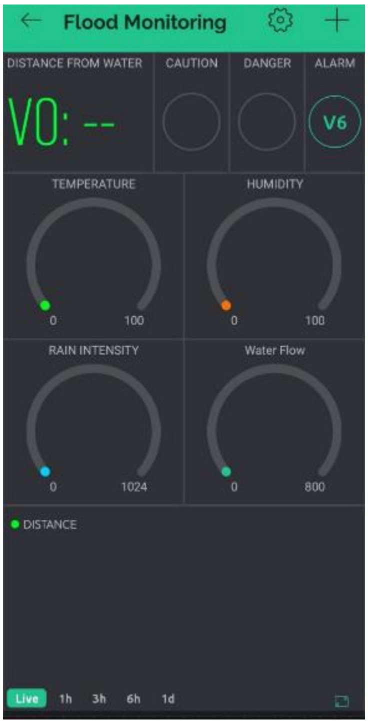

Fig. 5 *Blynk's interface on a mobile device*

Fig. 6 *Blynk's interface on the authorised website*

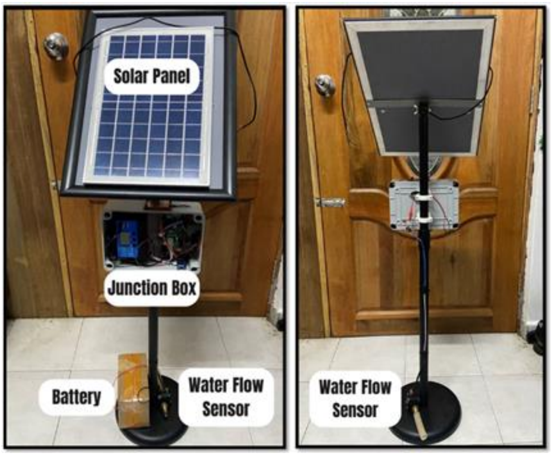

Fig. 7 *Front and back view of project design*

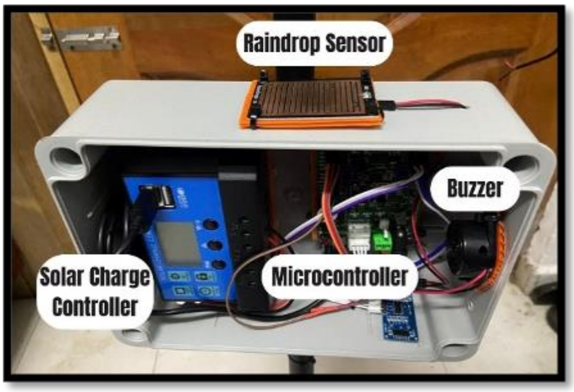

Fig. 8 *Top view of junction box*

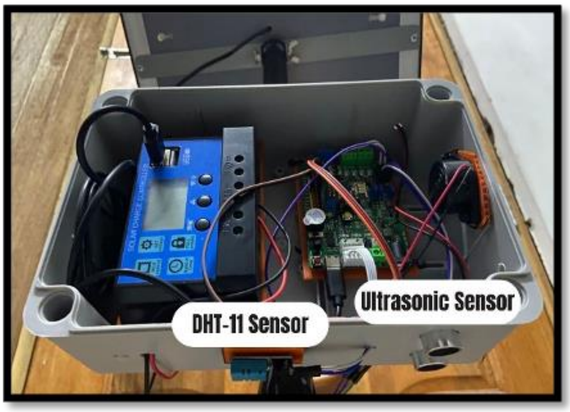

Fig. 9 *Back view of junction box*

3.2 Water Level Testing

The purpose of the test was to evaluate the sensor's capability to detect the presence of water accurately. During the testing process, water was added to a bucket through a pipe to simulate rising water levels. When the water level reached a range of 30 cm to 15 cm, the yellow LED on the Blynk application was activated. Upon further increase in the water level to within 15 cm of the sensor, the red LED was triggered, allowing the user to enable the alarm located inside the junction box.

As depicted in Fig. 10, the water level in the bucket gradually increased, reducing the distance measured by the ultrasonic sensor. Initially, the sensor displayed a distance of 50 cm when the bucket was empty, which decreased to 35 cm as the bucket filled with water. The results demonstrated that the ultrasonic sensor successfully detected changes in water levels and accurately transmitted this information to the Blynk application, validating its effectiveness in real-time monitoring.

