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SAFEHARBOR: A SMART IOT LANDSLIDE PRECAUTIONARY SYSTEM FOR ENHANCED COMMUNITY SAFETY

Engineering

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ABSTRACT

A landslide poses a significant threat to various locations, impacting social life. The current landslide monitoring systems lack efficiency, particularly in detecting rainfall, a crucial factor in tropical countries like India with intense rainfall. This research endeavors to develop a Smart Landslide Precautionary System for real-time and advanced landslide detection. The chosen rainfall sensor serves as a key component, providing early alerts to individuals, considering the diverse origins of people. Employing the NODE Mcu ESP3266 microcontroller with a Multiplexer for analog pin extension, the system is divided into Central and Remote Servers. The Remote Server integrates rainfall, vibration, and soil moisture sensors across different locations, transmitting real-time data to the Central Server via the Blynk IoT platform. In case of sensor values surpassing thresholds, the District Administrative Center receives alert calls through the GSM module. The findings indicate heightened landslide susceptibility in soil samples, with rain sensor readings reaching 85mm and soil moisture sensor readings hitting 35%. The proposed system offers enhanced accuracy for users to monitor and respond to landslide-triggering conditions effectively, showcasing a proactive approach to community safety.

KEYWORDS

Node Mcu, Blynk, Internet Of Things, Central Server, Remote Server

INTRODUCTION

Landslides are significant natural disasters that can cause the movement of a mass of rock, earth, or debris down a slope due to a disturbance in the stability of soil or rock. According to the Landslide Atlas of India provided by the Indian Space Research Organisation in the year 2023, various types of landslides, such as natural and human-made landslides, can occur. Landslides can severely impact the economic resources present on the earth's surface, such as gold, silver, and other precious metals.

Therefore, it is crucial to have a system that can monitor landslides in real-time and protect these natural resources.It is one of the most significant natural disasters that can cause loss of life and extensive property damage. There are several types of landslides such as falls, topples, slides, rotational slides, translational slides, and others. In India, the monsoon of 2014 saw 8093 landslides, according to ISRO's database. This highlights the critical need for efficient monitoring and precautionary systems to protect people and properties from these unpredictable and dangerous natural disasters. (may refer to Fig 1).

Sl. No.	State/UTs	Monsoon season 2014	Monsoon season 2017	Field-based/year	Event-based / year	Total
1	Jammu and Kashmir	6826	19	434 / 2011	1 / 2015	7280
2	Ladakh	23		-	-	23
3	Himachal Pradesh	922	172	413 / 1998	1/ 2017 51/2013 2/2021	1561
4	Uttarakhand	1593	455	1419 / 1998	32/2003 307/2010 473 / 2012 6610 / 2013 1 / 2017 329/2021 1/2022	11219
5	Sikkim	73	79	-	1408 / 2011 8 / 2012 1/ 2016	1569
6	West Bengal	24	82	-	66 / 2011	172
7	Arunachal Pradesh	2904	4709	-	75 / 2016 1/2021	7689
8	Nagaland	54	2071	-	7/2017	2132
9	Manipur	379	4559	-	556/2017 1/2022	5494
10	Mizoram	1205	2254	-	8926/2017	12385
11	Tripura	56	8014	-	-	8070
12	Assam	1243	793	-	533/2017 5091/2022	2569
13	Meghalaya	2127	512	-	-	2639
14	Maharashtra	97	3	-	5012/2021	5112
15	Goa	2	1	-	-	3
16	Karnataka	82	19	-	993/2018	1094
17	Kerala	9	45	-	5191/2018 756/2019 09/2020 29/2021	6039
18	Tamil Nadu	79	8	-	603/2018	690
19	Haryana	-	100	-	-	100
	Total	17,698	23,895	2,266	37,074	80933

Fig1. Data Of Landslides That Took Place In Past Years
Source: Isro Landslide Atlas 2023

Internet of Things (IoT) technology is an efficient technique to identify the present soil conditions in areas prone to landslides. It eliminates the need for cabling and provides real-time data. There are various wireless technologies available such as Wide Area Network (WAN), Long Range Wide Area Network (LoRaWAN), Zigbee, RFID, GPRS, and Bluetooth. In this study, the "slave" multiple "masters" ESP3266 method is used to collect data from different locations. Capacitive soil sensor, Rain Sensor, and vibration sensor data are converged in Remote ESP-3266, and then in Central ESP-3266. This approach ensures accuracy in determining the situation of and triggered by a landslide, making it simpler to monitor.Landslides have caused a significant amount of damage and loss of life in recent years, and unfortunately, many of them couldn't be predicted beforehand. It's a fact that every country is prone to landslides, but not all of them have installed a system that could predict landslides early before they occur. That said, in this modern era, there is a growing need for regional landslide monitoring techniques that consider various local live data. Fortunately, with the era of technology, people nowadays have access to abundant information at their fingertips.

