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Smart Water Level Detection System

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Abstract

Flash floods pose a significant threat in urban areas, particularly in underground parking structures and basements, where rapid water accumulation can lead to severe damage to vehicles, electrical systems, and infrastructure. These events often occur without warning, triggered by heavy rainfall, blocked drainage, or overflowing water sources. To address this challenge, a Smart Water Level Detection System was developed using Internet of Things (IoT) technology to enable real-time monitoring and early warning alerts. The system's main objective is to detect rising water levels promptly and notify users before critical levels are reached. It integrates two water level sensor switches and an ultrasonic sensor to classify water depth into three categories: Low (0–4 cm), Minimum (4–7 cm), and Maximum (above 8 cm). A NodeMCU ESP8266 microcontroller processes the data collected from the sensors and connects to Wi-Fi for remote communication. Notifications are sent to the user's smartphone through the Telegram messaging app, while local alerts are provided using a buzzer and OLED screen, offering immediate audible and visual feedback. The system was tested under various simulated water conditions, and the results confirmed accurate detection and reliable responses at all levels. Telegram notifications were received within 1 to 7 seconds depending on the network connection, while the buzzer and OLED screen responded instantly. At the Maximum water level, a high-alert message was triggered alongside buzzer activation. These outcomes validate the system's efficiency, speed, and suitability for flood-prone environments. By providing both local and remote alerts, this smart system enhances urban flood preparedness, minimizes property damage, and enables faster emergency responses in underground spaces.

1. Introduction

Flooding remains one of the most devastating natural disasters affecting both developed and developing countries, causing widespread destruction to infrastructure, property, and even human lives. In urban areas, particularly in Malaysia, flash floods have become more frequent due to intense rainfall, poor urban drainage systems, and uncontrolled development activities such as deforestation and land use changes [1]. One of the most vulnerable infrastructures during these events is underground parking areas, which are highly susceptible to water accumulation because of their below-ground design and limited drainage. As highlighted by the Department of Irrigation and Drainage Malaysia (JPS), there is a growing need for proactive flood protection mechanisms in such spaces to minimize damage and ensure public safety [2].

Various studies have explored the application of the Internet of Things (IoT) in flood and water management systems. IoT offers real-time data monitoring, remote alerting, and automation features that are vital in flood-prone environments [1], [3]. For instance [1], developed a flood monitoring system using ultrasonic sensors and Blynk IoT software to notify users when water levels rise, allowing timely action [1]. Similarly [3], proposed an IoT-based smart water management system with RF communication for real-time tank monitoring, which significantly reduced human dependency and resource wastage. These projects demonstrate the potential of IoT in improving the effectiveness of early warning systems, especially when applied in sensitive areas like basements and underground car parks.

However, many existing systems are either too complex or designed for broader flood-prone regions such as riversides or large catchment areas. Few solutions directly address the unique characteristics and risks faced by underground parking lots, where flash floods can rise rapidly and remain undetected until damage has already [4],[5] occurred. In these confined and often poorly ventilated spaces, even 10 cm of water can damage vehicle electronics, cause short circuits, or lead to electrocution hazards [7]. Manual inspection is ineffective in such scenarios due to the suddenness of flooding events and limited visibility. Therefore, a localized, real-time monitoring system tailored to basement structures is critical.

This project proposes a Smart Water Level Detection System that leverages IoT capabilities to provide real-time monitoring and immediate alerts for flood risks in underground parking areas. The system uses a combination of two water level sensor switches and an ultrasonic sensor to detect and classify water levels into three stages: Low (0–4 cm), Minimum (4–7 cm), and Maximum (above 8 cm). A NodeMCU ESP8266 microcontroller is responsible for processing the sensor data and transmitting alerts through the Telegram messaging platform. Local alerts are supported by a buzzer and OLED display to ensure both visual and audible warnings. This dual-alert mechanism ensures that users are notified immediately on-site and remotely, enabling faster response and decision-making.

By addressing the specific risks faced in underground parking environments, this system aims to fill a critical gap in current flood preparedness strategies. Similar works such as those by [4],[5] have shown that using microcontroller-based systems with cloud-connected alerts can effectively minimize water damage and enhance public awareness in emergency scenarios [4], [5], [7]. The proposed system's simplicity, affordability, and accuracy make it a practical solution for both private property owners and municipal authorities aiming to reduce the impact of flash floods in urban infrastructure.

