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Water Level and Flow Detection System: An IoT-Based Flood Monitoring Application

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ABSTRACT

In Malaysia, floods have become increasingly prevalent, causing significant damage to various aspects of life including infrastructure, property and the economy. The risk to human lives is particularly high in low-lying areas and areas with poor drainage systems. Water contamination during floods can also lead to health issues and the spread of waterborne diseases. The psychological impact of floods should not be underestimated, as individuals may experience a range of emotions such as frustration, sadness, fear and anger. To address these challenges, this study focuses on developing a flood alert system using Internet of Things (IoT) technology. By utilizing ESP32 microcontroller, flow sensor, float sensors, water flow as well as water level can be accurately measured and users can be alerted through the Blynk application. The system ensures accuracy in measuring flow rates, with recorded values ranging from 2.404 L/min to 2.444 L/min. This device can measure water flow and water level which will be generated through ESP32 microcontroller and notifying the user via the Blynk application as for the IoT part. This project has been carried out in indoor experiments to evaluate the efficiency of the float and flow sensors, respectively. Through indoor experiments, it has been demonstrated that this system is capable of effectively monitoring and alerting users to potential flood incidents, helping to safeguard lives and property.

1. Introduction

Floods are a common occurrence in Malaysia, particularly during the monsoon seasons. Heavy rainfall and poor drainage systems contribute to the widespread flooding, affecting various states and causing significant damage to people, property and infrastructure [1-3]. The 2014 flood in Kelantan was considered one of the worst in the states' history. Low-lying and urban areas, as well

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as regions with clogged drains, are most susceptible to flooding. Factors such as deforestation and climate change exacerbate the problem [4-6].

Floods have severe consequences, including loss of life, property damage, disruption of economic activities and the spread of waterborne diseases [7,8]. The 2014 flood resulted in the unfortunate loss of 21 lives [8]. Furthermore, infrastructure breakdown and damage disrupt transportation, electricity, healthcare and other essential services [9-11]. Victims of floods also experience psychosocial effects and trauma due to their losses.

The concept of the Internet of Things (IoT) system application was created to aid in management that needed human invention, such as requiring things to be tracked in real-time because each data monitored would result in a different outcome [12-15]. IoT technology is described as the use of sensors in conjunction with a system to build a system that can physically connect objects and software [16]. Users can connect to the system controller using this technology remotely, considering that there is an internet connection available.

There were some previous studies related to the topic of flood monitoring systems using the Smart IoT sensors [17-22]. The comparison in terms of components usage and limitation of those previous studies was tabulated in Table 1.

Table 1
Comparisons of previous related studies

Ref	Components	Limitation
[17]	Sensor type: ultrasonic sensor Microcontroller: ARM Mbed NXP LPC1768 IoT: ThingSpeak Additional component: GSM module	The ultrasonic sensor is sensitive to variations in temperature and it is more difficult to read reflections from various objects. Electronic interference can be one of the disadvantages of GSM because it uses pulse-transmission technology. It also had a limited rate of data transfer. Besides, ThingSpeak has limited data processing and forwarding.
[18]	Sensor type: water level sensor, water flow sensor Microcontroller: Raspberry Pi	Raspberry Pi is pricey compared to other processors.
[19]	Sensor type: ultrasonic sensor Microcontroller: Arduino Uno Additional component: GSM module	Arduino Uno has the lack of ability in terms of multitasking which it unable to run multiple programs compare to other microcontrollers.

Based on Table 1, considering the limitation of certain components that have been used in previous studies, this study proposes to develop a reliable flood alarm system using IoT technology, focusing on the manipulation of the flow and float sensors to study on the water flow and water level detection process. The ESP32 microcontroller was chosen for this study, as it is lower in cost as compared to Raspberry Pi but still has good capability for multitasking purposes. This comprehensive system will monitor water levels, water flow and provide timely alerts under various conditions. By integrating IoT devices, the system enables seamless communication and automated actions, reducing the reliance on human intervention [10].

