International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 02 , February - 2026

Design and Implementation of an IoT-Enabled Real-Time Flood Detection and Warning System Using Ultrasonic Sensing

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ABSTRACT - Floods are among the most common and devastating natural disasters. The growing number of flood-related fatalities and financial losses worldwide each year requires a more effective response to flood threats. Interestingly, over the past decade, numerous research efforts have examined how Internet-of-Things (IoT) network camera images and wireless sensor data can enhance flood control. This research includes a thorough literature evaluation of IoT-based sensors and computer vision applications for flood surveillance and mapping. This study highlights the principal computer vision algorithms and IoT sensor methods for monitoring floods, flood modelling, mapping, and early warning systems in the literature, including water-level estimates. The report also provides suggestions for further study. The research specifically offers strategies to better control and maintain coastal lagoons via the use of computer vision and IoT sensor approaches – an area not being examined in the literature.

Keywords: Internet of Things (IoT), Flood Detection, Ultrasonic Sensor, Water Level Monitoring, Arduino Uno, Early Warning System, Wireless Sensor Network (WSN), Disaster Management, Real-Time Monitoring, IoT-Based Monitoring System.

1. INTRODUCTION

Natural hazards such as floods, hurricanes, tsunamis, and other environmental disasters pose a significant threat to life and property worldwide. These hazards frequently lead to catastrophic events that result in major economic losses, social disruption, and damage to urban and rural environments when proper monitoring and mitigation measures are absent. Among natural disasters, floods are the most dominant risk, accounting for a large share of global natural hazards in recent decades. Historical records indicate that thousands of flood events have affected vast populations worldwide, resulting in substantial fatalities and economic losses. A flood disaster is generally defined as the overflow of water into normally dry areas, which severely disrupts human activities and social systems. The actual impact of floods becomes even more critical when small-scale, unreported flood events are considered, especially in developing, densely populated regions where monitoring infrastructure is limited. With increasing uncertainties related to climate change and the growing population in flood-prone zones, the need for improved flood monitoring and response systems is more essential than ever. Conventional flood surveillance methods often rely on manual inspection, fixed-point sensors, or delayed reporting mechanisms, which lack real-time responsiveness and wide-area coverage. These limitations reduce the effectiveness of early warning systems and increase the risk of disaster-related losses. To address these challenges, researchers have made significant efforts to develop cost-effective, comprehensive flood-monitoring technologies. One widely explored approach is the use of computer vision techniques, which capture and process images from urban surveillance cameras to support flood monitoring and decision-making. These cameras provide broad spatial coverage at relatively low cost and enable simultaneous detection of water levels at multiple locations. Compared to traditional fixed-sensor systems, computer vision-based monitoring offers enhanced observation capabilities and improved situational awareness. Image processing, which underpins computer vision, has been widely used across fields such as aerospace, medical diagnostics, traffic monitoring, and environmental analysis. Consequently, research on the use of computer vision for flood detection, flood mapping, debris flow estimation, and post-flood damage assessment has increased considerably over the past decade.

In addition to vision-based techniques, the development of reliable computational models and sensor-based monitoring systems has been a major focus in flood prediction research. Wireless Sensor Networks (WSNs) have emerged as an effective solution for real-time environmental monitoring due to their ability to collect and transmit data continuously from distributed locations. Seal et al. [1] proposed a forecasting model based on WSNs that performs rapid calculations to predict river flood conditions and generate early warning alarm signals, thereby helping save lives. Shebli et al. [2] analysed the energy consumption of sensor

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networks by considering parameters such as data flow rate, number of nodes, and transmission distance, emphasising the importance of energy-efficient design in long-term monitoring applications.

Furthermore, Ahmad et al. [3] presented a comprehensive study on flood analysis and prediction using Geographic Information Systems (GIS) combined with Ad hoc Wireless Sensor Network architecture. Their work demonstrated the usefulness of simulation tools for identifying flood risks before and after disasters. Similarly, Jong-uk Lee et al. [4] developed a real-time Flood Monitoring System (RFMS) deployed in island regions, where river and weather conditions were continuously measured using wireless sensor nodes equipped with multiple sensors.