2. Methodology

This section explains the overall methodology used when designing the Smart Water Level Detection System. Giving a thorough overview of the system design, including the integration of hardware and software, is the main focus of this methodology. The approach consists of the materials and components employed, the project design, and the system's logical operation. The NodeMCU ESP8266 microcontroller is used for data processing, sensor input handling, and multi-mode output distribution via audio, visual, and Internet of Things-based alerts. The approach starts with the system block diagram, which shows the data flow and essential functions.

2.1 Hardware Design and Simulation

The system employs water level sensor switches and an ultrasonic sensor to classify and monitor water levels in an underground parking area. The inputs from these sensors are transmitted to the NodeMCU ESP8266 microcontroller, which serves as the system's brain. It processes the sensor data and triggers outputs depending on the water level detected. These outputs include a buzzer for audible alerts, an OLED display for real-time visual feedback, and the Telegram application, which sends notifications to a user's smartphone via Wi-Fi.

Fig. 1 presents the complete block diagram of the system. The water level sensor switches are responsible for detecting the minimum and maximum thresholds, while the ultrasonic sensor continuously monitors the water's distance. All inputs are managed by the NodeMCU, which then controls the output devices. This combination of sensors and wireless communication enables both local alerts and remote monitoring, increasing system reliability and safety for flood-prone environments.

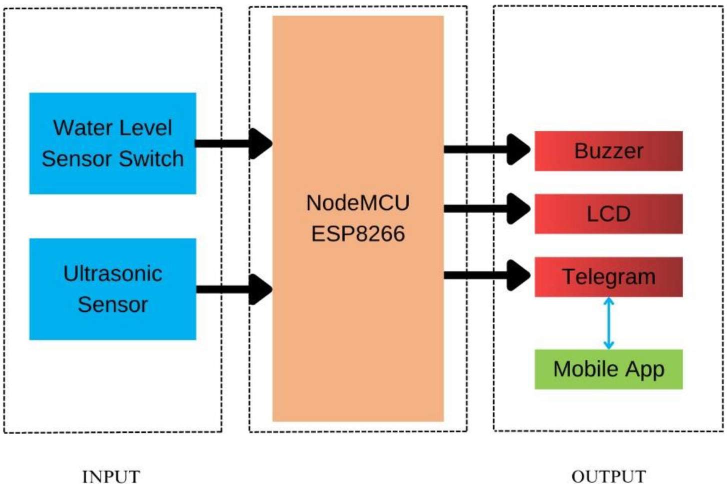

Fig. 1 *System block diagram of Smart Water Level Detection System*

The system's operational functionality relies on the data collected from the sensors, which is then processed to make informed decisions. The flowchart depicted in Fig. 2 provides a comprehensive outline of the sequential procedures involved in detecting early signs of flooding. The sensors gather and analyze the water level data, which is then displayed on the OLED screen and also transmitted to the user via the Telegram application installed on their mobile device.

