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Original Article

Mitigating the Impact of Floods: An IoT-Driven Monitoring and Alert System for Somalia's Rivers

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Abstract *- Natural disasters like floods significantly threaten human lives, infrastructure, and the environment. Millions of people are affected by floods yearly, among the most destructive and common disasters worldwide. Floods can significantly influence agriculture, causing harm to crops, soil fertility, and infrastructure in Somalia, where they account for 20% of the country's GDP and 5% of GDP volatility. Compared to other sectors, Somalia's agriculture is more vulnerable to climate and weather extremes, such as temperature changes, unanticipated rain patterns, and increased floods and droughts. The Internet of Things (IoT) recently came into existence as a powerful technology that has the potential to change how we live and work entirely. In this regard, an IoT-enabled river flood monitoring and alert system could be groundbreaking. This article suggests and develops a Somalia-specific real-time and cost-effective Internet of Things (IoT) Enabled River Flood Monitoring and Alert System. The system will use IoT sensors and data analytics to gather data about many aspects of the environment and the river. The data will be sent to a central database for further analysis. Such technology could provide authorities in Somalia and the community living close to flood-prone areas early warning of future floods, enabling them to take preventative action to mitigate the effects of these natural disasters.*

Keywords *- Floods, Rivers, IoT, Agriculture, Alert systems.*

1. Introduction

Natural disasters like floods significantly threaten human lives, infrastructure, and the environment [1]. Floods are among the most destructive and frequent natural disasters worldwide, affecting millions yearly [2]. Floods can have a significant impact on agriculture, causing damage to crops, soil fertility, and infrastructure [3]. In Somalia, the agricultural sector accounts for about 20% of the country's Gross Domestic Product (GDP) and 5% of GDP volatility [4]. Crop and livestock productivity is essential for the country's economic development, comprising more than 65% of the GDP and more than 50% of Somali exports [5].

Additionally, agriculture in Somalia is more prone than other industries to climate and weather extremes, including temperature changes, unexpected rain patterns, an increase in the frequency of floods and droughts, and others [6-8].

While the nation is experiencing its worst drought in four decades, the Shabelle River in central Somalia has triggered floods that have forced hundreds of thousands of people to flee their homes. In Beledweyne, the Hiiraan region's capital, the floods have destroyed buildings, destroyed crops, killed livestock, and temporarily closed schools and hospitals [9-11]. Floods are unpredictable and typically happen when much rain falls, and much water flows into dried-up riverbeds known as "wadis." Illegal logging, deforestation, and land degradation are making matters worse, while conflict, climate change, and overgrazing are making many places more vulnerable to disastrous floods [12]. Over 200,000 people have been affected by the flooding, and 79 percent of the town has been inundated, according to the FAO's Somalia Water and Land Information Management (SWALIM) division. Communities in Somalia devastated by the unprecedented Shabelle River flooding require immediate aid, such as food, water, shelter, and other life-saving supplies [13]. Rescue and relief operations are in progress. However, if heavy rains in Somalia and the Ethiopian highlands persist, the UN predicts that up to 1.6 million people might be affected by flooding, and more than 600,000 could be displaced [11].

Recently, the Internet of Things (IoT) has emerged as a powerful technology that can revolutionize the way we live and work [14-18]. According to [19], IoT applies to environmental and agriculture standards and is entirely devoted to providing emerging public and financial benefits. Therefore, it can be inferred that IoT can be used for environmental monitoring, as it can collect and analyze data from various sources to provide real-time insights into the state of our planet[20]. In Somalia, where floods are common and can cause significant damage to property and infrastructure [12], efficient water management can contribute to the growth of agricultural production by using the water for efficient irrigation [21]. An IoT-enabled river flood monitoring and alert system can be a game-changer. In this article, we propose and build a real-time and cost-effective Internet of Things (IoT) Enabled River Flood Monitoring and Alert System solution for Somalia. The system will collect data from various aspects of the environment and the river by leveraging IoT sensors and data analytics. The data will be transmitted to the central database for further analysis. Such a system can provide early warning of potential floods to Somalia's authorities and the society near the site prone to flood, allowing them to take proactive measures to mitigate the impact of these natural disasters.

2. Literature Review

Technology solutions in flood monitoring and alert systems are not limited to our proposed method in Somalia. Researchers worldwide are exploring the use of technology to develop smart flood monitoring systems that can provide real-time data on water levels, rainfall, and other environmental factors that contribute to flooding [22]. These systems can help people prepare for floods and take necessary precautions to minimize the damage caused by floods.

Ribeiro et al. proposed a web-based platform for information sharing and distribution that unifies critical data on river floods under a single user interface. The system includes various flood-related information, including data from sensor networks on water levels, flows, rainfall, and other pertinent data. The platform can act as a route for information between authorities and specialists to enhance communication and collaboration. It is also a web-based information source for the general public to meet their demand for fast information on water and flooding conditions [23].

