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Design and implementation of Low-Cost IoT System for Water Level Monitoring and Flood Risk Prediction

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Internet of things (IoT), smart agriculture, greenhouse monitoring, Arduino, ESP8266, soil moisture sensor, DHT11 SENSOR.

ABSTRACT

This project presents an Internet of Things (IoT)-based system for real-time monitoring of river and lake water levels and early flood prediction using the ESP32. Flooding is one of the most destructive natural disasters, causing severe damage to life, infrastructure, and the environment. To mitigate these risks, the proposed system employs water level sensors and rainfall sensors to continuously monitor environmental conditions. The ESP32 microcontroller collects data from the sensors and transmits it wirelessly to a cloud platform such as Thing Speak for real-time storage, visualization, and analysis. The system applies data analysis techniques, including Time Series Analysis, to identify rising water trends and predict potential flood situations. When the water level exceeds predefined threshold values, the system generates early warnings through alerts such as SMS notifications or alarms. The proposed solution is cost-effective, energy-efficient, and suitable for deployment in remote and flood-prone areas due to the low power consumption and built-in Wi-Fi capabilities of the ESP32. It enables timely decision-making and enhances disaster management efforts by providing accurate and real-time information. The system can be further improved by integrating machine learning algorithms and additional environmental sensors for more precise flood prediction

I. INTRODUCTION

Floods are among the most frequent and devastating natural disasters, causing significant loss of life, damage to infrastructure, and disruption of economic activities worldwide. In countries like India, especially in low-lying and river basin areas, floods occur due to heavy rainfall, overflow of rivers, and poor drainage systems. Traditional flood monitoring methods are often manual, time-consuming, and lack real-time responsiveness, making it difficult to provide early warnings to affected communities.

With the advancement of the Internet of Things (IoT), it has become possible to develop smart systems that can monitor environmental conditions continuously and provide timely alerts. IoT-based solutions enable the integration of sensors, communication networks, and

cloud platforms to collect and analyze data in real time. This technology plays a crucial role in improving disaster management systems by offering accurate and up-to-date information.

In this project, an IoT-based water level monitoring and flood prediction system is developed using the ESP32 microcontroller. The system utilizes water level and rainfall sensors to measure environmental parameters and transmit the data wirelessly to cloud platforms such as ThingSpeak. By applying data analysis techniques like Time Series Analysis, the system can detect rising water trends and predict potential flood conditions.

The main objective of this system is to provide a cost-effective, reliable, and real-time solution for monitoring water levels in rivers and lakes. It also aims to generate early warnings when water levels exceed safe limits, thereby helping authorities and local communities take preventive measures. The proposed system contributes to enhancing public safety and reducing the impact of floods through timely and efficient decision-making.

II. REVIEW LITERATURE SURVEY

Recent advancements in flood monitoring systems have focused on automation and real-time environmental monitoring using embedded systems and Internet of Things (IoT) technologies. Traditional flood monitoring methods rely on manual observation and periodic data collection, which are often inefficient, time-consuming, and unable to provide timely warnings during critical situations [1].

To address these limitations, sensor-based water level monitoring systems have been developed by various researchers. These systems commonly use ultrasonic sensors and float sensors to measure water levels in rivers and lakes. While such systems improve measurement accuracy, they are often limited to local monitoring and lack remote accessibility and real-time alert capabilities [2].

With the emergence of IoT, more advanced flood monitoring systems have been introduced that integrate sensors, microcontrollers, and cloud platforms. These systems utilize devices such as the ESP32 to collect real-time data and transmit it wirelessly to cloud platforms like ThingSpeak for visualization and analysis. This approach enables continuous monitoring and remote access to data, significantly improving response time during flood events [3].

Some studies have also implemented systems using the Raspberry Pi along with cameras and image processing techniques to monitor water levels. Although these systems provide high accuracy and visual confirmation, they increase system complexity, power consumption, and overall cost, making them less suitable for large-scale or rural deployments [4].

In addition, GSM-based communication systems have been widely used to send alert messages to users when water levels exceed predefined thresholds. These systems are particularly useful in areas with limited internet connectivity, ensuring reliable communication during emergencies [5].

Furthermore, recent research has explored the use of data analysis techniques such as Time Series Analysis for predicting flood conditions based on historical and real-time data. While these methods improve prediction accuracy, many existing systems still rely mainly on threshold-based alerts rather than advanced predictive models [6].