2. Methodology

This section describes the materials used and the methodology implemented for the development and implementation of the flood monitoring and alert system. The equipment utilized in the system, including the sensors, microcontroller, indicators and display module, are outlined. The step-by-step methodology is presented, covering sensor installation, programming, calibration, data collection, processing, real-time display, alert mechanism and user interface. Additionally, the equation used for calculating the flow rate is also provided.

Figure 1 is a schematic diagram for the prototype. In the schematic diagram, the system incorporates a flow sensor, float sensor and LEDs indicator. The proposed flood monitoring and alert system apparatus utilized two different sensors namely float sensor which is used to detect the water level and flow sensor (YF-S201) which is used to measure the water flow rate. ESP32 microcontroller was utilized as the central processing unit for system control. In addition, the light emitting diodes (LED) were used as indicators to provide visual notifications to indicate water level status while LCD display module was used for real-time visualization of water-related information. Finally, mobile phones are also needed for receiving pop-up notifications from the Blynk application.

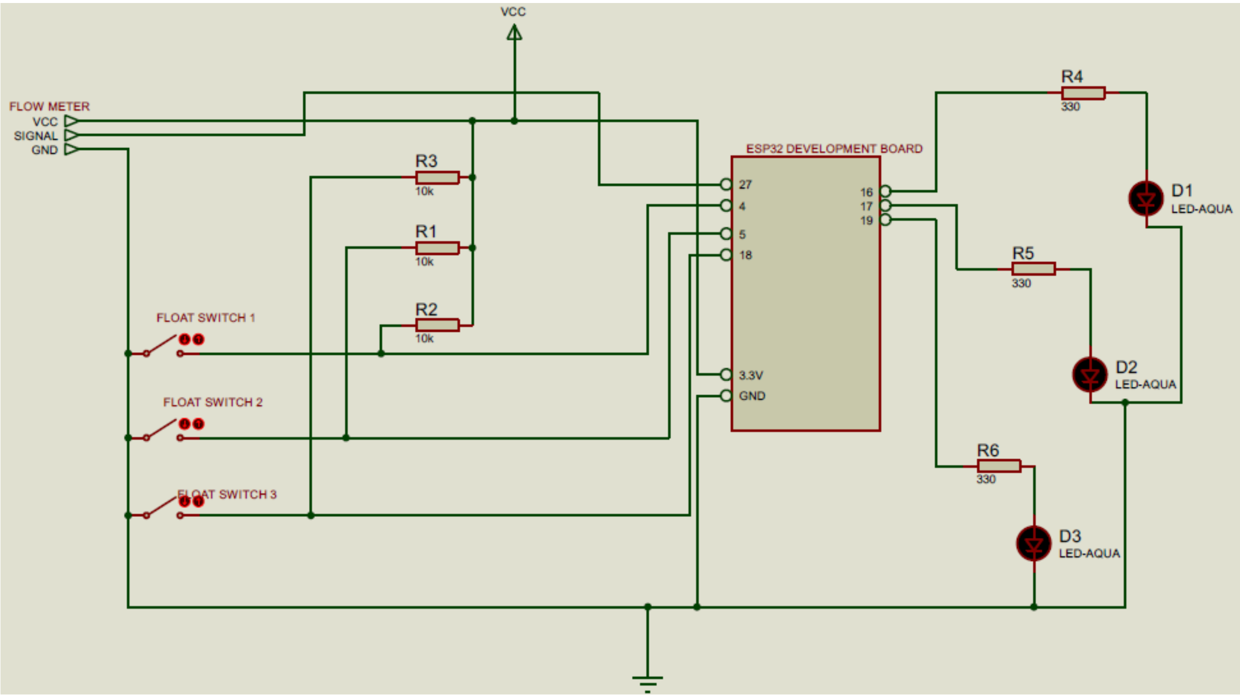

Fig. 1. The schematic diagram of the prototype

In indoor sensor testing, two experiments were conducted to assess the functionality and accuracy of the float sensor and flow sensor. The experiments aimed to evaluate the sensors' performance in detecting water levels and measuring the flow rate of water in a controlled environment. Valuable insights were gained regarding the capabilities and limitations of the sensors, providing a foundation for further analysis and improvements. The experiments included accuracy tests, data collection, analysis of flow rate measurements, comparison to the actual flow rate and visualization of flow rate data using the Blynk platform. The results indicated that while there were slight deviations in the measured flow rates, overall, the sensors performed well and provided reliable measurements. Further calibration and exploration of alternative sensor models were suggested to improve precision.