Previous research has explored various methods and techniques to address the issue of landslides. In Fig 2, a comparison can be seen between the components used in past research. However, previous studies did not utilize a central server, remote server, or GSM module. In contrast, this proposed system includes these components and aims for simplicity and cost-effectiveness. There are notable differences between this project and previous ones, with a focus on developing an early warning system.

A warning system for potential landslides should be installed in various areas prone to landslides across all districts of the state. The Smart Landslide Precautionary System is a great example of such a system, which utilizes Internet of Things (IoT) technology to analyze data on rain, soil conditions, and ground movement. This system will be highly beneficial for district disaster management authorities, as they can take necessary actions quickly to reduce public risk and minimize economic loss before any disaster occurs.

Methodology

This method can be separated into two main categories
i) Hardware
ii) Software

Research	Soil Moisture Sensor	Vibration Sensor	Rainfall Sensor	GSM Module	ULTRASONIC SENSOR	HC-12
Smart Landslide Precautionary System / 2023	✓	✓	✓	✓	✗	✗
Smart Monitoring and Warning Landslide System using IoT/ 2022	✓	✓	✓	✗	✗	✗
Landslide Detection System: Based on IoT/ 2021 [12]	✓	✓	✗	✗	✗	✗
Landslide Detection and Avoidance System	✓	✓	✗	✗	✓	✓

Fig 2. Comparision Of Components Past Research

Hardware

The diagram presented in Fig.3 illustrates the system's overall structure, which comprises of two major components: the Remote Server and the Central Server. The Remote Server comprises of a Vibration Sensor, a Rain Sensor, and a Soil Moisture Sensor. The Node Mcu microcontroller (ESP-3266) is used to operate the system. Additionally, a computer in the District Administrative Center (data center) is utilized along with the Central Server to display the system's output through the Blynk Application.

The system operates by detecting the threshold value for each sensor to obtain the data. Once the data is collected, NodeMCU transmits it from the Remote Server to the Central Server. In case the overall sensor exceeds the threshold value in the Remote Server, an alert call is automatically sent to the District Administrative Center. Furthermore, the employees can also monitor each location's conditions through the Central Server in the Blynk Application. (Fig 3 depicts the structure of the system)

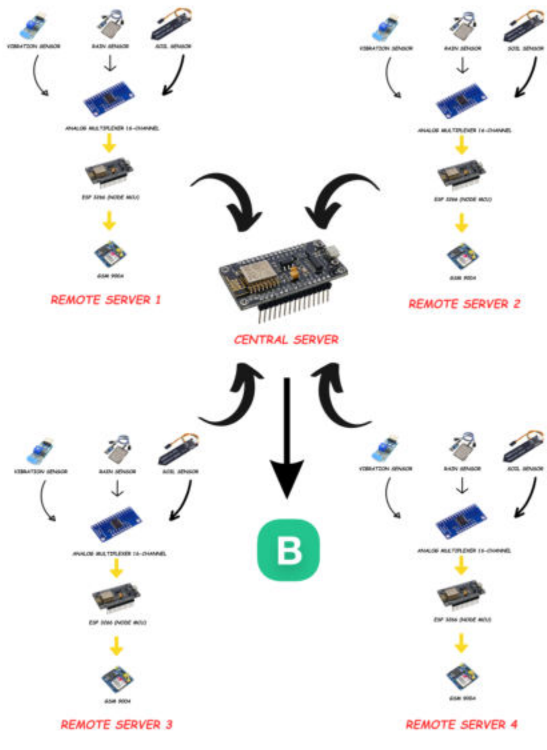

Fig 3. Structure Of The System

Component Description:

To collect key landslide monitoring parameters such as soil moisture, rainfall, and vibration, multiple sensors are typically required to cover a certain area. In this study, we utilized three sensors for this purpose. The proposed system used a soil moisture sensor that operates within the range of 3.3V to 5V. The soil moisture sensor employed is a capacitive type, consisting of two conductive plates or probes that are inserted into the soil. The soil between these plates acts as a dielectric material. When the soil is dry, it has a lower dielectric constant, resulting in lower capacitance. Conversely, when the soil is moist, its dielectric constant increases, leading to higher capacitance.

