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IoT Enabled Real-time Flood And Landslide Detection With Emergency Alerting System Using Embedded Sensors

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Abstract-Landslides and Flood , often triggered by factors like heavy rainfall, seismic activity, or human intervention, pose significant threats to both human lives and infrastructure. Traditional monitoring methods, however, often fall short due to their limitations in terms of coverage, real time data acquisition, and cost-effectiveness. Zigbee technology, which addresses these challenges by offering exceptional long-range communication capabilities and low-power consumption. This makes it an ideal candidate for establishing a robust IoT framework dedicated to landslide monitoring. Zigbee-based IoT approachbrings forth a multitude of benefits. Firstly, it enables early detection, allowing authorities and communities to take proactive measures in response to evolving conditions. The presented sensor node supports a large variety of low-power sensors; the range of applications is thus considerable. In this project a landslide monitoring system was built to detect the movement and humidity of the soil that generally causes landslides and flood monitoring. And also monitors the water level to detect the abnormal monitoring alert. The proposed system utilizes a network of low-power, Zigbee network technology. This system includes the various sensors such as humidity sensor, float sensor, moisture sensor and vibration sensor. These sensors are integrated with Arduino

Keywords: IoT,Landslide Detection,Flood Detection,Zigbee,WSN,Warning system often

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1. Introduction

Natural disasters are catastrophic events that result from natural processes of the Earth. They can cause widespread destruction, loss of life, and immense suffering. From earthquakes and tsunamis to hurricanes, floods, wildfires, and volcanic eruptions, natural disasters can strike with little warning, leaving communities devastated in their wake. The impact of these events is

population density, inadequate infrastructure, and climate change.

Throughout history, natural disasters have shaped human societies, influencing everything from settlement patterns to cultural practices and economic development. Despite advances in technology and disaster preparedness, their occurrence remains unpredictable, and their effects can be profoundly disruptive to individuals, communities, and entire regions. In this exploration, we will delve into the various types of natural disasters, their causes, impacts, and the strategies employed to mitigate their effects.

Every landslides cause more than $100 million in direct damage and cause thousands of fatalities The majority of these events are induced by prolonged and intensiverainfall. They are perhaps the most widespread natural hazard worldwide, yet they form the most undervalued hazard. In order to mitigate the landslide hazard, several landslide monitoring techniques have been developed over the last decades. Broadly, these can be categorized into remote sensing photogrammetric, geodetic, geotechnical geophysical wireless sensor networks (WSN) and most recently followed by the Internet of Things (IoT) Remote sensing, photogrammetric, and geodetic techniques are commonly used to gather information about the distribution and kinematics of surface displacements These techniques make use of aircraft, spacecraft, or terrestrial based platforms and are suitable for mapping vulnerable areas, monitoring displacements over a large area even with 3-D capabilities however, their applicability for real-time monitoring is limited due to the revisit period of satellites and the requirement of manual processing of the collected data. Geotechnical instruments such as inclinometers extensometers are widely used ground-based techniques to monitor parameters such as angle, distance of displacement, pore-water pressure (PWP), and ground vibrations, respectively. These are direct monitoring techniques and give point measurements specific to an area. Geotechnical instruments are used for real time monitoring and early warning of site specific landslides. Even when these techniques give accurate measurements of landslide-related parameters, they are not employed for monitoring large-scale landslides, because of the cost involved in deployment. Geophysical methods such as are electrical resistivity and seismic methods are ground-based techniques, which measure physical properties such as resistance and seismic velocities of the subsurface. These methods are used to investigate large volumes of the subsurface and real-time monitoring can be achieved by autonomous geophysical methods. However, these methods being in-direct methods which only provide proxies to parameters critical for landslide initiation, which limits their usage in reliable warnings. Satellite and airborne based landslide monitoring techniques are bounded to use for slow or moderate type of landslides. Whereas ground-based landslide monitoring techniques are adequate to monitor slow, moderate, and rapid types of landslides. However, the wide range in monitoring technologies with their associated measurement parameters, sensitivities, and temporal and spatial resolution poses a new question. For any given slope vulnerable to sliding due to various factors such as geological setting, cracks, severe rainstorms, tectonic activities, earthquakes, etc., which (combination of) techniques are the most appropriate for monitoring?