Mauricio Castillo-Effen et al. [5] introduced a flash-flood alert system for the Andean region that utilized advanced wireless communication and information technologies, with WSNs playing a key role in tracking environmental changes during disaster evolution. Hughes et al. [6] highlighted that the extent of flood damage is directly related to the warning time provided before the event and proposed a hybrid system integrating local and remote sensor networks to improve early alert mechanisms. Additionally, Sunkpho et al. [7] developed a web-based flood information system that facilitates communication between authorities, experts, and the public, thereby enhancing coordination and disaster management efficiency.

Energy efficiency is another critical factor in sensor-based monitoring systems. Halgamuge et al. [8] presented a comprehensive energy model for wireless sensor networks, identifying major energy consumption sources, including sensing, communication, processing, logging, actuation, and cluster formation. Their study emphasised the importance of optimising energy use for sustainable, long-term environmental monitoring systems.

Overall, the existing literature indicates that IoT, WSNs, GIS, and computer vision-based monitoring techniques provide effective solutions for real-time flood detection and early warning. However, many existing systems are either costly, complex, or difficult to deploy in remote and flood-prone areas. Therefore, there is a strong need for a low-cost, reliable, and easily deployable flood detection system that can provide continuous water level monitoring and timely alerts [9-19]. This motivates the development of an IoT-based early flood detection and avoidance system that integrates ultrasonic sensing, microcontroller processing, and real-time alert mechanisms to improve disaster preparedness and reduce flood risk.

2. SYSTEM SETUP AND RESULT DISCUSSION:

The proposed IoT-based early flood detection system is developed to monitor water levels in real time and generate early warning alerts using a sensor-based embedded architecture. The complete design flow of the flood detection process, including sensing, processing, and alert generation, is shown in Fig. 1. The system comprises sensing, control, display, alert, and actuation units, integrated via a microcontroller for continuous monitoring.

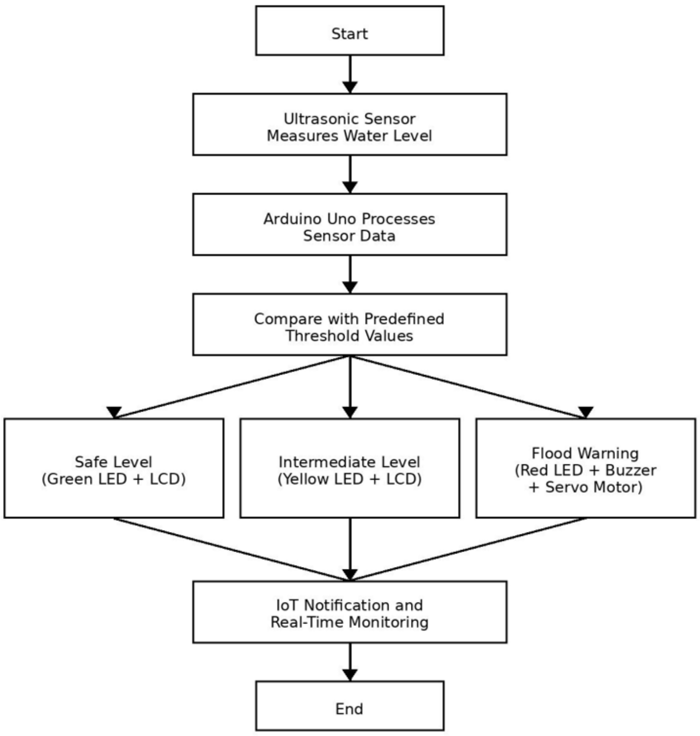

Figure 1: Design Flow of IoT-Based Flood Detection System

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The overall hardware architecture and component arrangement of the proposed system are illustrated in Fig. 2**.** The system uses an ultrasonic distance sensor as its primary sensing element, mounted above the water surface to measure the distance to the water level.

The sensor transmits ultrasonic waves and receives the reflected echo signal from the water surface. Based on the time delay between transmission and reception, the distance is calculated and converted into water level data.