It should be noted that resistive soil sensors were not employed in this study due to their vulnerability to electrolysis. Placing a resistive soil sensor in soil would lead to electrolysis and the copper plate in the soil sensor probe would disappear, necessitating frequent replacement. Therefore, capacitive soil moisture sensors were used in this study, as they are more reliable and require less maintenance. Overall, utilizing multiple sensors and employing capacitive soil moisture sensors has enabled us to collect comprehensive landslide monitoring data with greater accuracy.

The YL-83 Rain Detector is a highly efficient device that can quickly and accurately detect rain and snow. Unlike other rain detectors that work based on a signal-level threshold, the YL-83 operates through droplet detection. This allows the sensor to accurately identify light rain and distinguish it from rain cessation. Additionally, it has an analog Rain Signal that provides an estimate of rain intensity. The amplitude and variation of this signal depend on the percentage of moist or wet area on the sensor plate, which indicates the intensity of rainfall. This circuit works on a bias of 3.3V to 5V DC.

The multiplexer is responsible for collecting all the data from the sensors and transmitting it to the controller (NodeMCU ESP8266). The reason for using a multiplexer is that the NodeMCU ESP8266 has only one analog input pin and an in-built Wi-Fi module for transmitting the data. If the other controller has more analog input pins and is compatible with the Wi-Fi module interface, the use of multiplexer blocks can be eliminated.

The SW-420 vibration sensor comes with a breakout board that includes the LM 393 comparator and an adjustable onboard potentiometer of 10k for selecting the sensitivity threshold and signal indication LED. This sensor module produces logic states depending on the vibration and external force applied to it. When there is no vibration, this module gives a logic low output. When it detects vibration, the output of this module goes to logic high. The working bias of this circuit is between 3.3V to 5V DC.

The GSM module provides excellent performance for voice, SMS, data, and fax on GSM/GPRS 900/1800MHz frequencies. It is designed with a small form factor of 24mm x 24mm x 3mm and has low power consumption. This makes it suitable for applications that have slim and compact design requirements. Additionally, the module is integrated with the TCP/IP protocol, and extended TCP/IP AT commands are available for easy use. This feature is particularly useful for transferring data. The module can also communicate with controllers via AT commands (GSM 07.07, 07.05, and SIMCOM-enhanced AT Commands).

Lastly, the microcontroller used here in this project is the NodeMCU V3 Lua WiFi development board it is a compact and cost-effective microcontroller platform. It is based on the ESP8266 module and is designed to facilitate the development of IoT and embedded systems. The board has built-in Wi-Fi connectivity, a Lua-based firmware that simplifies programming, GPIO pins for interfacing with external devices, and a CH340 USB-to-Serial converter for easy communication with a host computer. Due to its versatility, it is widely used in research projects and academic settings to create interconnected devices and IoT prototypes.

Power Supply

In this research paper, we present a robust power supply system designed to ensure uninterrupted operation of a remote server. This system comprises five 3.7V 3000mAh lithium-ion batteries connected in parallel, providing a combined capacity of 15000mAh. The integration of a solar panel offers a sustainable means of recharging the batteries during sunny days, reducing reliance on traditional grid power and enhancing environmental sustainability. An Uninterruptible Power Supply (UPS) acts as a vital intermediary, seamlessly switching to battery power during power fluctuations or outages, while also conditioning incoming power to protect the server. Additionally, a 3.7V mobile adapter serves as an extra layer of backup for emergency situations.

Software

The system is seamlessly integrated with the Blynk IoT platform, enabling efficient data transfer and display for comprehensive remote server monitoring. Data generated by the remote server is transmitted to the central server, and this information is subsequently made accessible on the Desktop or Laptop systems at the District Administrative Center. Blynk is a versatile platform that extends its capabilities to both Android and iOS applications, making it highly accessible for controlling microcontrollers such as Arduino and Node MCU via the internet. Its user-friendly interface streamlines project management, offering three distinct widgets for each of the key sensors - the soil moisture sensor, vibration sensor, and rain sensor. Should any of these sensors surpass their predefined threshold values, an immediate alert is relayed to the District Administrative Center, facilitating timely response and proactive monitoring of the system's vital parameters.