2.1 Float Sensor Setup

Figure 2 shows the indoor experiment setup for float sensor testing which focused on the float sensor's functionality in detecting water levels. Three float sensors were positioned at three different heights. The objective was to assess its ability to accurately determine the presence or absence of water. The results of this experiment provided insights into the performance of the float sensor in a controlled indoor environment.

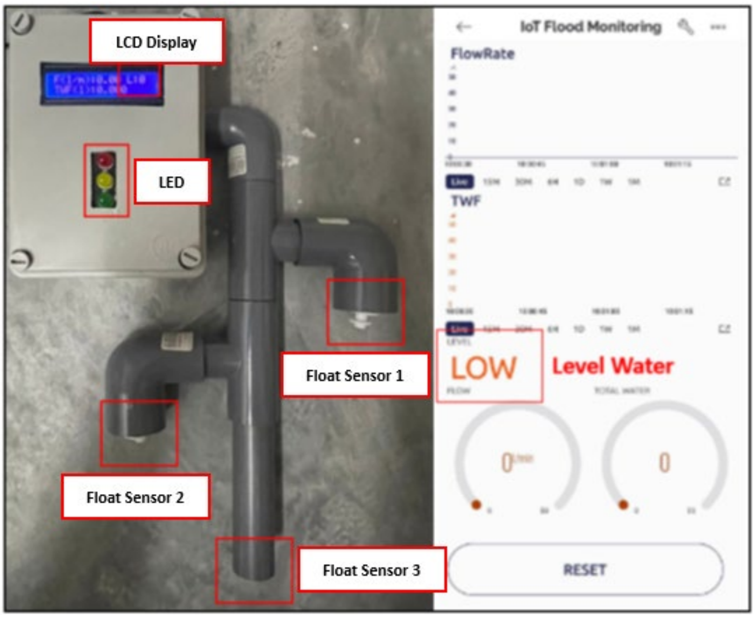

Fig. 2. Water level monitoring setup for indoor experiment

The float sensors are placed at various heights inside the pipe to capture water levels accurately. The positioning of the float sensors, in Figure 3, ensures that they cover a wide range of water level measurements, which in real flood situation may represent the rising of the water level.

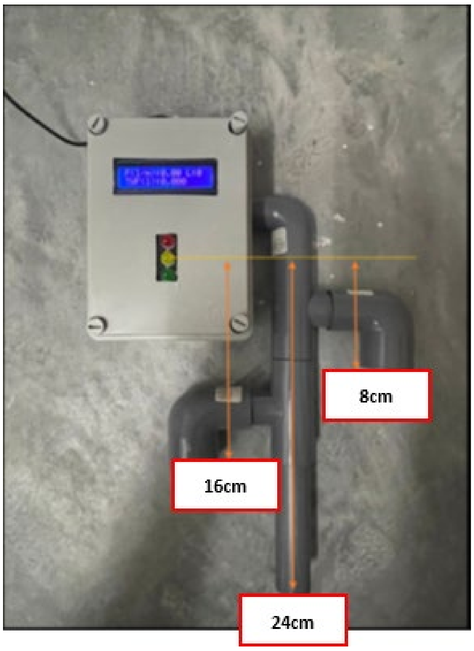

Fig. 3. Water level height

The following Table 2 provides an example of the placement of float sensors at different heights.

Table 2
Placement of float sensors at different heights

Float Level	Height (cm)
1	24
2	16
3	8

2.2 Flow Sensor Setup

Figure 4, depicts the installation of the flow sensor in the water flow path, ensuring its secure placement and appropriate connections. The setup includes a power supply and signal conditioning circuitry to interface with the sensor. The YF-S201 flow sensor, with its specified flow range and accuracy, was selected for this experiment. Its specifications include a flow range of 1-30 litres per minute (L/min) and an accuracy of ±2 %. Before conducting the measurements, the calibration factor (CF) of 4.5 for the YF-S201 flow sensor was determined following the manufacturer's recommended calibration process. This process involves considering any observed offsets or deviations during preliminary testing, ensuring that the CF value accurately aligns the sensor's output readings with known reference values.