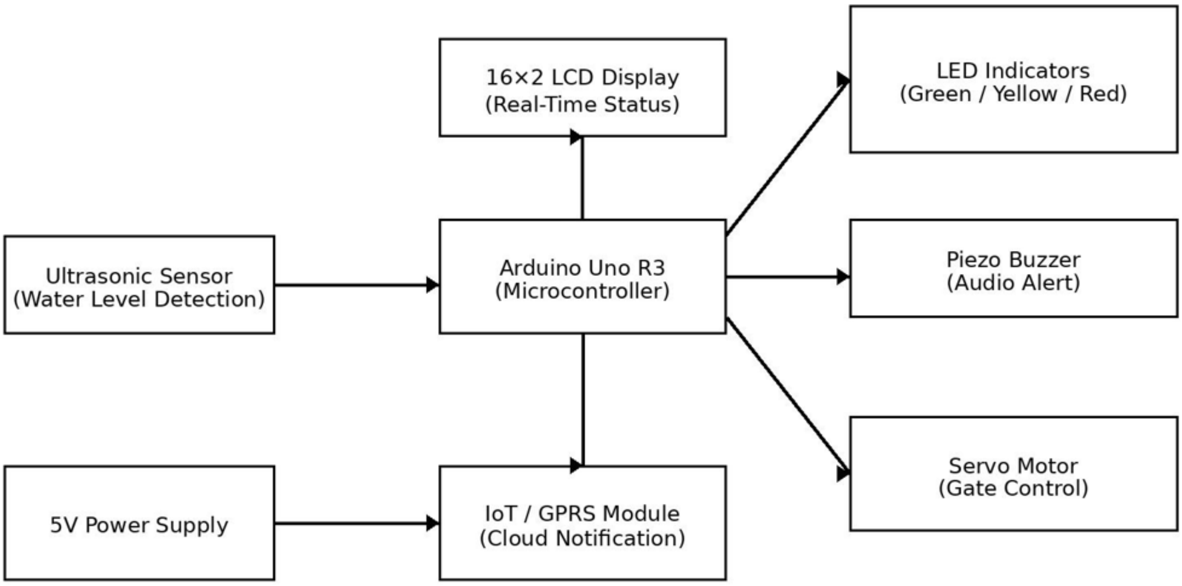

Figure 2: Hardware Architecture of the Proposed Flood Detection System.

The system also includes a piezo buzzer for audio alerts and a micro servo motor for automatic gate control to restrict entry into flooded areas or regulate water flow during high-risk situations. A potentiometer is used for LCD contrast adjustment, while resistors and jumper wires ensure stable circuit connections and proper operation of all components. The prototype system is designed to measure water-level variations over a short range (approximately 0–13 cm) and provide continuous monitoring via an IoT-enabled interface. The system parameters are shown in Table 1. The ultrasonic sensor's measured data is transmitted to the Arduino Uno R3 microcontroller, which serves as the system's central processing unit. The microcontroller continuously compares the measured water level with predefined threshold values to classify the condition as safe, intermediate, or critical. The detailed experimental prototype setup with all hardware components connected through jumper wires and resistors is shown in **Fig. 3**

Table 1: System Parameters

Parameter	**Specification**	**Function**
Sensor Type	Ultrasonic Sensor	Measures water level distance
Microcontroller	Arduino Uno R3	Processing and decision making
Detection Range	0–13 cm	Water level classification
Threshold Levels	Safe, Medium, High	Flood condition identification
Display Module	16×2 LCD	Real-time status display
Alert System	LEDs and Piezo Buzzer	Visual and audio alerts
Actuator	Micro Servo Motor	Automatic gate control
Power Supply	5V DC	System operation

