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Detection and Avoidance of Early Flood using Internet of Things (IoT)

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Abstract

Damage from floods is one of the biggest losses that occurs due to natural disasters affecting livelihoods, properties, and economic activities. Constant floods, a natural disaster with increasing frequency in Nigeria, attribute a proportionate level of socio-economic implications for which creative management approaches are imperative. The following work describes the design and deployment of the IoT-supported flood detection and prevention system for minimising the losses due to floods through controlled observations and alarms. Ultrasonic sensors, waterproof detectors, and Arduino-based controllers are the components of the system; it tracks water levels and shares the necessary information with the users with a mobile application. The detection system divides the areas that may be prone to floods into safe, mid, and danger levels as illustrated using Tinkercad simulation. In safe zones, water levels are maintained and are proven on LCD and green LED light indicators. If the car enters a medium zone, it receives warning alerts and turns yellow LEDs on, but if it gets into a danger zone, it receives critical alarms, and red LEDs light up. Information is relayed to a cloud host for storage, and retrieval is done on a real-time basis through a basic, easy-to-use mobile client. The use of solenoid regulators for water discharge and GPS for location tracking improves the delicateness of the preventive system. By using this model, the authorities and residents of flood-prone areas get early warnings, leading to an improvement of avoiding terrible damages. With regards to the challenges in flood management, this system shows enormous possibility in preventing deaths and reducing socio-economic impacts should it be applied in vulnerable nations such as Nigeria.

Keywords: IoT-based flood detection, flood detection, flood prevention, Water level sensors.

Citation
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Introduction

A flood is one of the most disastrous natural events that is characterised by large volumes of water submerging land, which is usually dry at least during part of the year (Ologunorisa et al., 2022). The possible causes that might lead to flooding are large rains, overflows from rivers or lakes, short drainage areas, instantaneous melting of snow, and storm flows from tropical cyclones or bores in seaside regions (Bruneau, 2022). Flooding may range in severity from a few inches of water to several feet. The effects of flooding are usually alarming and disastrous, often creating tremendous hardships, destroying crops, and resulting in loss of life as well as inundating expensive damages to both private and public properties (Wing et al., 2020).

Obinna & Mathew (2024) stated that the commonly identified types of floods are "river flood, coastal flood, storm surge, inland flooding, and flash flood." While some floods appear suddenly and subside immediately, others take days to months to create on account of variations in size, duration, and area.

According to research by Whitworth Malcolm (2015), Nigeria has knowingly been exposed to flooding, the most common natural disaster experienced within the country. In 2012 alone, Nigeria witnessed a terrible flood that resulted in losses amounting to 6.9 billion US dollars (Adeoye, 2019). This resulted in 363 deaths and displaced 2.3 million people. The main categories of flooding identified to take place in Nigeria include coastal flooding, river flooding, and urban flooding (Louw, 2019). Some factors that contribute to flooding in Nigeria include short or absent drainage systems, poor waste disposal and management, urbanisation not going in tandem with control, poor enforcement of planning laws, and corruption, among others Oladokun & Proverbs, 2016). These serious impacts from flooding call for appropriate flood disaster management: preparation, prevention, response, and mitigation phases (Glago, 2021). This is usually due to catastrophic storm or heavy rainfall events, sudden snowmelt, storm surges, failure of dams, and levees. This additional amount of water in its streams, which it cannot sustain, increases the level of water in the river and leads to the overflow of water from streams; this is generally referred to as a flood. They may be in a local or short flash flood with a small-scale area but with significant effects, or it may be a large-scale riverine flood covering a large area for a long period.

Iyekekpolo et al. (2018) present Wireless Sensor Networks (WSN) as tools for detecting floods and monitoring flood patterns. The authors establish that flooding continues to affect Nigeria's urban areas because of their insufficient drainage infrastructure. A WSN-based flood monitoring system with sensor node deployment in flood-prone locations serves to detect early warning signals, according to the authors. These sensors generate live measurements regarding rainfall and water elevations that automatically transmit wireless signals to a cloud-based analytic interface. The study places central importance on GPS module integration for providing exact location identification of flood-affected areas. The authors conducted tests of the system under flooded conditions, which demonstrated that it could properly detect both swift flood conditions and (IoT) involving water overflow. The study demonstrates how cloud computing handles environmental data before it sends warning alerts through mobile-based systems.

