Wireless Flood Early Warning System for High-Density Population Areas by Combining Ultrasonic and Water Level Sensors

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Abstract: We introduce an innovative solution that integrates ultrasonic sonar systems and water level sensors for real-time monitoring of flood conditions. Utilising wireless communication, it transmits data and issues timely alerts when water levels reach critical thresholds. Designed for densely populated regions, this system enhances community preparedness and safety by providing accurate information to help mitigate risks of floods.

Keywords: Flood, Early warning, NodeMCU, Wireless Sensor

1. Introduction

a. Research Background

In high-density urban areas situated near rivers, the risk of flooding poses a significant threat to lives and property. To address these challenges, the development of advanced *Flood Early Warning Systems* (FEWS) that utilise ultrasonic and water level sensors at critical points across a few regions would be beneficial in providing early warnings to the communities living in those areas. This innovative technology will provide real-time monitoring of water levels, allowing for timely alerts that can save lives and facilitate effective evacuations.

Figure 1 illustrates examples of bottlenecks in a high-density area in Bandar Lampung City, Indonesia. As shown in Figure 1, bottlenecks caused by urban structures such as densely packed houses and bridges create blockages that are prone to flooding. Thus, adding a network of FEWS on those bottlenecks will help in giving earlier warning of potential flooding.

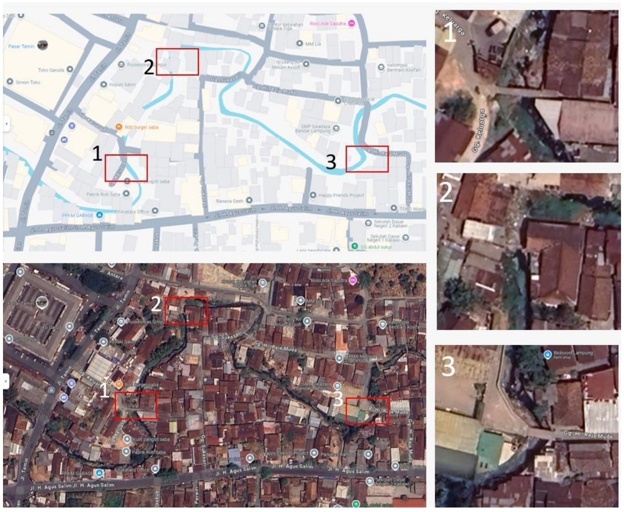

Figure 1 : Locations of identified bottleneck in the the river around high density populated area in Bandar Lampung City, Indonesia

Wireless flood early warning systems combine data from ultrasonic sensors, which measures the distance to the water surface, with traditional water level sensors [1]. This dual approach enhances accuracy and reliability, enabling rapid detection of rising water levels. By transmitting data wirelessly to centralised monitoring systems, urban planners and emergency responders can receive instant notifications about potential flooding, ensuring that timely warnings reach the community.

The integration of this technology is particularly vital in densely populated areas, where the risk of traffic congestion during evacuations is increased. Effective communication of flood warnings can significantly reduce evacuation times and improve safety results [2]. Real-time data allows authorities to assess the situation and make informed decisions about how to handle the issue at hand, this is due to the fact they have been warned ahead of time.

Additionally, case studies have shown that cities employing advanced FEWS experience lower casualty rates and fewer economic losses during flooding events. For example, research highlights the success of such systems in cities like Jakarta, where a combination of sensor technologies have led to more effective flood management strategies [3]. Furthermore, a study has shown the importance of early warning systems for individuals living in high risk areas [4].

b. Problem Formulation

In highly populated urban areas which are located near rivers, the risk of flooding is a major threat to public safety [5]. Residents often have insufficient time to evacuate when flooding occurs, as rapidly rising water levels can cause life-threatening situations in a matter of minutes. The close proximity of large populations to potential flooding complicates emergency responses, making timely evacuations difficult [6].

Due to the high population density, evacuation efforts can be severely hampered [7]. As many individuals attempt to flee at the same time, congestion can occur, impeding movement toward safe areas and delaying emergency services. This effect of congestion not only increases the risk of injury and loss of life but also emphasises the need for an effective early warning system that can provide real-time warnings [8].