Based on the reviewed literature, it is evident that IoT-based flood monitoring systems using ESP32, combined with sensor networks and wireless communication, provide a cost-effective, scalable, and efficient solution. However, there is still a need to enhance prediction accuracy and system reliability. The proposed system aims to address these challenges by integrating real-time monitoring with basic predictive analysis to provide an effective early warning system for flood management.

III. RESEARCH METHODOLOGY

The proposed system is designed to monitor water levels in rivers and lakes in real time and provide early flood warnings using Internet of Things (IoT) technology. The methodology involves data acquisition, processing, transmission, analysis, and alert generation.Initially, water level data is collected using ultrasonic sensors, which measure the distance between the sensor and the water surface. A rainfall sensor is also used to detect precipitation levels, which helps in understanding environmental conditions that may lead to flooding. These sensors are interfaced with the ESP32 microcontroller, which acts as the central processing unit of the system.The ESP32 processes the sensor data and

calculates the water level based on predefined reference values. The processed data is then transmitted wirelessly to a cloud platform such as ThingSpeak using built-in Wi-Fi capabilities. The cloud platform stores the data and provides real-time visualization through graphs and dashboards.

To analyze the collected data, techniques such as Time Series Analysis are applied to identify trends and patterns in water level changes. Threshold values are predefined for different conditions such as safe level, warning level, and danger level. When the water level exceeds these thresholds, the system automatically triggers alerts.For alert generation, the system uses communication methods such as GSM modules or internet-based notifications to send warning messages to users and authorities. This ensures timely dissemination of critical information, enabling quick response and preventive measures.The overall system is powered by a stable power supply, which can be supported by batteries or solar panels for remote deployment. The integration of sensors, microcontroller, cloud computing, and communication technologies ensures a reliable, cost-effective, and efficient flood monitoring system.

IV. PROPOSED METHODOLOGY

The proposed system aims to develop an efficient, low-cost, and real-time flood monitoring and prediction solution using IoT technology. The system is designed to continuously monitor water levels in rivers and lakes and provide early warnings when abnormal conditions are detected. The methodology integrates sensor data acquisition, wireless communication, cloud processing, and alert generation.The system is built around the ESP32 microcontroller, which acts as the central processing unit. It collects real-time data from sensors such as ultrasonic water level sensors and rainfall sensors. These sensors measure environmental parameters that are critical for detecting potential flood conditions.The collected data is processed by the ESP32, which calculates the actual water level based on reference height values. The processed data is then transmitted to a cloud platform such as ThingSpeak using Wi-Fi connectivity. The cloud platform enables real-time visualization, storage, and remote access to the data.For analysis, the system uses techniques such as Time Series Analysis to observe trends in water level variations over time. Based on predefined threshold values, the system categorizes water conditions into safe, warning, and danger levels. If a rapid rise in water level or threshold breach is detected, the system immediately triggers alerts.The alert mechanism includes buzzer alarms for local warning and GSM or internet-based notifications for remote users and authorities. This ensures quick dissemination of information, allowing timely preventive actions to reduce flood impact.The proposed system is designed to be scalable and can be deployed in multiple locations using a network of sensor nodes. The use of ESP32 ensures low power consumption, cost-effectiveness, and reliable wireless communication, making the system suitable for remote and flood-prone areas.

WORKING PRINCIPLE

The working principle of the proposed IoT-based flood monitoring and prediction system is based on continuous sensing, real-time data processing, wireless communication, and threshold-based alert generation. The system is designed to monitor water levels in rivers and lakes and provide early warnings in case of potential flood conditions.The system uses an ultrasonic sensor to measure the distance between the sensor and the water surface. This distance is converted into actual water level using a predefined reference height. A rainfall sensor is also used to detect rainfall intensity, which helps in analyzing environmental conditions that may contribute to rising water levels.All sensors are connected to the ESP32, which acts as the main controller of the system. The ESP32 continuously reads sensor data, processes it, and determines the current water level status. The processed data is then transmitted through Wi-Fi to a cloud platform such as ThingSpeak for real-time monitoring and visualization.On the cloud side, the data is displayed in graphical format, allowing users to observe changes in water level over time. The system also applies trend analysis using Time Series Analysis to identify rapid increases in water levels that may indicate a flood situation.The system operates based on predefined threshold levels such as safe, warning, and danger. When the water level exceeds these thresholds or shows a sudden rise, the system immediately triggers alerts. These alerts can be in the form of buzzer signals for local warning and SMS or internet notifications for remote users and authorities.Thus, the system ensures continuous monitoring, real-time data transmission, and

early flood warning, making it an effective solution for disaster prevention and management.