Fig. 10 *Water level monitoring testing.*

3.3 Prototype Testing and Data Performance Analysis

This section presents a summary of data analysis and system performance by gathering data from different sensors, including those that measure water level, humidity, precipitation intensity, temperature, and flow rate. The purpose of these analyses is primarily to provide information to the relevant authorities, such as the Johor Meteorological Department, who are experts on handling flood-related concerns. The proposed prototype as depicted in Fig. 11 is located near the sewer. This application is activated during rainfall, resulting in a slight increase in the water level.

Fig. 11 *Prototype testing nearby sewer*

The data collection process for each sensor was conducted between 12:40 PM and 1:40 PM on the first day. The system installation, completed at 12:30 PM, operated under hot weather conditions, leading to elevated temperatures and low humidity levels. Around 1:10 PM, the weather became overcast, causing a reduction in temperature and an increase in humidity. Throughout the data collection period, no water flow was detected, maintaining a consistent rate of 0 litres per minute. Additionally, no precipitation was observed, as indicated by the unchanged rain intensity values. Table 1 presents the sensor data recorded at 10-minute intervals, while Fig. 13 illustrates the water distance measurements extracted from the Blynk App and tabulated in Excel format.

Table 1 *Data collection*

Time / Parameters	12:40	12:50	13:00	13:10	13:20	13:30
Temperature (Celsius)	32	33	34	32	30	29
Humidity (%)	75	70	67	71	77	80
Rain Intensity	1023	1023	1023	1023	1023	1023
Water Flow (litre/hour)	0	0	0	0	0	0

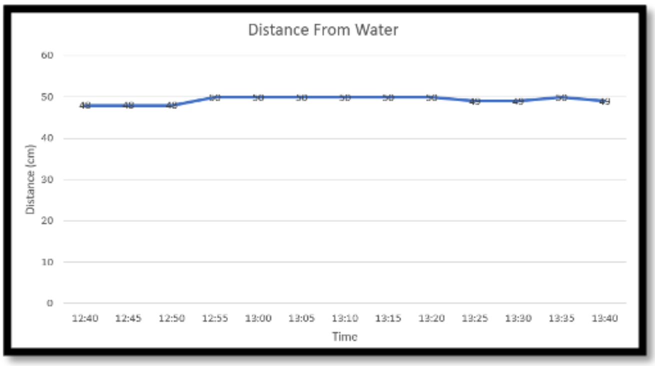

Fig. 12 *Water distance measurements in Excel format*

3.4 Solar Panel Performance

This section evaluates the solar panel's effectiveness as a power source for the system while simultaneously charging a 12V battery. The testing utilized a 12V, 10W solar panel, positioned in direct sunlight for a continuous duration of four hours. During this period, with ambient temperatures reaching up to 34°C, voltage readings were recorded every 30 minutes using the solar charge controller. As shown in Figure 14, the solar charge controller received a direct input of 7.3V from the solar panel, as indicated on the display. The complete dataset collected over the four hours, including voltage measurements at 30-minute intervals, is summarized in Table 2.

Fig. 13 *Voltage displayed on Solar Charge Controller*

Table 2 *Data collected from Solar Charge Controller for 4 hours.*

Time	Temperature (°C)	Voltage from Solar	Battery capacity
11:30 AM	34	7.3 V	12.7 V
12:00 PM	33	6.7 V	13 V
12:30 PM	34	7.1 V	13 V
1:00 PM	33	6.8 V	13 V
1:30 PM	33	6.8 V	13 V
2:00 PM	33	6.9 V	13 V
2:30 PM	33	6.9 V	13 V
3:00 PM	33	6.8 V	13 V
3:30 PM	30	6.6 V	13 V

Conclusion

The Solar-Powered Flood Early Warning System successfully meets its objectives, providing an eco-friendly and reliable solution for real-time flood monitoring in Parit Raja. The system combines solar power and IoT technologies to ensure continuous operation without relying on conventional energy, promoting environmental sustainability. Testing confirmed the system's accuracy and effectiveness, with sensors reliably detecting water levels and other environmental parameters such as water flow, temperature, humidity, and rainfall. Real-time data was displayed through the Blynk application, enabling clear and timely alerts. The solar panel proved sufficient for powering the system and maintaining stable energy output under different weather conditions. This system reduces flood risks by delivering timely and accurate alerts, enabling proactive responses. It offers a scalable, sustainable solution for flood-prone areas, fulfilling all its objectives.

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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 their contribution to the paper as follows: ***study conception and design:*** *MAMS and MJT;* ***data collection:*** *MJT;* ***analysis and interpretation of results:*** *MJT and ZZA* ***draft manuscript preparation:*** *MJT, MAMS, ZZA and NBG. All authors reviewed the results and approved the final version of the manuscript.*

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