Refice et al. proposed an accurate flood monitoring High-precision flood maps can be created from remotely sensed data using a remote sensing system that combines signal and image processing, modelling, and interpretation. Radar sensors like Sentinel, optical sensors like Landsat and the Moderate Resolution Imaging Spectroradiometer (MODIS), and land surface hydrologic routing models can all be used to estimate the extent of a flood [24].

Another study by Bihamdi et al. proposed an Internet of Things Prototyping System for Flood Detection at Pondok Gede Housing. Their approach uses the NodeMCU ESP8266 as a controller, transistors as water level sensors, flow meter sensors, LEDs and LCDs as pointers, and a buzzer as the highest-level alarm. Android smartphones are used to monitor river water levels using the Blynk app. The NodeMCU ESP8266 acts as an information transmitter for the Blynk Application when the Automatic Flood Detection System prototype design generates information. When the water reaches its peak level, the system has an inaccuracy rate of 7.85 percent and a time window of 4 minutes and 3 seconds. Notifications are set up within the Blynk App [25].

3. Methods

This study aims to develop an IoT-based flood detection and warning system for river floods in Somalia to mitigate their impact. We propose and build an Internet of Things (IoT) system to detect floods early and alert the authorities and society near the flood site. The proposed method is composed of several IoT devices. Each device consists of an Arduino Uno microcontroller, water level sensor, river flow sensor, rain sensor, DHT11 sensor, GSM/GPRS, and alarm buzzer. These sensors will collect and communicate to the authorities and society critical parameters from the river, such as water level, river flow, rain, humidity, and temperature. The devices will be deployed in a river site prone to floods to collect data from that site, and the data will be sent to a server for further analysis. It will be displayed on a web application, and the system will send an SMS to notify the authorities and the society around that site. The system will also trigger an alarm to inform the community. Fig 1. shows the proposed Flood detection system architecture. The sensors and devices used are briefly explained below.

3.1. Arduino Uno

The Arduino Uno microcontroller is based on the ATmega328P as the board's foundation. This board has 14 digital input/output pins, 6 of which can be used as PWM outputs, six analog inputs, a 16 MHz quartz crystal, a USB port, a power jack, an ICSP header, and a reset button. An external power supply or a USB connection can power the device [26]. For this project, this board has been selected to connect all the sensors and process the data that they transmit to the board.

3.2. Water Level Sensor

To measure the river's water level, we used both a Water level sensor and an ultrasonic sensor to increase the accuracy of the data and minimize false positives. A water level sensor measures the water level in a tank, reservoir, well, or other water-containing area like a river. It uses various techniques to detect and provide accurate information about the water level [27]. This sensor will measure the water level of the river site that the device is connected. Then, the sensor will send the data to the Arduino board for further processing.

Ultrasonic sensors operate by timing the gap between sending out, typically a few brief pulses, and catching the signal's reflection. The two main components are the transmitter and the receiver. A transmitter block can contain any of these two types of transducers: As its fundamental principle, low-frequency magnetostrictive transducers work by changing the mechanical length of magnetic material. According to the inverse piezoelectric effect theory, high-frequency piezoelectric transducers operate. Transmission of mechanical waves reflected in an electrical signal is the fundamental principle underlying an ultrasonic receiver [28]. This sensor determines the distance between the sensor and the water surface. By measuring this distance, the water level can be indirectly calculated.