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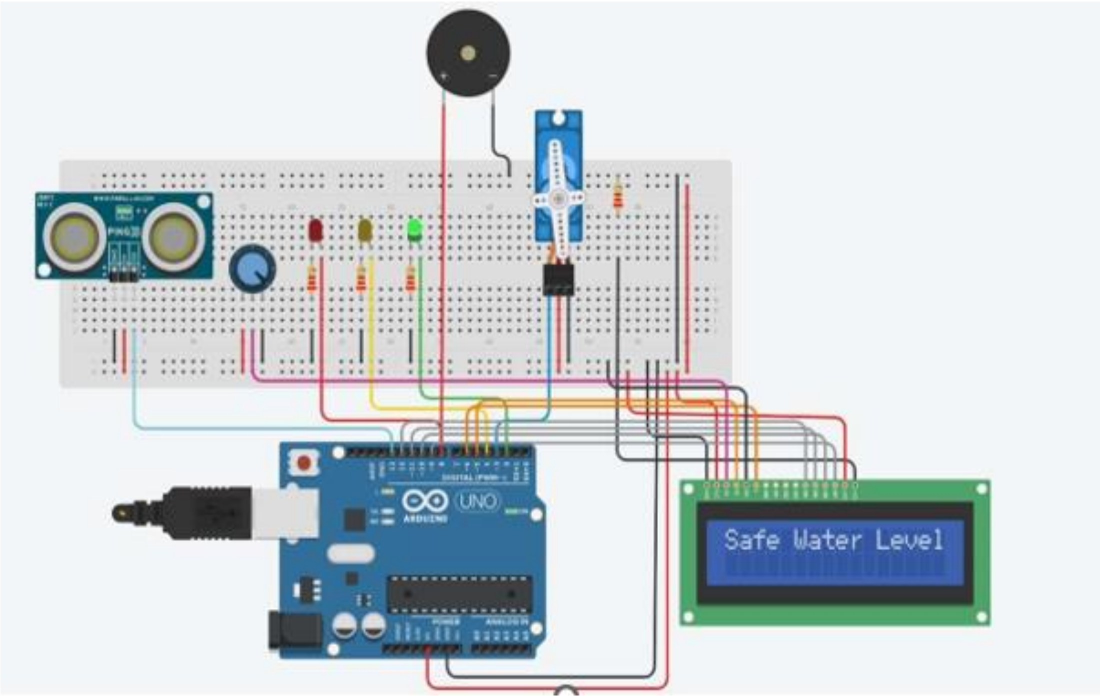

Figure 3: Experimental Setup of Flood Detection Prototype

A 16×2 LCD display is integrated into the system to provide real-time monitoring of water level status. When the water level is within the normal range, the LCD displays the message "Safe Water Level" and the green LED glows, indicating safe conditions. As the water level rises and reaches the intermediate threshold, the yellow LED is activated to provide an early warning as shown in fig. 4. When the water level exceeds the critical threshold, the red LED, piezo buzzer, and servo motor are automatically activated to indicate a flood warning condition and initiate preventive control actions. The output indication at different water levels, including safe, moderate, and high flood conditions, is depicted in **Fig. 5**