2. Literature Review

2.1 Development of an Early Warning System for Landslides using IOT Sensors and Machine Learning

Authors: A. Balachandar et al.

Description: This conference paper presents a field-oriented early warning system that fuses IoT sensing with machine learning to identify imminent landslide conditions. The authors describe a distributed sensor network composed of soil moisture probes, tilt/vibration sensors, and rainfall detectors that transmit periodic readings via a low power wireless mesh (conference notes specify ZigBee/WSN-style communications). Data are aggregated at a central node where preprocessing and feature extraction are applied to generate time-series indicators of slope stability. The study reports use of supervised learning models trained on labeled episodes (stable vs. pre-failure) and shows that combining multiple environmental features improves detection sensitivity relative to single-sensor thresholds. Practical considerations include node power management, data loss handling, and threshold tuning to reduce false alarms in regions with high seasonal variability. The paper emphasizes rapid, local alarm dissemination so that communities receive timely buzzers or local siren alerts, and it documents a small field deployment used for validating the algorithmic approach. Overall, the work contributes a pragmatic integration of low-cost IoT hardware and ML analytics for localized early warning in terrain where centralized geotechnical monitoring is sparse.

2.2 Comprehensive review of remote sensing integration with deep learning in landslide forecasting and future directions

Authors: Nilesh Suresh Pawar and Kul Vaibhav Sharma

Description: This extensive review surveys the burgeoning literature that combines remote sensing data (optical, multispectral, SAR, DEMs) with deep learning models for landslide forecasting and susceptibility mapping. The authors systematically catalog studies using convolutional neural networks, U-Net variants for segmentation, and hybrid models that couple spectral, topographic, and hydrometeorological inputs. They highlight how satellite imagery and airborne LiDAR provide large-scale spatial context, while deep models can automatically extract texture and morphologic features that correlate with slope instability. Key challenges identified include limited labeled datasets for supervised learning, domain shift between regions, imbalance between stable and failure samples, and the need for interpretable models for operational stakeholders. The review calls for multimodal frameworks that fuse in-situ IoT sensor streams with remote sensing to improve temporal resolution, and recommends transfer learning, data augmentation, and physics-informed priors to improve generalization. The paper concludes with future directions emphasizing open benchmarks, standardization of evaluation metrics, and closer collaboration between remote sensing specialists and on-the-ground practitioners to move from research prototypes to operational forecasting systems.

2.3 LANDSLIDE MONITOR: a real-time landslide monitoring system

Authors: Pradeep Singh Rawat and Anurag Barthwal(2024)

Description: This journal article describes a turnkey system LANDSLIDE MONITOR—designed for continuous, real-time slope surveillance and early warning. The system integrates a network of geotechnical sensors (pore-water pressure, soil moisture, inclinometers), accelerometers, and precipitation gauges, coupled with edge computing units that perform local filtering and simple anomaly detection to reduce communication load. Data are transmitted to a centralized dashboard for visualization and historical analysis; the authors discuss thresholds and event-trigger logic that convert raw measurements into graded alarm levels. A major value of the work is the demonstration in a real high-risk watershed where the system ran over multiple monsoon seasons, providing empirical evidence on sensor durability, data continuity and how ground-truth events (minor slides and slope movements) were captured. The paper includes discussion of false positives during intense weather and proposes redundancy schemes multiple sensor types per station—to improve reliability. Implementation lessons such as power backup, site anchoring of hardware, and local community engagement for alarm response are emphasized, making the work a practical reference for operational deployments.

3. Methodology / Proposed System

The proposed system leverages Zigbee-based IoT technology to monitor landslides and floods in real time. It consists of a network of low-power sensors, including humidity, float, moisture, and vibration sensors, which are integrated with an Arduino NANO. These sensors continuously collect environmental data and transmit it through the Zigbee network, ensuring efficient and reliable communication. This approach overcomes the limitations of traditional monitoring methods by providing wide coverage, real time data acquisition, and cost-effectiveness.

The system detects soil movement, humidity changes, and water level variations to identify potential landslides and floods. When abnormal readings are detected, alerts are sent to authorities and local communities, enabling timely preventive actions. This early warning mechanism enhances disaster preparedness and minimizes damage, making the proposed system a valuable tool for environmental monitoring and disaster management.