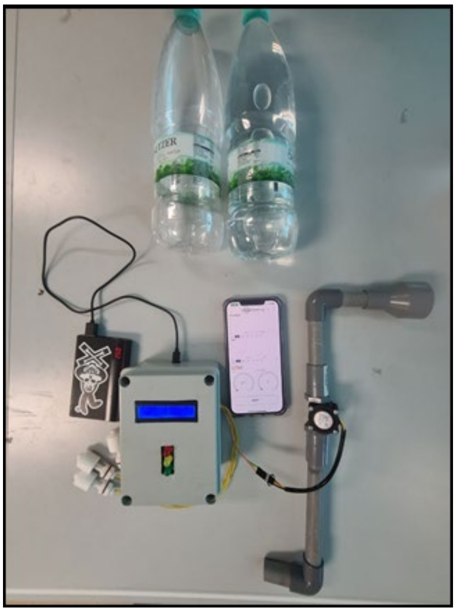

Fig. 4. Setup for flow sensor

The experiment involves two bottles: one filled with 1250 mL of water and the other empty. To collect the necessary data for assessing the flow rate, the following steps were followed:

i. The empty bottle was positioned beneath the flow sensor outlet.
ii. The water flow was initiated and the timer was started simultaneously.
iii. The time taken to fill the empty bottle completely, within a fixed duration of 30 seconds, was recorded.
iv. The LCD output connected to the flow sensor displayed the volume of water accumulated in real-time.

v. The volume display on the LCD and time measurements were recorded for each trial, ensuring multiple repetitions for accuracy and reliability.

The flow rate (Q) was determined using Eq. (1), where Q represents the flow rate in mL/s, v represents the volume of water in mL and t represents the time taken to fill the empty bottle in seconds.

$$Q = \left(\frac{v}{t}\right) \tag{1}$$

This calculation allowed for the measurement of water flow through the YF-S201 flow sensor. The methodology employed an LCD module for real-time volume display, incorporating the sensor's specifications and a fixed 30-second duration. This approach ensured consistent and accurate data collection, enabling precise assessment of water flow rate measurements.

3. Results

3.1 Float Sensor Testing

This section discusses the combination of LED indicators, an LCD display and IoT integration which was successfully utilized to provide comprehensive water level monitoring capabilities. Figure 5(a) - 5(d) visually represent the setup, which was further demonstrated through three different testing (for each height, 8 cm, 16 cm and 24 cm, respectively) to showcase its functionality. The results obtained from these cases highlight the effectiveness of the system in accurately detecting and displaying water levels in real-time. The successful integration of these components enables remote access and monitoring of the water level information, enhancing water management's overall efficiency and convenience.

In Figure 5(b), float sensor 3 accurately detected the water level at a height of 24 cm inside the regular pipe. As a result, the green LED indicator illuminated, indicating that the water level reached the threshold for Level 1. The LCD display concurrently displayed the water level as Level 1, providing a visual confirmation. Additionally, the user platform displayed the same information, allowing for remote access and monitoring of the water level status. This demonstrates the successful integration of the components and the system's ability to provide real-time water level updates across different platforms.

In Figure 5(c), float sensor 2 accurately detected a water level of 16cm inside the system. In response, the yellow LED indicator illuminated, indicating that the water level reached the threshold for Level 2. The LCD display was promptly updated to reflect the water level as Level 2, providing an on-site visual reference for monitoring purposes. Additionally, the user platform connected to the IoT integration displayed the current water level as Level 2, enabling remote monitoring and facilitating data analysis. This demonstrates the effective functionality of the system in detecting and relaying water level information across multiple platforms.

In Figure 5(d), float sensor 3 accurately detected a water level of 8cm within the system. This triggered the red LED indicator to illuminate, indicating Level 3. The LCD display was promptly updated to show the water level as Level 3, providing an easily accessible on-site reference. Simultaneously, the user platform accessed through the IoT integration displayed the corresponding water level as Level 3, facilitating remote monitoring and real-time visualization of the data. This demonstrates the system's effectiveness in detecting and communicating water level information across various platforms for comprehensive monitoring capabilities.

