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Disaster – Resilient Smart Street Light

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ABSTRACT

The increasing risk of disasters in urban areas has led to the development of smart monitoring systems. In this project, an ESP32-based Smart Streetlight Disaster Management System is designed to detect hazards like fire and floods automatically. The system uses fire sensors and water level sensors to monitor environmental conditions, along with a GPS module to track the exact location. The ESP32 processes the sensor data and compares it with predefined limits to detect abnormal situations. When a disaster is identified, the system activates alerts and sends real-time data for quick response. The system is cost-effective, energy-efficient, and can be easily implemented for smart city applications.

1. INTRODUCTION:

Urban areas are increasingly vulnerable to disasters such as fires and floods, while traditional monitoring systems rely on manual methods and lack real-time alert capabilities, leading to delayed responses and increased damage. This project aims to develop an IoT-based Smart Streetlight Disaster Management System using ESP32 that can detect hazards through sensors, provide instant alerts using a buzzer, and track locations using GPS for quick response. The motivation behind this work is to overcome the limitations of existing systems by enabling early detection, automation, and efficient communication. The project focuses on transforming conventional streetlights into intelligent units capable of real-time monitoring, improving public safety, reducing human intervention, and offering a cost-effective and scalable solution for smart city applications.

2. LITERATURE SURVEY:

The "IoT-Based Flood Monitoring System" (2021) was developed to monitor water levels and provide early flood warnings using sensors like water level and ultrasonic sensors. It enabled real-time monitoring, reduced manual effort, and improved response time through IoT-based alerts and remote access. However, its performance depended on sensor accuracy and internet connectivity, and it was limited to flood detection only.

The "Lightweight Neural Network for Fire Detection" (2019) used deep learning techniques to detect fire and smoke efficiently on IoT devices. Its lightweight design allowed faster processing and better compatibility with embedded systems, improving detection speed and reducing false alarms. However, there was a trade-off between model size and accuracy, and the system focused only on fire detection.

The "IoT-Based Fire and Gas Detection System" (2024) was designed to detect fire hazards and gas leaks using flame and gas sensors, providing real-time alerts through mobile notifications. It improved safety, reduced manual monitoring, and enabled quick response. However, it had limited scalability, required maintenance, and did not support multiple types of disasters.

The "IoT-Based Multi-Sensor Fire Detection System Using ESP32" (2025) improved fire detection accuracy by integrating multiple sensors such as flame, gas, and temperature sensors. It provided reliable detection, reduced false alarms, and enabled real-time monitoring through IoT platforms. However, it was limited to fire detection, depended on sensor calibration, and lacked scalability and multi-disaster integration.

3. PROBLEM STATEMENT

Urban areas are increasingly vulnerable to disasters such as fires and floods, which can cause significant damage to property, infrastructure, and human life. Traditional monitoring systems often rely on manual observation or isolated detection mechanisms, resulting in delayed identification of hazardous conditions and slower emergency response. In many cases, the absence of real-time monitoring and immediate alert systems makes it difficult for authorities to take timely action, thereby increasing the severity of the impact. Additionally, existing streetlight infrastructure is primarily used only for illumination and lacks intelligent capabilities for environmental monitoring or disaster detection. There is a need to transform these widely distributed systems into smart, multifunctional units that can continuously monitor conditions such as fire and water levels while providing instant alerts with accurate location information.
Therefore, a cost-effective, automated, and IoT-based solution is required to enhance disaster preparedness and improve response efficiency in urban environments.

4. PROPOSED SYSTEM

The proposed system, the Disaster-Resilient Smart Street Light using IoT, aims to enhance disaster management by

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transforming ordinary streetlights into intelligent monitoring units. This system replaces traditional methods with a smart and automated approach using sensors, GPS modules, and a microcontroller like ESP32. The system continuously monitors environmental conditions such as fire, water levels, and vibrations using dedicated sensors. When any abnormal condition is detected, it instantly triggers alerts through a buzzer and sends location-based information using GPS. All sensor data is processed in real time, enabling faster decision-making and emergency response. This approach ensures early detection, improves safety, and reduces dependency on manual intervention, making the system efficient and reliable for modern smart city applications