The application of Internet of Things and cloud technologies as per this study leads to better flood risk management by allowing fast interventions that minimize disasters' impacts. System deployment success demands community involvement to maintain systems and respond to flood threats effectively, according to the authors. Ashraf et al. (2023) suggested that the implementation of such systems can reduce the impact of flooding, saving lives and minimising losses in socio-economic terms. One of the severest natural disasters known to cause damage to the economy, loss of life, and property destruction is flooding. Flooding has been identified as one of the most frequent and disturbing disasters in Nigeria. In this respect, flood detection systems will be liable to help in the prediction of the occurrence of floods through proactive procedures aimed at the protection of life and reduction of socio-economic losses.

Methodology

The system integrates IoT into this design for making data transmission between detection devices and mobile applications. Energy is converted to ultrasound by an ultrasonic sensor, while a waterproof sensor actively detects and monitors water levels periodically. Also, there is inclusion of a flooding prevention approach within the system, utilising a solenoid regulator in the regulation of excessive water discharge with the view of controlling the water level and preventing flooding. The flood detection and avoidance system not only alerts citizens via a mobile phone application for early preparation but also enables round-the-clock monitoring of water levels. Additionally, an avoidance system is implemented to regularly lessen rising water levels, providing users with sufficient time to prepare before a flood occurs. Figure 1 indicates the block diagram of the study.

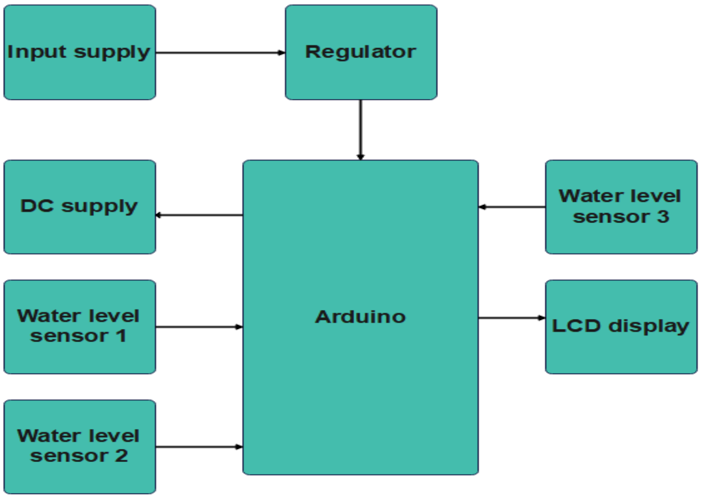

Figure 1: Block diagram of the flood detection system

The single-chip CPU used in the block diagram is Atmel's ATmega328p, to which all of the different sensors and modules are attached. While an HC SR04 Ultrasonic Sensor is employed to determine the target water level in stored water bodies like reservoirs or dams, two Y89 soil moisture sensors are utilised to measure the water level in the ground. The ESP 8266 Wi-Fi module provides internet access, and a 16x2 LCD display is used to show the project's operating status on the board. Figure 2 below indicates the flowchart of the study.

