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IoT Based Bridge Adjustment for Flood Level Monitoring and Automated Alert System

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ABSTRACT: Bridges and water channels are a very dangerous source of flooding that can destroy the infrastructure and endanger people. The traditional flood control procedures are based on manual surveillance and thus they might result in a sluggish response in cases of emergency. The paper describes the design and implementation of an IoT-based Smart Bridge System to monitor flood level in real-time and automatically control the gates. The system incorporates microcontroller ESP32/ATmega328, water level sensor, gates that are controlled by servo, GPS module, Wi-Fi communication, LCD display, and buzzer alert. The water level is raised beyond a specified threshold level, the system triggers warning bells, opens the gates with the help of servo motors, and sends real-time location information via a Telnet server, which is based on the Wi-Fi network. GPS module gives the correct geographical positioning, which allows prompt response to emergencies. The suggested system will minimize human intervention; improve the response time as well as increasing safety in flood-prone areas. Such a smart system can be efficiently installed in bridges, dams, and water control systems to avoid damages and loss of lives.

KEYWORDS: Smart Bridge, Flood Monitoring System, IoT, ESP32, Atmega328, Water Level Sensor, Servo Motor, GPS Module, Wi-Fi Communication, Embedded Systems, Real-Time Monitoring, Telnet Server.

I. INTRODUCTION

River crossing and bridges that are built close to water bodies are very susceptible in times of high rainfall and floods. Unpredictable increases of water level may undermine the foundations, destroy the supporting structures, and become a great threat to people and transport systems. The conventional forms of monitoring are mainly based on manual searching and physical observation which are commonly slow, inaccurate and unsafe in extreme weather conditions. Thus there is a high demand on automated and real-time monitoring systems, which are able to monitor water levels continuously and can give early warnings to avoid disasters.

The intelligent monitoring solutions are easier to implement and less expensive with the fast evolution of the Internet of Things (IoT). IoT systems consist of sensors, microcontrollers, and wireless communication to gather information on the environment and transmit it to remote monitoring centers. With such systems, they can be monitored continuously without the need to have human presence all the time. The usefulness of IoT in bridge condition monitoring and safety alerts generation has been proven in earlier works, and the authors emphasize how sensor networks may contribute to improvement of the infrastructure surveillance and overcome maintenance delays [1], [2], [11].

Another important field where the IoT has been transformative is in flood monitoring. Water level sensors will be attached along with embedded controllers to monitor increases in water levels in real time and provide an alarm in case the preset levels have been surpassed. These systems are able to provide warnings via wireless networks and this assist authority to take prompt preemptive measures. Flood monitoring solutions based on IoT have been effectively used in embankments, dams and river

basins to minimize the damage caused by floods as well as enhance emergency response [3], [6], [7].

The current developments have also enhanced the accuracy and distance of communication of flood sensors and monitors. LoRaWAN and Wi-Fi-based communication technologies enable sensor nodes to work in distressed regions and transmit the data to distant points using a low amount of power. Smart sensing devices fitted on catchment areas can measure the change in water level and provide warnings to the centralized dashboards or mobile devices, thus guaranteeing earlier and broader dissemination of warning messages [8], [10].

Besides detection of floods, monitoring systems coupled with alert systems will increase the general safety. Audible warning signals, visual indications, and computer-controlled responses can be enabled in case the level of danger is met. Bridge monitoring and alert generation systems IoT-based have demonstrated that environmental senses and automated messages can greatly decrease the reaction duration in the event of an emergency [5], [9]. Through these systems, the local communities and the concerned authorities are given timely alerts.

Driven by these advancements, this project will present an IoT Based Smart Bridge Flood Monitoring and Alert System which constantly measures the water level in the areas around a bridge construction. The system employs water level sensors, a microcontroller unit, wireless communication and alert modules to identify possible flood conditions and give real-time warnings. The proposed system will facilitate the safety of bridges, reduce destruction of infrastructure, and save human lives in case of floods by allowing early warning and automated notification.

II. LITERATURE SURVEY

The paper by Muddala et al. introduces an IoT-driven bridge monitoring framework which is based on structural condition evaluation in real-time through sensors, including vibration sensors, load sensors, and crack sensors. The system constantly gathers information and sends it to a distant server to analyze it, and it is possible to detect structural flaws in time. Their article demonstrates the significance of IoT in decreasing the amount of manual inspection and enhancing bridge safety with appropriate alerts. Nevertheless, the research primarily focuses on structural variables and not inclusive on the environmental hazards such as floods. [1].

Al-Ali et al. suggest a new hi-tech road bridge health monitoring and warning system using IoT with combining various sensors, cloud storage and smart alerts systems. The system observes structural health, traffic load and other environmental conditions and gives real-time alerts to the government and road users. This paper illustrates that the study is more reliable and scaled than the conventional monitoring systems and that it is appropriate in the smart city infrastructure. The work focuses on preventive maintenance and improvement of the safety of people. [2].