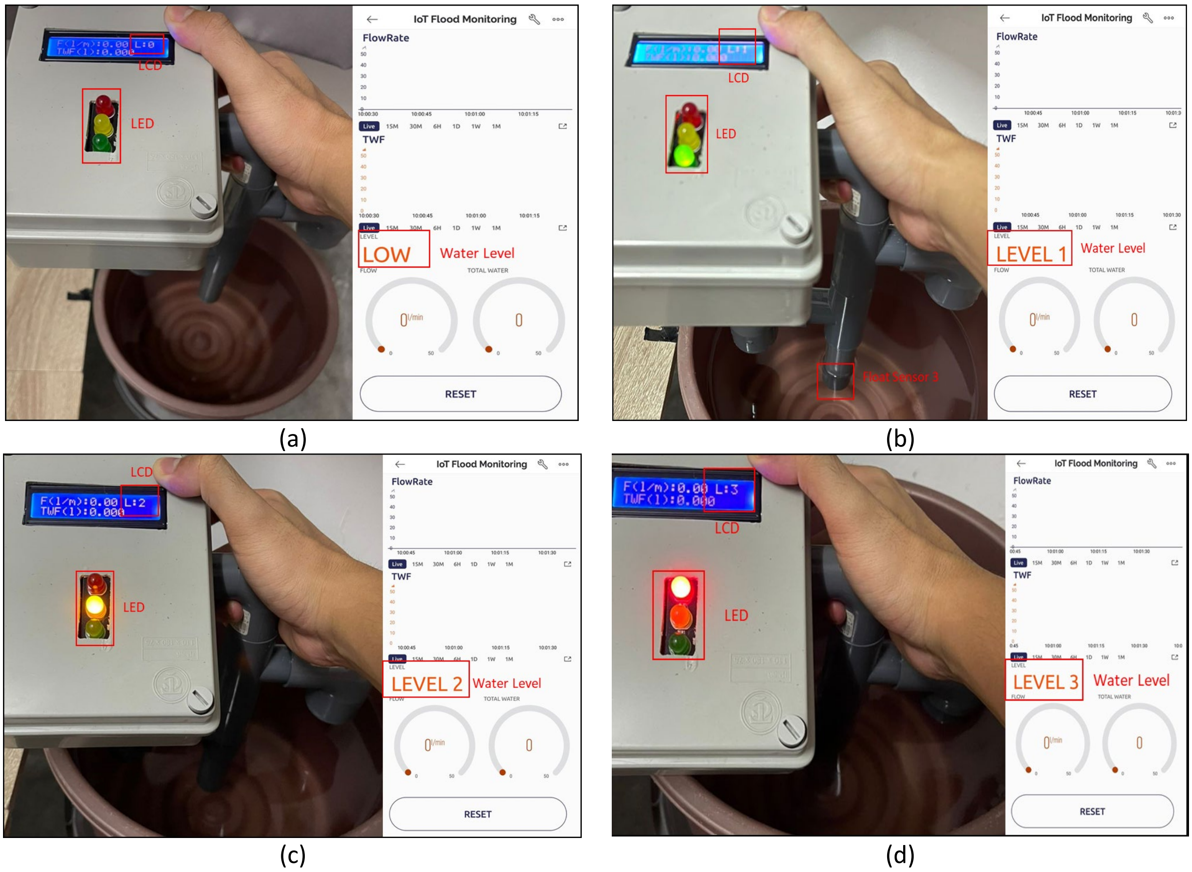

Fig. 5. Setup for flow sensor (a) before the testing performed (b) testing for water level 1 (c) testing for water level 2 (d) testing for water level 3, respectively

The integration of LED indicators, an LCD display and IoT technology in the experiment setup enabled effective water level monitoring at different thresholds. The LED indicators provided visual cues, the LCD display showed precise readings and the IoT integration allowed remote access through a user platform. This comprehensive system allowed for real-time monitoring and data analysis, enhancing the efficiency and accuracy of water level monitoring.