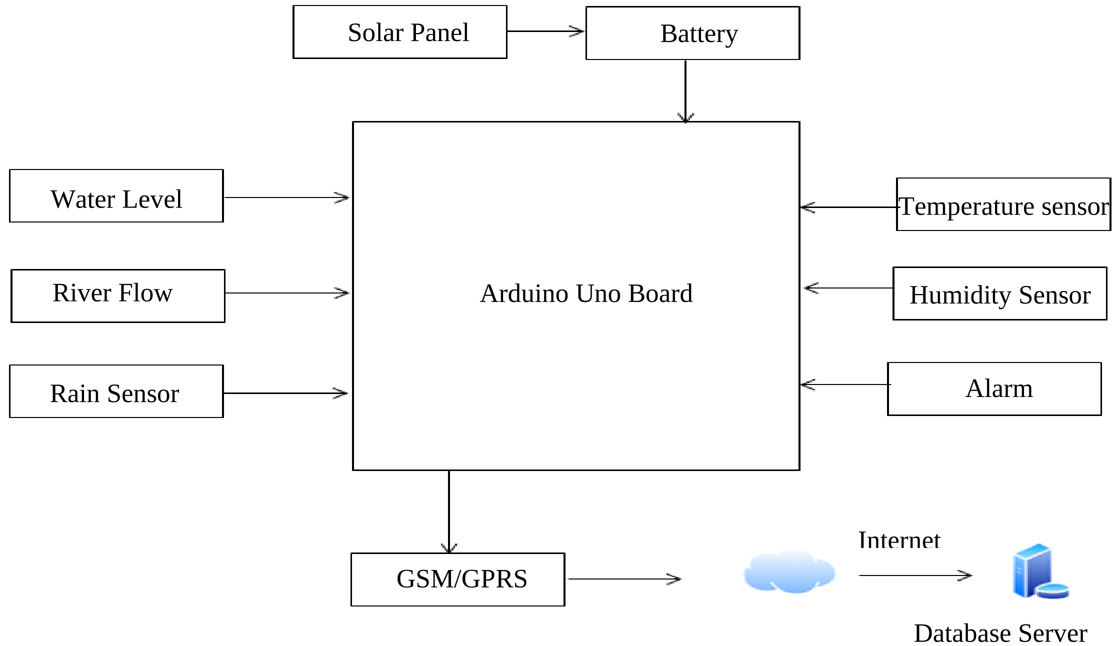

Fig. 1 Proposed flood monitoring and alert system

3.3. Water Flow Sensor

Using a pinwheel sensor, this sensor measures how much water has passed through it. A small magnet is attached to the pinwheel, and a hall effect magnetic sensor on the opposite side of the plastic tube can count the number of rotations the pinwheel has done through the wall of the plastic tube. The sensor can remain secure and dry using this technique. We can monitor fluid movement by counting the pulses from the sensor's output; each pulse equals twenty-five millilitres [29]. This sensor will measure the river's water flow from upstream to downstream, and the collected data will be communicated to the microcontroller.

3.4. DHT11

The DHT11 sensor module generates a calibrated digital output signal while simultaneously measuring temperature and humidity. It features a calibrated digital signal output and a moisture and temperature complex. DHT11 gives us precise humidity and temperature readings with exceptional dependability and long-term stability. With resistive and NTC temperature and humidity sensing elements and an integrated 8-bit microcontroller that reacts rapidly and is reasonably priced, this sensor has a 4-pin single-row architecture [30]. This device is selected to monitor the humidity and temperature of the environment.

3.5. SIM900

SIM900 is a widely used quad-band GSM/GPRS module for embedded applications manufactured by SIMCOM. It provides a set of AT commands for interfacing with a host microcontroller, allowing for voice and data communication over the cellular network. The module supports SMS and MMS messaging, TCP/IP connectivity, and GPS location tracking, making it a popular choice for remote monitoring, telemetry, and IoT applications. The SIM900 module requires an external SIM card for cellular connectivity and can be powered by a 5V DC supply [31]. This module will communicate the data to the server using GPRS that this sim provides, and it also transmits SMS data to the community using the GSM feature of this module.

3.6. Rain Sensor

When the sensor surface is in contact with water or becomes wet, the rain sensor will turn on. The digital output of the rain sensor will be logic 0 (LOW) and 5V in voltage. This means the rain sensor will be involved if the sensor has logic 0 (LOW), also known as active low. If the sensor cannot detect water or the sensor surface is not moist, the sensor will be inactive, and the digital output will have logic 1 (HIGH). Due to reduced resistance caused by the lack of water on the sensor surface, the voltage will be 5.02V simultaneously [32]. This sensor will monitor if there is rain or not and how long it is raining to include the parameters that the system needs to decide on floods.

3.7. Alarm

Alarm buzzers are electronic parts that can transform electrical signals into audible vibrations. The Buzzer, a hearing device, is frequently used to give others a head is up. Which uses DC voltage inversely proportionate to speakers that utilize AC voltage. The air will vibrate as each coil attached to the diaphragm moves back and forth, creating a sound or Buzzer [33]. The alarm will be triggered based on the processed and analyzed data that the Arduino board will be communicated to the Buzzer if a river flood is imminent.

4. Results and Discussion

The developed IoT-based flood detection system for river floods in Somalia was successfully tested and validated. The system was deployed at Beledweyne and Afgooye, a site prone to river floods. Data was collected from the IoT sensors installed at these strategic locations within the river basin, including upstream and downstream, to measure water levels, stream flows, rainfall, humidity, and temperature. The collected data was transmitted to a central server for analysis and processing. The collected data was analyzed and processed to detect flood events and generate timely warnings.

The system could accurately detect flood events and generate timely alerts disseminated to local authorities and communities through various communication channels, such as SMS and Web application. Below, Table 1 shows the threshold values of our system.