An IoT-based flood embankment monitoring system presented by Michta et al. aims at monitoring the level of water and the state of the embankment through the use of distributed sensor nodes. The data that is collected is sent through the air and hence it can be monitored continuously so that authorities are able to identify when there is an early warning of floods or a collapse of embankment. This article emphasizes the relevance of IoT to flood-prone regions, but only with regards to embankments but not a bridge set-up. [3].

Selvi et al. propose the IoT-based system of automated monitoring and auto-alarm of water level that measures water level increase with the help of sensors and sends out alerts when the set limits are crossed. The system can be useful in the prevention of floods and disaster management since it allows real-time monitoring and remote accessibility. Their strategy has an advantage of increasing responsiveness and minimizing human dependency, but it is not coupled with structural health parameters of bridges. [4].

Anupama et al. suggest a system of the bridge monitoring and alert generation based on the IoT technologies to provide the structural safety and timely warnings. The system employs sensors that track stress, vibration and outside conditions and send notifications when there is an occurrence of abnormalities. The research shows the potential of IoT to improve bridge safety and disaster preparedness, but the large scale implementation and long term performance analysis is yet to be tackled. [5].

Selvi and S.S. create an IoT-based flood monitoring system, which is destined to be used in dam monitoring and mitigation of risks. The system regularly checks the water levels and climate, and sends early alerts in advance of disastrous failures. Even though the work is oriented to dams, its methodology and warning systems can be extremely applicable to bridge flood monitoring systems, particularly in risk areas at the downstream. [6].

The paper by Siddique et al. is a comprehensive review of systems based on the IoT to monitor and give an early warning about floods and discusses the architectures, sensors, communication technologies, and issues. The paper outlines the efficacy of the IoT in disaster risk mitigation and real time data collection. It also marks the problems like sensor reliability, power consumption, and scalability, which can be used to gain valuable information when developing a robust bridge flood monitoring system and alert system. [7].

III. PROPOSED METHOD

To avoid the damages caused by floods the proposed system introduces an IoT based Smart Bridge Flood Level Monitoring and Alert System that are aimed at watching an increase in water levels around the bridge constructions and creating early warning of possible floods to make the devices avoid any losses. The system incorporates sensing, embedded control, wireless communication and automated alert system in order to make it real-time monitoring and responding in emergency cases.

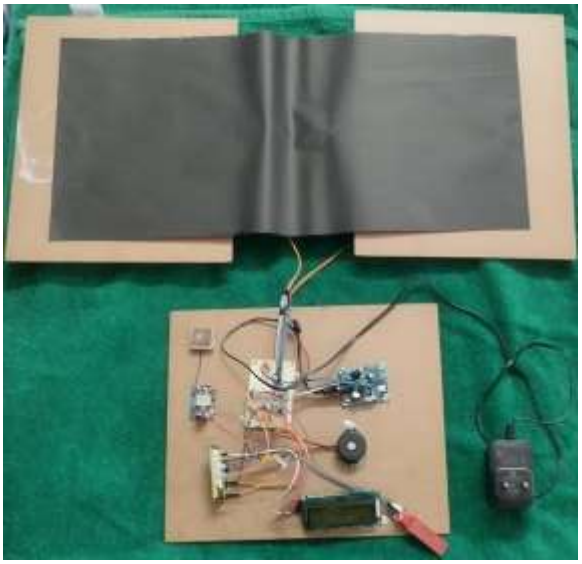

Fig. Overall Bridge Prototype Designed for the Proposed Application

Above set is the proposed prototype which has an important controller as ESP32 which has flood level monitoring ability as well as alerting system.

3.1 System Architecture

Its general architecture comprises of a sensing layer, a processing and control layer, a communication layer, and an alert and actuation layer. The layers collaborate with each other to monitor the changes

in water levels, analyse the risk conditions, and provide warnings at the bridge location and to the authorities. The architecture will be configured to run continuously without having to have a lot of human intervention and hence it can be implemented in flood prone areas.

3.2 Water Level Monitoring

The main use of the system is to check the water level close to the bridge foundation. The sensor to measure the water level is placed at an appropriate height where water height changes can be effectively measured. The sensor constantly measures the difference between the water surface and a fixed reference point and translates the difference into an electrical signal. This signal is delivered to the microcontroller which is then processed. The system is programmed with predefined threshold values to indicate the safe, warning and critical levels of floods. The system will prepare to issue alerts when the water level is detected to exceed the warning limit. Once the level attains the critical value, emergency responses are automatically activated to reduce the risks that may occur.