3.2 Flow Sensor Testing

The flow sensor was observed to be functional, accurately measuring water flow through the pipe and displaying readings on the LCD screen. The experiment aimed to evaluate the precision of the flow sensor by using two 1250 mL bottles, one filled with water and the other empty. The objective was to obtain conclusive results regarding the sensor's accuracy in measuring water flow. Table 3 presents the collected data, including measured water outputs in millilitres (mL) and the corresponding calculated flow rates in litres per minute (L/min). The data was obtained using Eq. (1) to calculate the flow rates. The table provides a detailed record of the water outputs and flow rates for each trial conducted during the experiment.

Based on Table 3, accurate readings were obtained by conducting the experiment 10 times, with each test lasting 30 seconds. The reference volume measurements for the experiment were based on 1250 mL bottles. The aim was to ensure precise and reliable data collection during the assessment of the flow sensor. The minimum flow rate corresponds to the lowest recorded value observed in the testing was at 2.404 L/min, while the maximum flow rate was at 2.444 L/min. The mean flow rate, which serves as an estimate of the central tendency, representing the average value of the flow rates was at 2.431 L/min with standard deviation of 0.015 L/min.

Table 3
The recorded water outputs and calculated flow rates

Test Number	Time, s	Volume, mL	Total Output Water, mL	Flow rate, mL/s	Flow rate, L/min
1	30	1250	1221	40.7	2.442
2	30	1250	1216	40.533	2.432
3	30	1250	1218	40.6	2.436
4	30	1250	1221	40.7	2.442
5	30	1250	1222	40.733	2.444
6	30	1250	1217	40.567	2.434
7	30	1250	1220	40.667	2.44
8	30	1250	1210	40.333	2.419
9	30	1250	1214	40.467	2.428
10	30	1250	1202	40.067	2.404

Table 4 presents the comparison between the measured flow rates and the corresponding actual flow rate for each trial, allowing for an assessment of the agreement between the two. Based on the comparison in Table 4, the measured flow rates closely approximate the actual flow rate, showing minimal deviations. The small differences observed between the measured and actual flow rates indicate the precision and accuracy of the measurement system. To quantitatively assess the level of deviation, the percentage error can be calculated using Eq. (2), which compares the measured flow rate to the actual flow rate.

$$Percentage\ Error = \left(\frac{(measured\ value - actual)}{actual}\right) x\ 100\% \quad (2)$$

Table 4
Comparison of flow rate measurements to the actual flow rate

Test Number	Actual flow rate, (L/min)	Measured flow rate, (L/min)	Percentage error, %
1	2.5	2.442	-2.32
2	2.5	2.432	-2.72
3	2.5	2.436	-2.56
4	2.5	2.442	-2.32
5	2.5	2.444	-2.24
6	2.5	2.434	-2.62
7	2.5	2.44	-2.40
8	2.5	2.419	-3.24
9	2.5	2.428	-3.00
10	2.5	2.404	-3.84

The percentage error calculated using Eq. (2), ranges from -2.32% to -3.84% as shown in Table 4. The negative values indicate a slight underestimation of the flow rate by the measurement system. On average, the deviation from the actual flow rate is approximately -2.64%, indicating consistent and accurate measurements that closely align with the ground truth.

This comparison to the actual flow rate confirms the reliability of the measurement system in accurately capturing and quantifying the flow rates. The small percentage of errors demonstrates the system's accuracy and precision, highlighting its robustness and reliability for flow rate assessment.

Figures 6 depict the flow rate graph displayed in Blynk, showcasing the fluctuations in flow rate over time. The graph is generated using data collected from the flow sensor, which accurately measures the speed at which water moves through the system. Through the Internet of Things (IoT) connectivity, the flow rate values are transmitted to the Blynk platform, enabling real-time monitoring and visualization of the flow rate data.