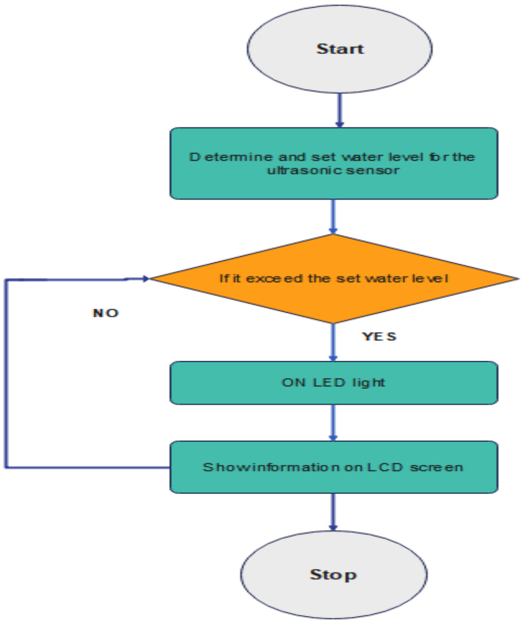

Figure 2: Flowchart of the Flood detection system

Upon activation of the circuit, the ESP 8266 Wi-Fi module will initiate a Wi-Fi connection. Once the connection is successfully established, and the circuit is linked to the internet and cloud services, the data from relevant sensors will be recorded. If necessary, the dam gates will be opened using the servo motor, and water will be released up to the point where the dam approaches the critical limit. If the values fall below the safe range, the data will be updated on the cloud and shown on both the liquid crystal display (LCD) and the graphical interface of the user's Android application.

Software Details

Compiling and writing code for the Arduino Module is the primary function of the open-source Arduino IDE software. Because it is official Arduino software, code compilation is so simple that even the average person without any technical background may start learning. It operates on the Java Platform, which has built-in functions and commands that are essential for debugging, editing, and compiling code in the environment. It is readily available for operating systems such as Linux, Windows, and MAC. Table 1 present the component used.

Table 1: List of Components

Name	Quantity	Components
Name	1	Arduino Uno R3
U1	1	250kΩ Potentiometer
Rpot1	1	220 Ω Resistor
R1	1	LCD 16 x 2
U2	1	Ultrasonic Distance Sensor (4-pin)
DIST1	1	LED RGB
D1	3	1 kΩ Resistor
R2 R3 R5	1	Piezo
PIEZO1	1	Arduino Uno R3

Results

The flood detection system was design using the TinkerCAD software. Figure 3 shows the implementation based on safe zone.

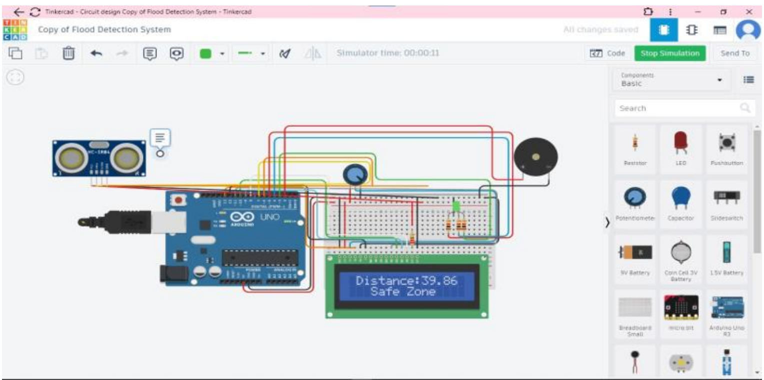

Figure 3: Tinkercad software implementation in a safe zone

The early flood detection using IOTs, developed using Tinkercad software, was tested under three distinct scenarios to assess its capability to monitor water levels and provide real-time alerts. In Figure 3 (Safe Zone), the system detected a water surface distance of 39.86 cm using the HC-SR04 ultrasonic sensor. The code, executed through the Arduino IDE, interpreted this distance as a non-threatening level.

As a result, the LCD displayed "Safe Zone," and the green LED light turned on, indicating safety. Figure 4 indicates the result for medium zone.

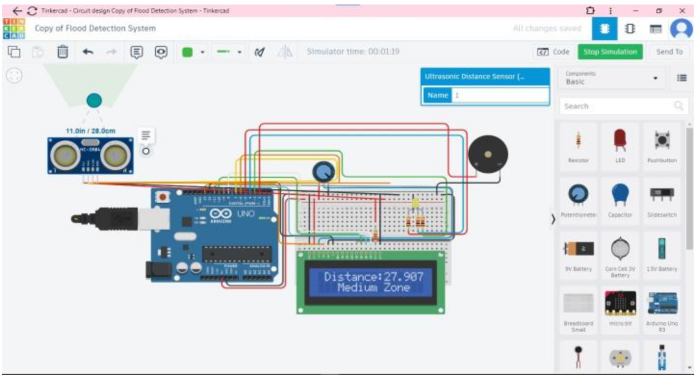

Figure 4: Tinkercad software implementation on a medium zone

In Figure 4 (Medium Zone), the sensor detected a reduced distance of 27.90 cm, suggesting a rising water level that calls for attention. Through the Arduino code, the system classified this as a "Medium Zone," displayed it on the LCD, and activated the yellow LED light and a warning alert was triggered to notify users of the medium flood risk.