Flood Monitoring and Alert System

Utilizing IoT technology, flood monitoring systems incorporate sensors placed in flood prone areas to measure water levels, rainfall intensity, and river flow rates in real-time. These sensors transmit data wirelessly to a central control center where it is analyzed to detect potential flood risks. When the system identifies an impending flood, it automatically triggers alerts through various communication channels such as SMS, email, or mobile applications, notifying authorities and residents to take necessary precautions. Additionally, these systems can integrate with floodgates and pumps to automate flood mitigation efforts, reducing response times and minimizing damage to property and infrastructure.

A. Landslide Detection and Warning System

These sensors continuously collect data and transmit it to a central monitoring station where sophisticated algorithms analyze patterns and anomalies indicative of potential landslide activity. Upon detecting such signals, the system issues early warning alerts to authorities and residents via text messages, sirens, or mobile apps, enabling timely evacuation and implementation of preventive measures to safeguard lives and property.

B. System architecture

The proposed landslide and flood monitoring system is designed using a Zigbee-based IoT architecture that integrates multiple low power sensors with a central processing unit to provide real-time environmental monitoring. At the sensor layer, various sensors such as soil humidity, moisture, vibration, and float sensors are deployed in vulnerable areas to continuously capture critical parameters that indicate potential landslides or flooding. These sensors are interfaced with Arduino NANO microcontrollers, which collect, preprocess, and digitize the data. The communication gateway, even in challenging terrains. The gateway layer receives the sensor data and performs real-time analysis, comparing measurements against predefined safety thresholds for soil movement, water level rise, or abnormal vibrations. When critical conditions are detected, the system generates automatic alerts to authorities and communities via notifications or SMS, allowing timely preventive measures. Additionally, all sensor data is logged for historical analysis, trend prediction, and infrastructure planning. This scalable and energy-efficient architecture ensures continuous monitoring over large areas while minimizing maintenance costs, providing a practical, cost-effective solution for early detection and mitigation of natural disasters such as landslides and floods.

Fig.2 Block diagram

For flood monitoring, a float switch and level switch are used to detect water levels. These sensors provide real-time data to Arduino NANO, which processes the inputs and triggers necessary actions based on predefined thresholds.The Arduino NANO receives power from a power supply and interacts with output components like an LCD display, buzzer, and Zigbee module. The LCD display provides a real-time status update, while the buzzer generates an alert when a potential landslide or flood is detected. The Zigbee module enables wireless data transmission to external devices, facilitating remote monitoring. This design ensures a proactive approach by alerting authorities and users about hazardous conditions before they escalate.The second part of the diagram focuses on data transmission and visualization. The Zigbee module connects to a USB interface, allowing data transfer to a PC. The collected data is analyzed through GUI visualization and GUI analysis tools, making it easier to interpret trends and anomalies. Additionally, the system supports IoT integration via the ThingSpeak website, enabling remote access and real-time monitoring from any location. This comprehensive framework enhances disaster preparedness by providing timely alerts and data-driven insights.

4. Conclusion

In the proposed Zigbee-based IoT framework for landslide and flood monitoring effectively addresses the limitations of traditional methods by providing real-time data acquisition, wide coverage, and cost-efficient operation. By integrating various sensors, including humidity, float, moisture, and vibration sensors, with Arduino NANO, the system ensures accurate detection of soil movement and abnormal water levels. The early warning capabilities enable timely interventions, reducing risks to human lives and infrastructure. This project demonstrates the potential of low-power, long-range Zigbee technology in disaster monitoring, paving the way for more scalable and efficient early detection systems in vulnerable regions.

5. Future Work

Future work for this project includes enhancing the system with machine learning algorithms for better prediction of landslides and floods. Real-time data visualization and mobile alerts can be integrated to improve accessibility. Adding GPS and satellite-based remote sensing will provide more accurate location tracking. Energy efficiency can be improved by using solar-powered sensors for continuous operation. Expanding the network with IoT technologies like LoRaWAN or 5G will enhance communication and scalability, making the system more effective in disaster prone areas.

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