The flow rate graph in Figure 6 displayed through the Blynk platform, offers a visual representation of water flow dynamics, facilitating the analysis of patterns and trends in flow rate measurements. By easily identifying fluctuations or anomalies, users can conduct further investigations or make necessary adjustments to the system. This real-time monitoring and analysis tool empowers users to make informed decisions based on the flow rate data, enhancing system performance and optimization. The calculated flow rates consistently fall below the actual value of 2.5 L/min, suggesting potential factors that contribute to this deviation, including calibration inaccuracies, limitations in the flow sensors' design or inherent measurement errors. However, it is important to highlight that despite the deviation, the measured flow rates still maintain a relatively close proximity to the actual value. Enhancing the precision of the flow sensor could be achieved through refining the calibration process or exploring alternative flow sensor models with higher accuracy specifications.

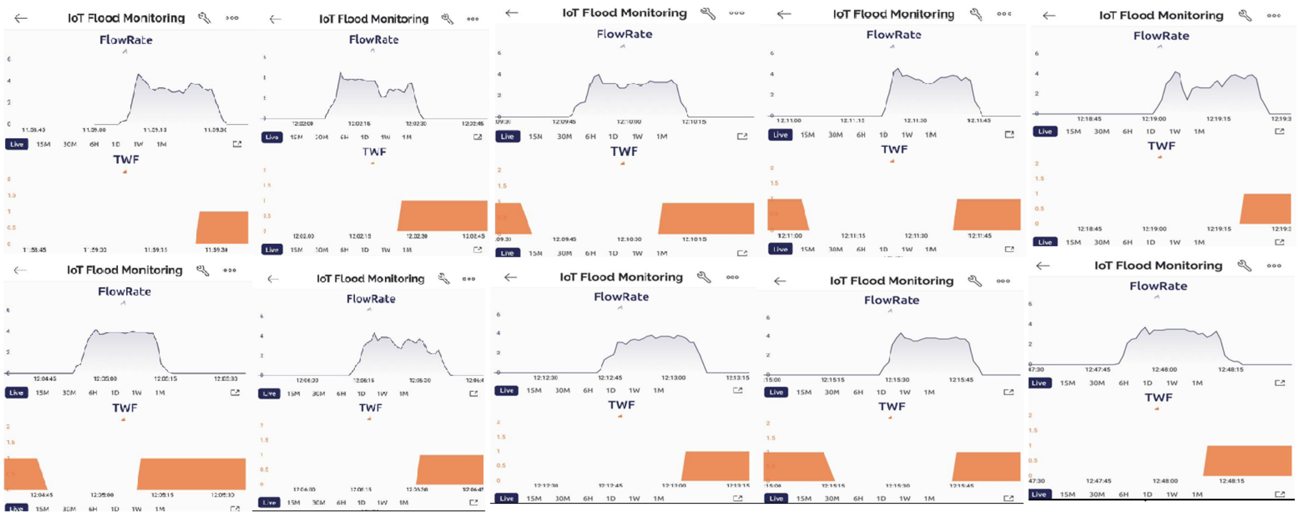

Fig. 6. Flow rate analysis on Blynk application

The flow rate measurements were conducted using the YF-S201 flow sensor, calibrated with a factor of 4.5. However, certain factors such as the height of the pipe, pressure and the presence of a 90-degree elbow in the piping system could have influenced the accuracy of the flow sensor readings. These factors may have caused variations and deviations in the measured flow rates. Nevertheless, the collected data allowed for the calculation of flow rates in millilitres per second (mL/s) based on the volume of water and the time taken to fill the empty bottle. The integration of float sensors provided real-time monitoring of the water level. The Blynk application visualized the water level status using graphical representations, facilitating effective water resource management. The system demonstrated accurate flow rate measurements and reliable water level monitoring, although considering the potential impacts of pipe height, pressure and the presence of a 90-degree elbow.

4. Conclusions

In conclusion, this study successfully developed an IoT-based water flow rate and water level monitoring system using sensors and the Blynk application. The system demonstrated accurate measurement and monitoring of water flow rates and levels. The YF-S201 flow sensor and float sensors performed effectively in their respective tasks. The integration with Blynk enabled remote access and real-time data visualization. Moving forward, improving measurement accuracy and conducting outdoor testing are recommended. Exploring additional functionalities and integrating with data analytics can enhance the systems' capabilities. Overall, the system offers valuable tools for water management, resource utilization and decision-making in water resource management and conservation.

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