Table 1. Flood threshold values

Flood Status	River Flow (m^3/s)	Water Level (m)
Drought	0	0
Normal	1 – 100	1 – 3
Action	100 – 500	3 – 5
Moderate	500 – 1000	5 – 7
Major	5,000 – 10,000	7 – 10
Extreme	>10,000	>10

The developed IoT-based flood detection system has the potential to improve flood management and response in Somalia significantly. The system can help reduce the impact of floods on the environment and human lives, enhancing the resilience of local communities to future flood events. Below, Fig 2. shows the system interface of the web application. However, some challenges were encountered during the development and deployment of the system, including limited internet connectivity in some areas, which affected the transmission of data from the IoT sensors. This issue was mitigated using low-power sensors that could store and transmit data locally when internet connectivity was available. The system will use SMS to communicate the information to the local communities. The below Fig 3. shows the SMS messages the system sent to the local community. Overall, the results of this case study demonstrate the potential of IoT-based flood detection systems for improving flood management and response in regions prone to river flooding. The developed method can be scaled up and replicated in other areas facing similar challenges, contributing to the global efforts to mitigate the impact of floods on the environment and human lives.

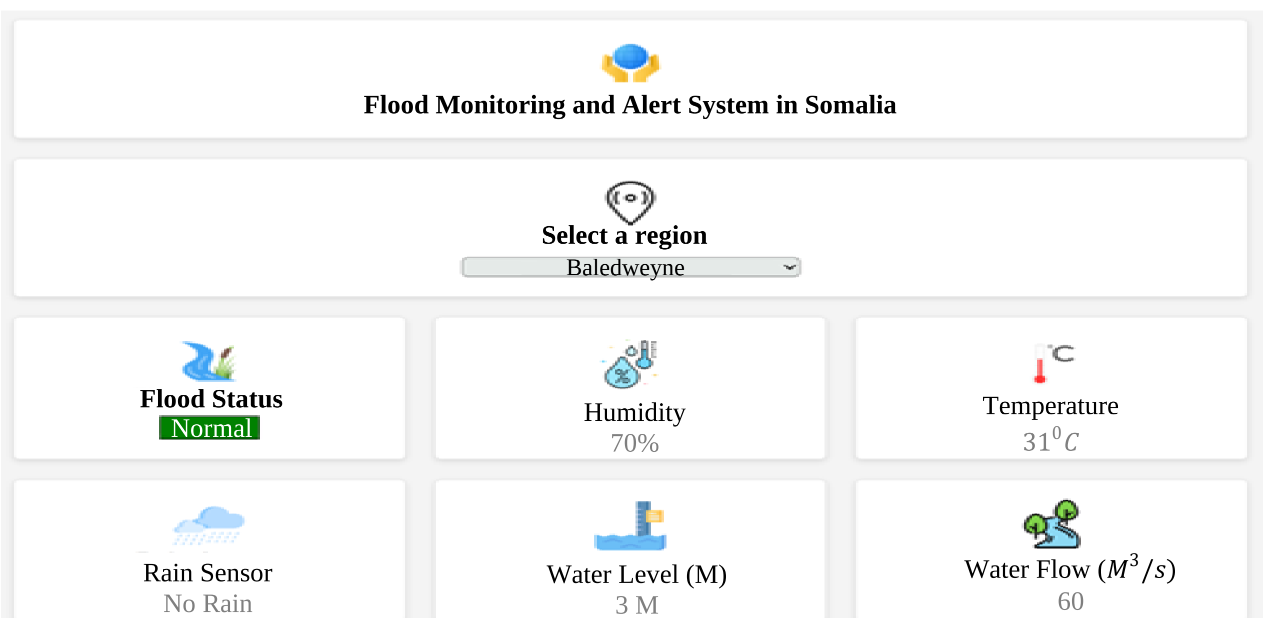

Fig. 2 Web application interface

Fig. 3 SMS messages to the local community

5. Conclusion

This article outlines developing and validating an Internet of Things-based flood detection system for Somalia's river floods. The system was built to collect data on water levels, stream flows, rainfall, humidity, and temperature to detect flood events and send timely warnings to local authorities and communities. According to the study's findings, a flood detection system has been developed that efficiently detects flood events and issues early warnings, thereby minimizing floods' impact on nearby communities.

The method can enhance flood mitigation and response in areas vulnerable to river floods due to its quick response time and high detection accuracy. However, the study also points out numerous challenges in the design and implementation of the system, such as poor connectivity to the Internet in some areas. Low-power sensors that could send and store data locally when internet connectivity was available, as well as SMS to communicate the information to local authorities and the general public, helped to address these problems. Global efforts to reduce the effects of floods on the environment and human lives will be enhanced by the proposed IoT-based flood detection system, which has the potential to significantly strengthen flood management and response in areas prone to river flooding. The approach can be expanded and copied in other sites dealing with similar problems, offering a helpful tool for lowering the effects of floods and enhancing community resilience.

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