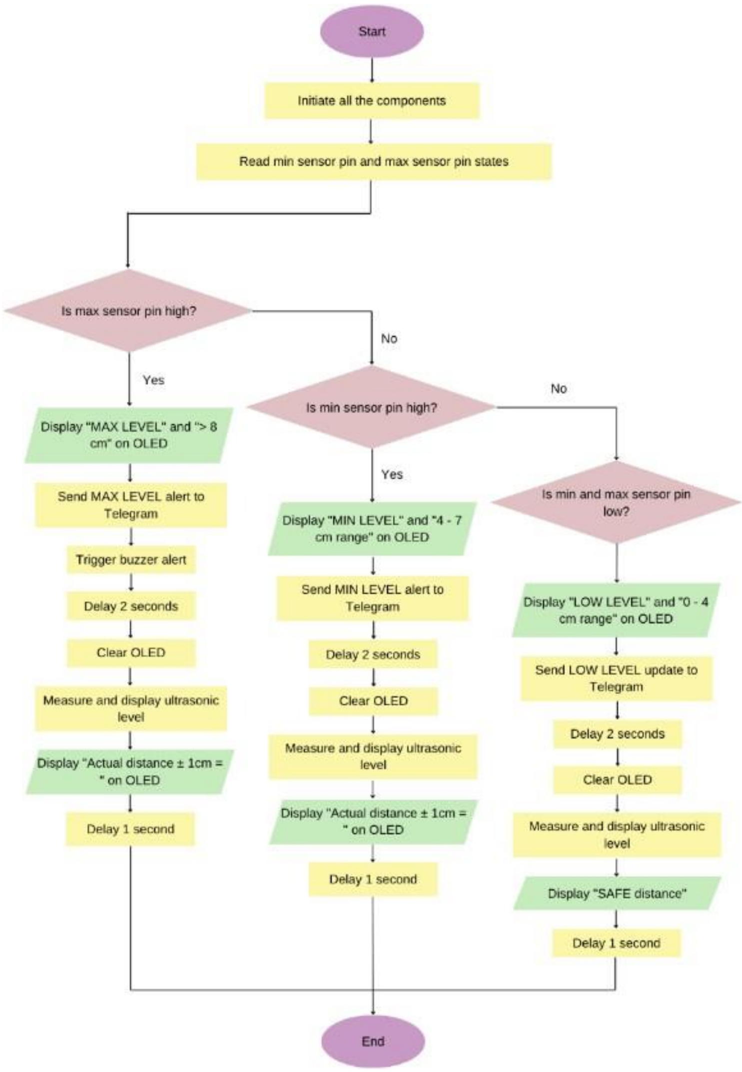

Fig. 2 *Flowchart of Smart Water Level Detection System*

Fig. 2 illustrates the logical operation of the Smart Water Level Detection System. The process begins by initializing all hardware components, followed by reading the input states of the minimum and maximum level sensor switches. Based on the sensor input, the system classifies the water level into one of three conditions: MAX, MIN, or LOW. For each condition, the OLED screen displays the corresponding status, and a Telegram alert is sent to the user.

If the maximum level is reached, the system activates the buzzer, displays a "MAX LEVEL" warning, and sends an alert. If only the minimum level is detected, a "MIN LEVEL" message is shown, and a corresponding notification is issued. When neither sensor is triggered, the system identifies a low water level, displays a "LOW LEVEL" warning, and sends an update without activating the buzzer. In all cases, the ultrasonic sensor is used to measure and display the real-time water level in centimetres on the OLED screen. The system incorporates short delays and screen clearing steps to ensure smooth, readable operation and avoid repeated notifications.

2.2 Schematic Circuit

Fig. 3 shows the schematic circuit diagram of the Smart Water Level Detection System using the ESP32 microcontroller. The circuit begins with a USB power supply connected to the ESP32 board, which provides 3.3V and 5V outputs to support all components. The ESP32 acts as the central processing unit that reads sensor inputs, executes decision logic, and controls outputs.

Two push buttons are connected to simulate water level sensors: the yellow button represents the minimum water level, and the red button represents the maximum water level. When these buttons are pressed, they trigger their respective input pins on the ESP32. Corresponding yellow and red LEDs are connected in parallel to provide a visual indication for each level condition. These simulate actual water level sensor switches used in physical implementations.

An ultrasonic sensor (HC-SR04) is connected to the ESP32's digital pins to measure the distance to the water surface. It provides continuous readings used to calculate the actual water level in centimetres. The result is displayed on a 16x2 LCD module, which is wired to the ESP32 using parallel data lines and power connections. The LCD shows both the level status (LOW, MIN, MAX) and the measured distance.

A buzzer is also connected to the ESP32 to provide an audio alert when the water reaches the maximum level. The buzzer is activated programmatically via a digital output pin, ensuring users receive real-time alerts for high-risk conditions. This schematic demonstrates how each component interfaces with the ESP32 to monitor and respond to water level changes effectively.

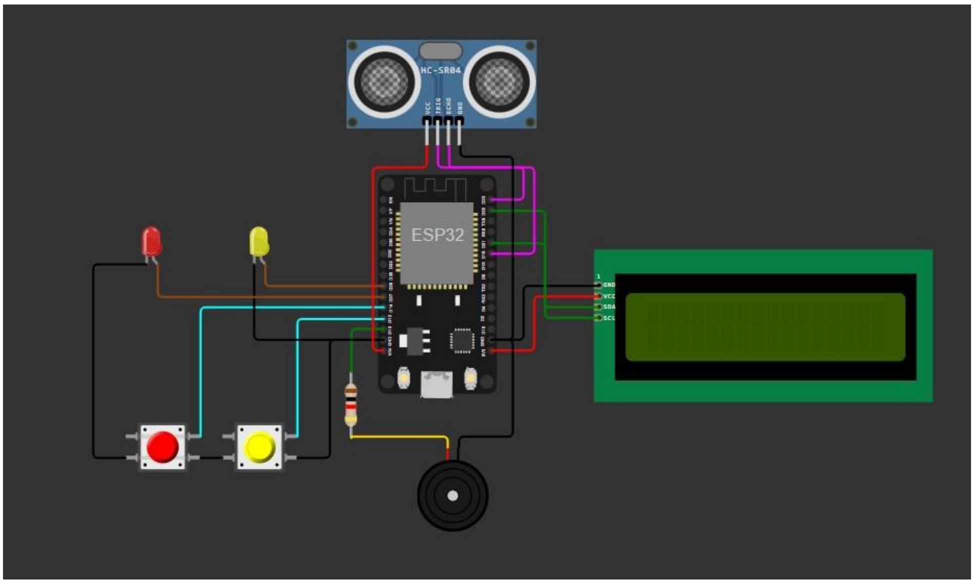

Fig. 3 *Simulated schematic circuit of the Smart Water Level Detection System using Wokwi software*