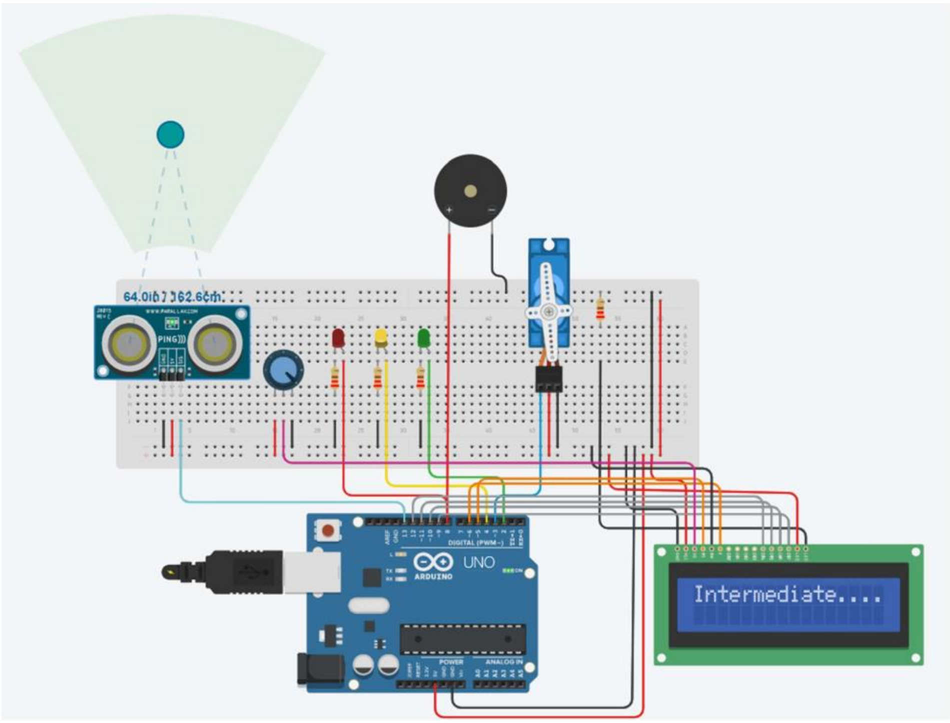

Figure 4: LCD Display Showing Intermediate Water Level Status

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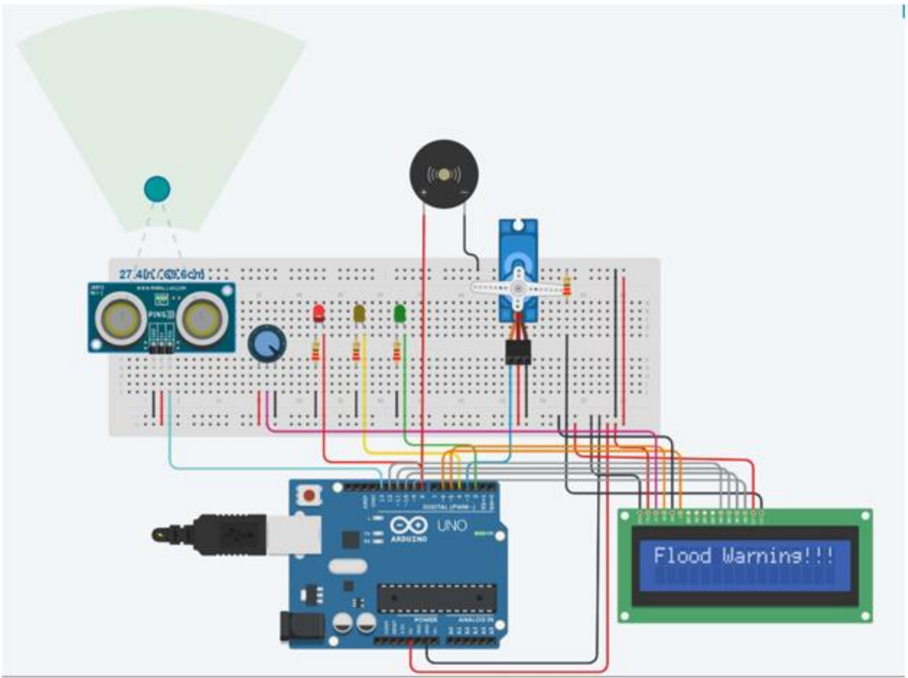

Figure 5: LCD Display Showing Flood Warning Water Level Status

The ultrasonic sensor measured water level variations within the range of 0–13 cm and transmitted the data to the Arduino Uno microcontroller for processing. The system classified the water level into three categories: safe, intermediate, and flood warning. Table 2 shows the observed system response for different water levels. The results indicate that the system accurately detects water-level changes and responds immediately in accordance with the programmed threshold limits. The LCD display provides real-time status updates, which enhance monitoring efficiency.

Table 2: Water Level Detection and System Response

Water Level (cm)	System Status	LED Indication	Buzzer	Servo Motor	LCD Display
0–4 cm	Safe Level	Green LED ON	OFF	OFF	Safe Water Level
5–8 cm	Intermediate Level	Yellow LED ON	OFF	OFF	Intermediate Level
9–13 cm	Flood Warning	Red LED ON	ON	Activated	Flood Warning

3. CONCLUSION AND FUTURE WORK

Disasters, as the name suggests, bring about great havoc on lives and property indiscriminately across the globe. A flood is a natural disaster that is difficult to predict, but we worked on this issue and developed a system that detects floods and provides early notification to nearby people. A lot of effort is required to develop systems that help to minimise the damage through early disaster predictions. The system provides a real-world application of the Internet of Things and offers services like accurate level monitoring. Sensors are important elements in the flood detection system. A complete flood detection and avoidance system has been proposed. The notification sent can be read globally through IoT. An ultrasonic sensor is connected to the microcontroller, which measures the water level in dams or rivers and sends that information to the microcontroller. The GPRS sends that notification through the internet on the webpage using IoT network. The flood detection system will be easy to install and maintain if it is powered by solar cells. Using solar energy will also provide a cheaper power source for the entire system. In the future, we can integrate several sensors, such as a pressure sensor and a camera, into the system to achieve more accurate detection.

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