3.3 Processing and Control Unit

The main processing unit is an embedded microcontroller, i.e. an ESP32 or an Arduino-based controller. It also reads the data of the water level sensor constantly and compares it with the set threshold limits. The controller functions on a periodic basis in which sensor measurements are performed at a fixed time so as to maintain current monitoring. With normal conditions, the controller logs the data and transmits it to the communication to be logged remotely. The controller triggers the alert mechanisms when abnormal or dangerous water levels have been detected, and, when it is built into control systems, triggers the control measures, like the operation of a gate mechanism. This automated decision making saves time on response and provides timely response in case of floods.

3.4 Communication Module

The system employs a wireless communication unit like Wi-Fi to make it be monitored remotely. The data is then sent through a microcontroller to a cloud server or web-based monitoring platform that has undergone processing. This enables the authorities and disaster management teams to monitor the water level developments in real-time even without having to be in the physical location of the bridge. The system will also have a GPS module to give the exact geographical location of the bridge. When an alarm is raised, the system will send the warning message and location details, and it is easy to identify the affected area, and respond to the emergencies faster.

3.5 Alert and Actuation Mechanism.

The system contains on-site and remote alert systems in order to have a good dissemination of warnings. An audible message is given in the form of a buzzer close to the bridge when the water line reaches a danger level. A real-time status message is displayed in an LCD display displaying normal level, warning level, or flood alert, enabling the nearby personnel to comprehend the situation immediately. Besides the local alerts, warning notifications are also dispatched over the wireless network to a monitoring dashboard or authorized users. In case the system has a mechanical control system, e.g. a servo motor opening the gates, then the controller may automatically switch it to operate when there is a critical flood situation. This sensing, communicating, and actuation make a whole automated flood monitoring and response system of bridge safety possible.

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IV. RESULTS ANALYSIS

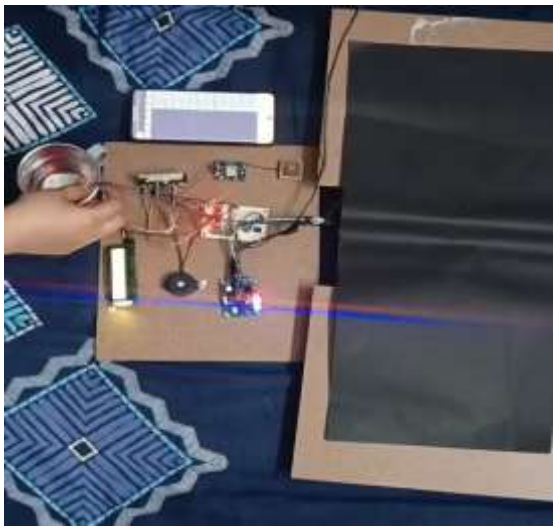

Fig. Hardware Circuit Implementation of the IoT-Based Smart Bridge Flood Monitoring System

Fig. Physical Bridge Prototype Model Used for Flood Monitoring Experiment

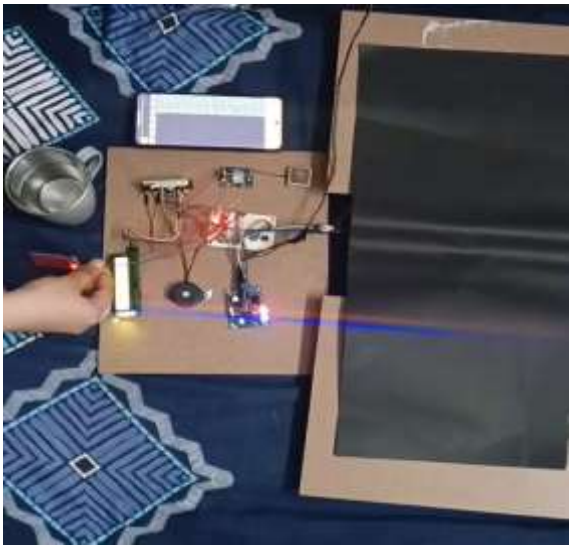

Fig. Alerting for Flood Detection

Whenever there is detection of flood then alert will be sent to the recepient.

V. CONCLUSION

The Smart Bridge Flood Alert System can be successfully regarded as an example of how embedded systems and IoT technologies can be used to monitor and control floods automatically. The combination of a water level sensor, microcontroller, and servo motors, a GPS module, and a Wi-Fi communication will guarantee the real-time identification, automatic gate control, and remote alerts transmission. This system will minimize the reliance on manual supervision and increase efficiency in responding to the emergency situation when floods take place. The given model enhances infrastructure safety and reliability by offering live location updates and automatic control mechanisms. Further improvements could be made to the system to increase the scalability and sustainability of the system in the future by adding cloud-based data logging, integration of mobile applications, predictive flood analysis through AI and providing solar-powered functionality to the system.

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