The schematic in Fig. 3 was developed using the Wokwi simulator, which does not support all actual components used in the physical prototype. As a result, some elements have been substituted for simulation purposes. The LEDs represent the water level sensor switches (minimum and maximum), while push buttons simulate water reaching those levels. The ESP32 is used in the simulation as a substitute for the NodeMCU ESP8266, which is used in the actual system. Additionally, the HC-SR04 ultrasonic sensor represents the JSN-SR04T waterproof ultrasonic sensor used in the real hardware setup. Although resistors are included in the simulation for

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safety, they were not used in the actual circuit, as the voltage and current were within safe operating limits. Despite these substitutions, the schematic accurately reflects the system's functionality and logic.

3. Results and Discussion

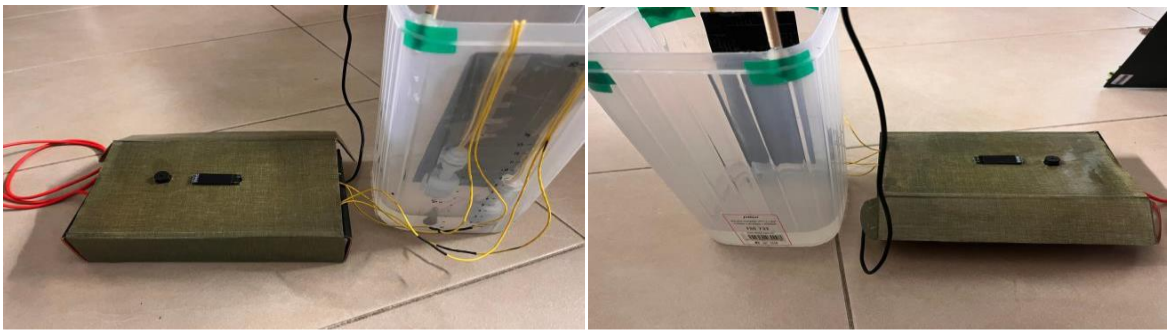
This section presents a summary of the results derived from the project simulation, along with a discussion on their implications and overall significance.

3.1 Project Design and Prototype

Fig. 4(a) presents the top view of the Smart Water Level Detection System, showcasing the external layout and overall structure of the prototype. The front and back views are illustrated in Fig. 4(b), providing a clear perspective of the mounted components and casing design. Fig. 4(c) displays the internal view of the junction box.

(a)

(b)



(c)

Fig. 4 *(a) Top view; (b) front and back view; (c) Internal view of project design*

3.2 Smart Water Level Detection System Testing

Table 1 presents the testing and observation results of the Smart Water Level Detection System. It summarizes a series of tests aimed at evaluating the system's functionality and responsiveness, including sensor triggering, buzzer activation, Telegram notifications, water level transitions, ultrasonic sensors, Wi-Fi connectivity, and response times for both OLED display and Telegram alerts. The tests were designed to reflect real-world conditions, such as changing water levels and temporary Wi-Fi disconnection. Overall, the system performed reliably and prompted local alerts. A minor delay was noted in Telegram message delivery, likely due to variations in internet connectivity and server response time.

Table 2, on the other hand, presents the ultrasonic sensor accuracy test results. The actual water height is in centimetres and the measurements obtained by the ultrasonic sensor are contrasted in this table. With variations surpassing ±2 cm, the data indicates that the sensor readings are unreliable and unstable at water heights below 4 cm. The readings become more consistent after 5 cm, with an acceptable accuracy of ±1 cm, and nearly match the actual water level. This demonstrates that the ultrasonic sensor can locate MIN and MAX thresholds within the specified range, but it is unreliable at very low water levels.