BLOCK DIAGRAM

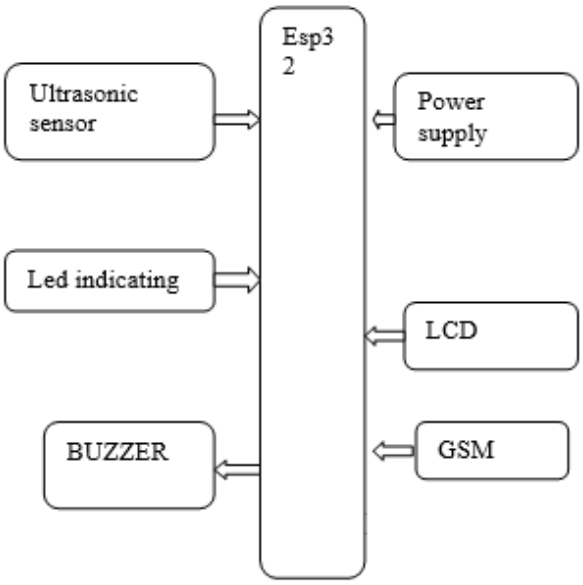

Fig. 4.1. Block Diagram

V. RESULTS AND OUTCOMES

The implementation of the proposed IoT-based flood monitoring and prediction system successfully demonstrates real-time water level monitoring and early warning capabilities. The system continuously collects data from sensors and provides accurate measurements of water level variations in rivers and lakes.Using the ESP32 microcontroller, the sensor data is efficiently processed and transmitted to the cloud platform such as ThingSpeak. The real-time data visualization on the cloud dashboard enables continuous observation of water level changes, making it easier to identify abnormal patterns.The system successfully categorizes water levels into safe, warning, and danger zones based on predefined threshold values. When the water level rises rapidly or crosses the danger threshold, the system generates immediate alerts through buzzer notifications and remote messaging, ensuring timely awareness for users and authorities.The application of Time Series Analysis on collected data helps in observing trends and predicting potential flood conditions with improved accuracy compared to traditional manual monitoring methods.

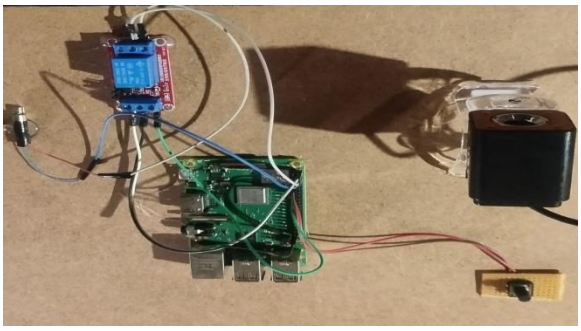

Fig. 5.1. Output1

Fig. 5.2. Output2

Fig. 1. This enhances the system's ability to provide early warnings and reduce response time during emergency situations.Overall, the proposed system achieves reliable performance in terms of real-time monitoring, data accuracy, and alert generation. It is cost-effective, scalable, and suitable for deployment in flood-prone and remote areas. The results confirm that IoT-based monitoring using ESP32 significantly improves disaster preparedness and contributes to effective flood risk management

VI. CONCLUSION

The proposed IoT-based flood monitoring and prediction system provides an efficient and reliable solution for real-time water level monitoring in rivers and lakes. By integrating sensors with the ESP32, the system enables continuous data acquisition, processing, and wireless transmission to cloud platforms such as ThingSpeak.

The system successfully demonstrates the use of real-time monitoring and data analysis techniques such as Time Series Analysis to identify rising water level trends and potential flood conditions. The implementation of threshold-based alert mechanisms ensures timely warnings to users and authorities,

thereby helping in effective disaster management and risk reduction.

Compared to traditional manual monitoring methods, the proposed system is more cost-effective, accurate, and responsive. It reduces human intervention and provides faster decision-making capabilities during critical situations. The use of IoT technology enhances system scalability, allowing multiple monitoring stations to be deployed in different locations.

Overall, the system contributes significantly to improving flood preparedness and public safety. With further enhancements such as machine learning-based prediction models and integration of additional environmental sensors, the system can be made even more accurate and robust in future implementations.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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