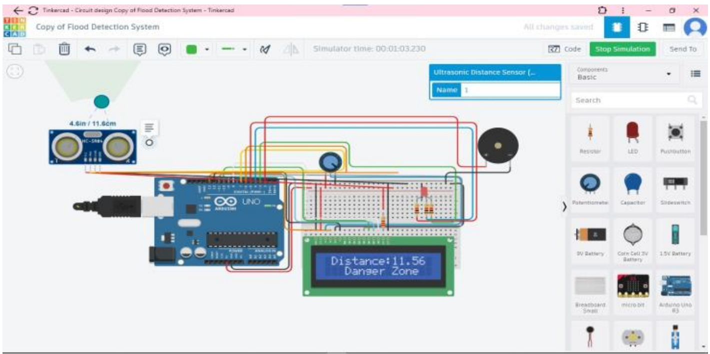

Figure 5: Tinkercad software implementation in a danger zone

In Figure 5 (Danger Zone), this recorded a critical water level with a distance of 11.56 cm. The system identified this as a "Danger Zone," displayed it on the LCD, and switched on the red LED light to signify imminent danger also a warning alert was activated to emphasize the urgent flood threat. Each scenario was accurately simulated to ensure the Arduino code accurately processed sensor data, controlled the LEDs, and triggered alerts, effectively providing comprehensive flood monitoring and warning capabilities.

Connections

- **Ultrasonic Sensor**: Connected to the Arduino to measure the distance.
    - **Trig Pin**: Connected to a digital pin on the Arduino.
    - **Echo Pin**: Connected to another digital pin on the Arduino.
    - **VCC and GND**: Connected to the 5V and GND pins of the Arduino.
- **LEDs and Buzzer**: Connected to digital pins on the Arduino through the breadboard.
    - **Red LED**: Connected to a digital pin with a current-limiting resistor.
    - **Yellow LED**: Connected to another digital pin with a current-limiting resistor.

- **Buzzer**: Connected to a digital pin to sound an alarm when necessary.

- **LCD Display**: Connected to the Arduino to display the distance and alerts.
  - **RS, E, D4, D5, D6, D7**: Connected to the respective digital pins on the Arduino.
  - **VCC and GND**: Connected to the 5V and GND pins of the Arduino.

Discussion

The proposed model offers a solution to the current challenges authorities face in managing flood-related disasters. It has the potential to engage users and provide them with essential crisis information effectively. Real-time monitoring of information will be possible for both water management authorities and users. Furthermore, the integration of cloud services will ensure long-term storage of all logged data on servers. The operation's status can be monitored directly on the project's circuit using the 16x2 LCD display, which will show the mode of operation. This feature can be especially useful for operators who are required to follow safety protocols that prohibit personal electronic devices, such as phones, in the operating area.

Conclusion

In summary, this product has been effectively utilized to utilize the ultrasonic sensor for water level detection and transmitting the data to the mobile app through IoT. By activating GPS Neo-6 M to establish a connection with the satellite, precise flooding locations can be tracked and monitored via the mobile app. Additionally, the Arduino Uno R3 is employed to manage the water level functions of the system (safe level, warning level, and critical level), enabling the system to detect water levels based on predefined values for each level. When the water level reaches the warning level, the solenoid valve is activated to pump out the excess water and users are notified through the mobile application. The solenoid valve's action remains the same, and a notification message appears on users' mobile phones to alert them about the critical rise in water level once it reaches the set value. This ensures that users are warned and can take precautionary measures before the flooding escalates.

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