To reduce these risks, a Wireless FEWS combining ultrasonic and water level sensors can be developed. This system aims to provide accurate and timely flood warnings, reducing evacuation times and alleviating bottleneck situations in densely populated areas, ultimately improving public safety.

c. Research Objectives

In response to the increasing risk of flooding in high-density population areas, our research aims to develop a comprehensive wireless flood early warning system. This system will integrate ultrasonic sonars and water level sensors to provide accurate and timely alerts, helping residents and local authorities prepare for impending flooding events. A key objective is to minimise false alarms, particularly those caused by debris and garbage carried in bodies of water. By refining detection algorithms and utilising advanced signal processing techniques, we will ensure that the system can differentiate between genuine flood conditions and non-threatening anomalies.

2. Materials and Methods

2.1 Hardware

a) NodeMCU

NodeMCU is a low-cost open-source IoT platform. It includes firmware on the ESP8266 Wi-Fi system on a chip (SoC) and hardware based on the ESP-12 module. It can be programmed using Arduino IDE software to obtain data from the sensor and connect to the internet for real-time data transmission. Its compact size and built-in Wi-Fi capabilities make it suitable for remote monitoring in flood-prone areas.

b) HC-SR04

The HC-SR04 is an ultrasonic distance sensor that utilises sonar technology to measure distance. It consists of a transmitter and receiver that emits ultrasonic waves and measures the time it takes for the echo to return. This sensor is crucial for detecting water levels by measuring the distance from the sensor to the water surface. Its high accuracy and reliability make it ideal for flood detection, especially in high-density population areas where timely alerts are essential.

c) Water level sensor

The water level sensor is designed to detect the presence and height of water in a given area. It typically consists of conductive probes that measure the resistance of water, providing an analog signal proportional to the water level. This sensor is particularly useful for monitoring water accumulation in real-time, allowing for early detection of potential flooding situations. Its simplicity and ease of integration with NodeMCU ensures consistent performance in various environmental conditions.

d) Piezo Buzzer

The piezo buzzer serves as an audible alert system for the flood warning. When the NodeMCU processes sensor data and detects critical water levels, the buzzer emits a loud 31Hz sound to alert nearby residents of the incoming flood. This feature is crucial in high-density population areas, where timely warnings can prevent loss of life and property. The buzzer is compact and power-efficient, making it suitable for continuous use in emergency situations.

e) Lithium battery and shield

A 3.7 Volt Lithium battery is used to power the system. However, since the NodeMCU requires a 5 Volt input voltage, a battery shield is employed to boost the voltage from 3.7 Volts to 5 Volts. This shield not only ensures a stable power supply but also provides protection against overcharging and discharging, thereby enhancing the longevity and reliability of the system. The lightweight nature of the lithium battery makes it easy to deploy in various locations without adding significant bulk.

2.2 Software

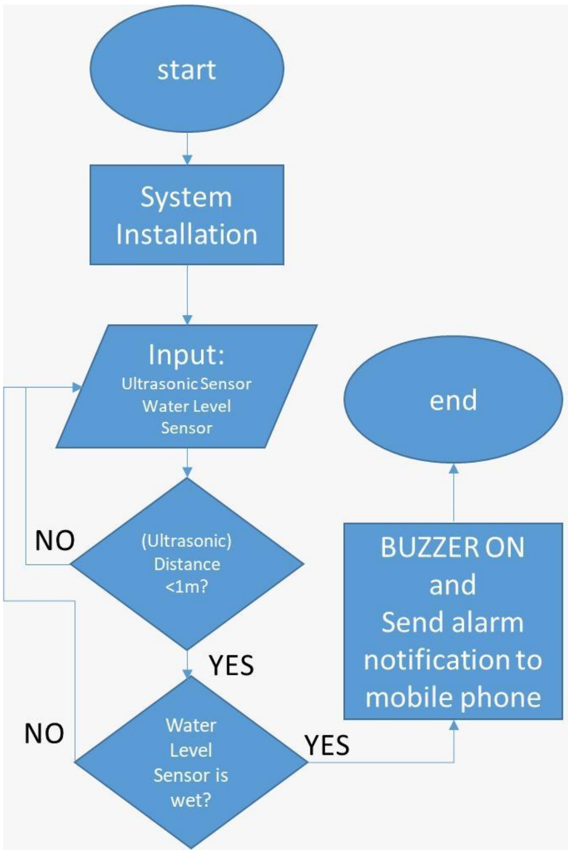

Figure 2 : The Flowchart of the Wireless FEWS system

a) Arduino IDE

The Arduino integrated development environment (IDE) is a cross-platform application (for Microsoft Windows, macOS, and Linux) that is written in the Java programming language. It can be used to program various hardware, including the NodeMCU for our flood warning system, with the program flowchart shown in figure 2.