Table 1 *Smart Water Level Detection System testing results*

Test Type	Test Description	Actual Result
Level Sensor Switch Trigger Test	Activate MIN and MAX level switches manually at set water levels.	As expected, sensor logic works correctly.
Ultrasonic Sensor Test	Evaluate accuracy of ultrasonic readings at various water levels	Accurate at 5 cm and above; unstable below 4 cm
Buzzer Alert Test	Raise water to MAX level to trigger buzzer.	Buzzer activates correctly and functioning.
Telegram Notification Test	Simulate LOW, MIN, MAX levels and check	Messages received correctly. Telegram notifications working.
Rising Water Simulation	Gradually fill tank and observe transitions between levels.	Smooth transition observed. System detects level changes properly.
Falling Water Simulation	Slowly drain water and observe system response	System accurately detects dropping levels
WiFi Disconnection Test	Disconnect WiFi and trigger MAX level	Local alerts worked. System functions offline for local alert
Response Time Test to OLED Display	How fast does the system show updated water level information on the OLED after a sensor state change (LOW → MIN → MAX)	1 second delay
Response Time to Telegram Notification (IoT Alert)	Time between triggering a level change and receiving a Telegram message on the phone	Received notification after 7–6 seconds.

Table 2 *Ultrasonic sensor accuracy testing results*

Actual Water Height (cm)	Sensor Reading (cm)	Accuracy	Remarks
1	Unstable / Fluctuating	± > 2 cm	Not reliable 4 cm and below
2	Unstable / Fluctuating	± > 2 cm	Not reliable 4 cm and below
3	Unstable / Fluctuating	± > 2 cm	Not reliable 4 cm and below
4	Inconsistent	+3 cm	Not reliable 4 cm and below
5	4.9 – 6.0	±1 cm	Stable
6	5.9 – 7.0	±1 cm	Stable
7	6.8 – 7.9	±1 cm	Stable
8	7.9 – 9.0	±1 cm	Consistent with MAX threshold trigger
9	8.9 – 9.8	±1 cm	Stable
10	9.9 – 10.8	±1 cm	Stable

3.3 Discussion

Throughout all performance and functionality testing, the Smart Water Level Detection System operated dependably, showing precise readings and smooth operation in a range of situations. When tested at their respective water heights, the MIN and MAX level sensor switches both functioned precisely as intended, and the OLED display correctly displayed the water level status at that moment. During the rising and decreasing water simulations, the system also smoothly switched between the LOW, MIN, and MAX states, demonstrating the successful implementation of the control logic and wiring. When the Wi-Fi was disconnected, local functionality continued to function, guaranteeing uninterrupted operation even during network interruptions. The buzzer also correctly engaged at the MAX level, providing a dependable local warning.

In terms of accuracy, the ultrasonic sensor produced stable and reliable readings above 4.9 cm, with a margin of error around ±1 cm, which is acceptable for the system's intended use. However, readings below 4 cm were found to be unstable and overestimated the actual water height, confirming that the sensor is not suitable for very low-level detection. Despite this limitation, the system performed well overall, with real-time Telegram notifications working correctly—though delayed by 6 to 7 seconds due to possible network latency. The OLED response time was around 1 second, which is satisfactory for on-site monitoring. Overall, the project ran smoothly, with only minor setbacks that do not significantly affect its ability to provide early flood warnings in underground parking areas.

4. Conclusion

In conclusion, the Smart Water Level Detection System effectively solved the key issue of undetected water accumulation in underground parking areas and fulfilled its project objectives. The objective of creating a dependable sensor circuit was achieved when the device successfully detected water levels utilizing both level sensor switches and an ultrasonic sensor. During testing, both local (OLED and buzzer) and distant warnings worked well, and integration with the ESP8266 microcontroller allowed real-time notifications via Telegram. These characteristics provide a proactive way to reduce property damage and safety hazards in underground parking facilities, thereby addressing the problem statement's emphasis on the critical necessity for early flood detection.

Despite the system's normally reliable performance, there is still room for development to increase its practical usefulness. A backup power source, like a solar panel or rechargeable battery, would guarantee uninterrupted functioning in the event of power interruptions, which are frequent during flood occurrences. The system would be more reliable, scalable, and appropriate for commercial deployment if it added multi-zone monitoring, enhanced component waterproofing, added alarm alternatives beyond Telegram, and added data logging features. With these improvements, the system might support more general disaster prevention objectives and provide even more protection for urban areas that are highly susceptible to flooding.

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Conflict of Interest

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

Author Contribution

The authors confirm sole responsibility for the following: ***study conception and design****: Debbie Vivi Lim, Mohd Sabani Mohd;* ***data collection****: Debbie Vivi Lim;* ***analysis and interpretation of results****: Debbie Vivi Lim, Mohd Sabani Mohd; and* ***manuscript preparation****: Debbie Vivi Lim. All authors reviewed the results and approved for the final version of the manuscript.*

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