5. METHODOLOGY:

The proposed Smart Streetlight Disaster Management System is an IoT-based automated system.

a. Data Collection
Environmental data is collected using sensors such as fire sensors, water level sensors, and vibration sensors placed on streetlights. These sensors continuously gather real-time data about surrounding conditions and send it to the ESP32 microcontroller.

b. Data Monitoring
The ESP32 continuously monitors the incoming sensor data to track environmental conditions such as fire presence, water level changes, and abnormal vibrations in real time.

c. Data Processing and Analysis
The collected data is processed and compared with predefined threshold values. This helps in identifying whether the conditions are normal or indicate a potential disaster such as fire or flood.

d. Decision Making (Automation)
Based on the analysis, the system automatically detects disasters. If sensor values exceed safe limits, it identifies the type of hazard and determines the severity of the situation.

e. Control and Notification System
Once a disaster is detected, the ESP32 activates a buzzer for local alerts and sends notifications along with GPS-based location data for remote monitoring. The system continuously operates in a loop to ensure real-time disaster detection and quick response.

6. ALGORITHM:

1. **Start**
2. **Initialize the System**
   - Initialize ESP32 microcontroller
   - Configure GPIO pins for:
   - Fire sensor (input)
   - Water level sensor (input)
   - Buzzer (output)
   - Initialize UART communication for GPS module
   - Initialize Wi-Fi for IoT communication
   - Set threshold values for fire and water level detection
3. **Begin Continuous Monitoring Loop**
   - Enter an infinite loop to continuously monitor environmental conditions.
4. **Read Sensor Data**
   - Read fire sensor value
   - Read water level sensor value
5. **Check Fire Condition**
   - If fire sensor detects flame (value exceeds threshold):
     → Set Fire_Status = TRUE
   - Else:
     → Set Fire_Status = FALSE
6. **Check Flood Condition**
   - If water level exceeds threshold:
     → Set Flood_Status = TRUE
     Else:
     → Set Flood_Status = FALSE
7. **Decision Making**
   - If (Fire_Status == TRUE OR Flood_Status == TRUE):
     → Proceed to alert process

Else:
→ Continue monitoring (go back to Step 4)

8. **Acquire GPS Location**
   - Read latitude and longitude from GPS module
   - Store location data
9. **Trigger Local Alert**
   - Activate buzzer
   - Generate audible warning signal
10. **Transmit Data to IoT Cloud**
    - Connect to Wi-Fi network
    - Send the following data:
      - Fire status
      - Flood status
      - GPS location

Update cloud/monitoring platform

11. **Delay and Reset**
    - Wait for a short interval (to avoid continuous triggering)
12. **Repeat Process**
    - Return to Step 4 for continuous monitoring

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7. RESULTS:

The figure shows the output of the Light Dependent Resistor (LDR) sensor used in the smart pole system. The LDR detects ambient light intensity based on its resistance variation—its resistance decreases in bright light and increases in darkness. This sensor is connected to the ESP32 microcontroller, which continuously reads the sensor values and processes them using predefined threshold levels.