As shown in figure 2, firstly, the program reads the input data from the ultrasonic sensor and calculates the threshold values for the flood detector. If the distance exceeds the threshold, then it will continue reading the water level sensor. If the water level is HIGH, it will activate the buzzer and send web requests to the IFTTT website.

b) IF This Then That (IFTTT)

IFTTT is a web service that allows its users to create simple instructions called applets. Applets can be used to send a notification to the IFTTT app when the flood detector sends the web request via WIFI.

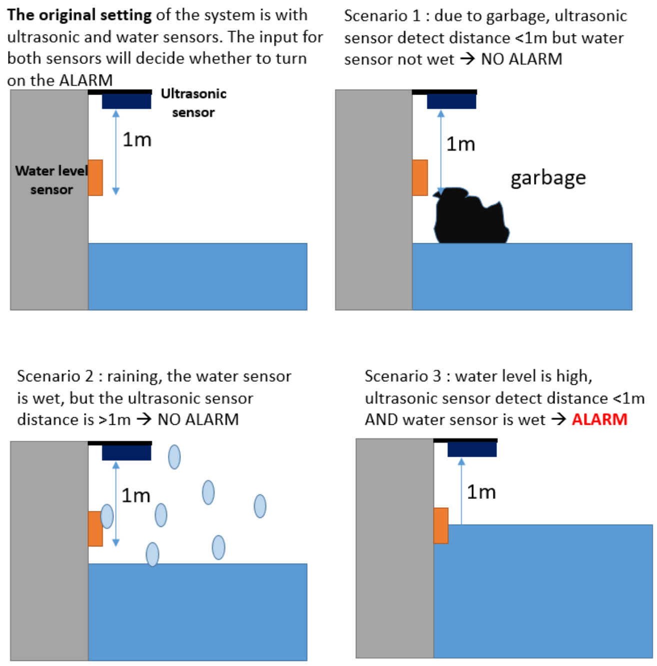

Figure 3 : The use case scenarios of the system

c) Use-case scenarios

Some examples of use-case scenarios are shown in figure 3. One of the main features of the system is to prevent a false alarm as shown in scenario 1 and 2. The alarm and the notification will be sent only in scenario 3.

3. Result and Discussion

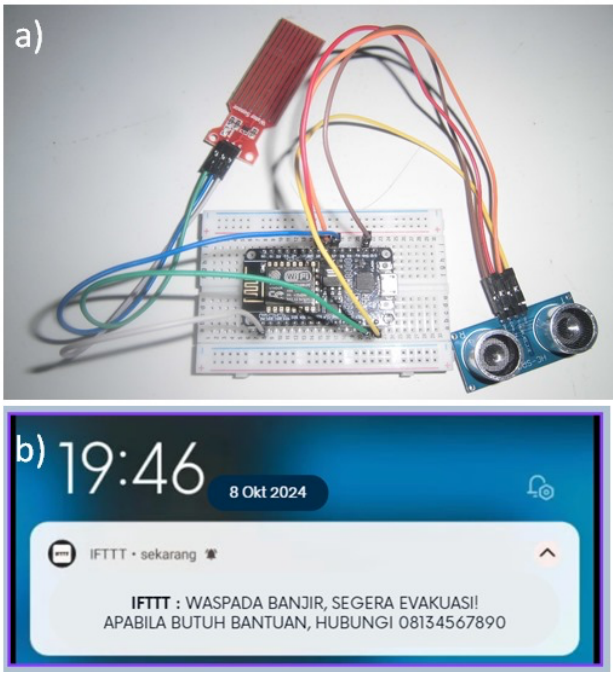

Figure 3 : The prototype of the wireless FEWS a) the hardware of the systems and b) the example of notification send to mobile phone

The prototype of the hardware on a breadboard is shown in figure 3a with examples of notification is shown in figure 3b. As shown in the figure 3a, the overall system is relatively compact and will be easy to be installed in the river areas. The development and implementation of the wireless flood early warning system demonstrate significant advancements in flood detection and community preparedness in high-density areas. By effectively minimise false alarms and improving communication, this system has the potential to save lives and mitigate the impacts of flooding in urban environments.

4. Conclusions and Future Works

We have developed a wireless flood early warning system to urban areas that minimizes false alarms using ultrasonic and water level sensors. We will concentrate on enhancing network connectivity to ensure that the system operates reliably even in areas with poor cellular coverage. Additionally, we will explore the integration of various sensor capabilities to provide a more comprehensive understanding of flood risks and enhance the accuracy of our flood predictions.

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