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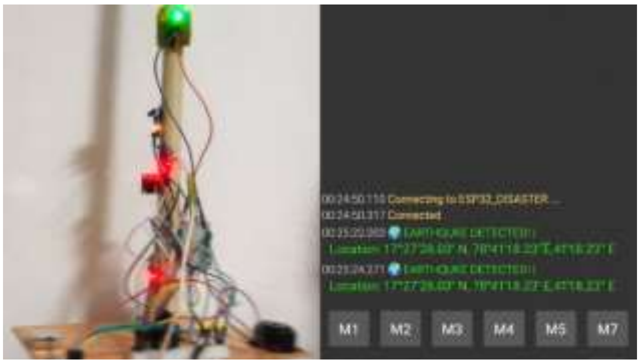
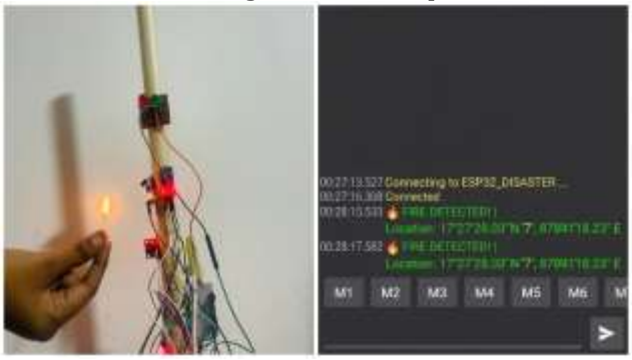
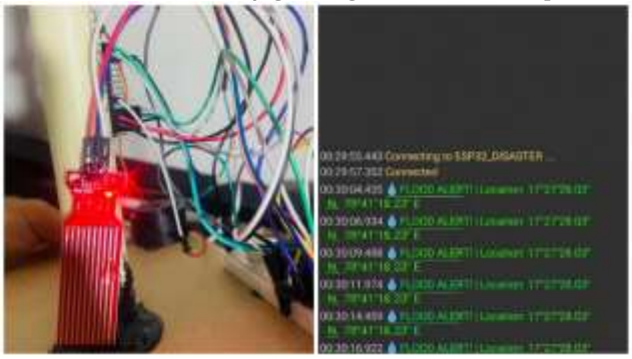


The above diagram shows the implementation and output of the earthquake detection module integrated into the smart pole system. The vibration/earthquake sensor detects sudden ground movements or vibrations and sends signals to the ESP32 microcontroller. When the sensed vibration exceeds a predefined threshold value, the system identifies it as a potential earthquake event. The hardware setup displays this condition through LED indications, where the alert LED turns ON to signify detection.



The second diagram illustrates the working of the fire detection module in the smart pole system. A flame/smoke sensor is used to detect the presence of fire by sensing infrared radiation emitted by flames. When a fire source, such as a matchstick, is brought near the sensor, it detects the change in radiation levels and sends a signal to the ESP32 microcontroller. The system then activates the alert mechanism, indicated by glowing LEDs in the setup.



The above diagram shows the implementation and output of the flood detection module integrated into the smart pole system. A water level sensor is used to detect the presence of water by measuring changes in conductivity across its exposed traces. When water comes into contact with the sensor and rises above a predefined threshold level, the sensor sends a signal to the ESP32 microcontroller. The system identifies this condition as a potential flood situation, and the hardware setup indicates detection through an LED, which turns ON to signal the alert state.

Simultaneously, the ESP32 processes the sensor data and transmits an alert message through the communication module. As shown in the terminal output, the message "FLOOD ALERT!" is displayed repeatedly along with the corresponding location coordinates. This ensures real-time monitoring and immediate notification to users or concerned authorities. The system is designed to provide continuous alerts until the water level returns to normal, thereby enhancing safety and enabling quick response during flood situations.

8. CONCLUSION:

The proposed IoT-based Smart Streetlight Disaster Management System using ESP32 has been successfully developed to enable real-time detection of disasters such as fire and flooding in urban areas. The system integrates sensors, a microcontroller, GPS

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module, and communication technologies to monitor environmental conditions and provide quick alerts through a buzzer and remote data transmission with location details. It operates continuously with minimal human intervention, ensuring reliable and automated monitoring while transforming conventional streetlights into intelligent, multifunctional units. The system is cost-effective, scalable, and suitable for smart city applications, improving public safety and disaster preparedness. However, limitations such as sensor accuracy, internet dependency, and environmental factors need to be addressed. Future enhancements like cloud integration, mobile applications, AI-based prediction, and renewable energy sources can further improve its efficiency and reliability, making it a practical solution for safer and smarter urban environments.

9. FUTURE SCOPE:

The proposed system can be enhanced through cloud integration, mobile application development, AI-based prediction, and smart city integration to improve efficiency and scalability. Cloud platforms enable large-scale data storage, real-time monitoring, dashboards, and better decision-making, while mobile applications provide instant alerts, live data access, and GPS-based tracking for users. The integration of AI and machine learning allows predictive analysis, reducing false alarms and enabling early disaster warnings. Additionally, connecting the system with smart city infrastructure such as traffic management and emergency services improves coordination and response during disasters. These enhancements make the system more intelligent, automated, and suitable for real-world smart city applications.

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