Explanation Of The System Through Flow Chart:

Fig.4 depicts the flow chart and the working procedure of the system. When the system is powered up, the Remote server configures itself to the Central server, wifi, and Blynk applications. The connection successfully initializes the multiplexer. Then, it will accept the readings from all the sensors: soil moisture sensor, vibration sensor, and rainfall sensor. The soil moisture reads and compares with the programmed threshold value. Next, after reading the presence of rain, the microcontroller sends it to Blynk. If the threshold value of all three sensors exceeds the maximum threshold values, such as the soil moisture sensor exceeding>50%, vibration sensor >90, and rainfall sensor >55% the GSM will get initiated and an alert call will go to the District Administrative Center, side by side it will be publishing rainfall and soil moisture sensors, microcontrollers receive vibration sensor readings. All the values from sensors are mapped in percentage (%) level and would be displayed on the Desktop/Laptop of the District Administrative Center.

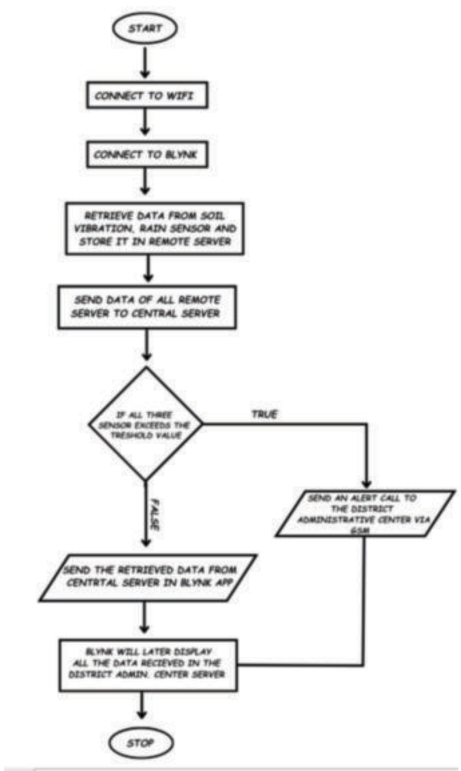

Fig 4. Flow Chart Of The System

Blynk Software

The system uses the Blynk IoT open-source platform to operate. Blynk is a platform that enables the control of microcontrollers, such as Arduino, through apps designed for Android, IOS, and websites over the internet. It is an easy-to-use platform and is ideal for interfacing with the project. In Fig.5, you can see the sensor data transmitted by the microcontroller. Each sensor has three widgets, but we have currently used only two locations for testing purposes. If the threshold values are exceeded, the GSM module sends an alert call to the District Administrative Center.

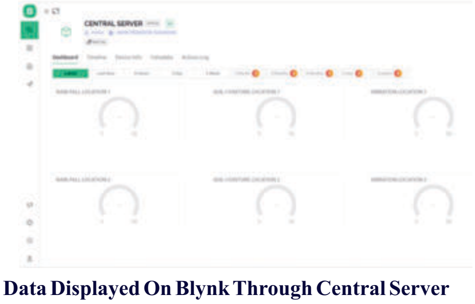

Fig .5 Data Displayed On Blynk Through Central Server

RESULT AND DISCUSSIONS

The system comprises three key sensors: the rain sensor module, soil moisture sensor, and vibration sensor module, which operate continuously to track environmental changes. These sensors collect data and transmit it to a microcontroller, often referred to as the remote server. The remote server processes the data and subsequently forwards it to another microcontroller, known as the central server, utilizing HC-12 communication modules. The central server's role is to provide a user-friendly interface where the current environmental conditions are displayed through the Blynk IoT platform in various locations and track real-time data.

The system is equipped with predefined threshold values, and it continually compares the real-time sensor data with these thresholds. If the monitored data exceeds these preset threshold values, the system is programmed to initiate an alert call, immediately notifying the District Administrative Center. This prompt alert system ensures that appropriate action can be taken swiftly in response to potentially critical environmental conditions, enhancing the overall safety and preparedness of the region

Sensor	Value	Threshold limits	Results
Vibration \Sensor	0 - 10,000Hz	Value > 20Hz	Alert sent
Capacitive soil Sensor	0% - 100%	Value > 35%	Alert sent
Rainfall Sensor	0-100mm	Value > 85mm	Alert sent

Fig.6 This Figure Depicts The Threshold Value Set In The Microcontroller

CONCLUSIONS

The main goal of the proposed system is to establish a cost-effective early warning detection system that can identify and alert authorities of potential landslides. The system is not only capable of detecting landslides but is also able to send emergency notifications to the District Administrative Center. It operates in real-time and can be monitored by office personnel. The system has predefined threshold values, and when the sensor readings exceed these preset limits, it will automatically trigger an alert call to the District Administrative Center. This early warning mechanism is crucial to preventing harm to humans, animals, and valuable properties, contributing to better disaster preparedness and mitigation.

Future Works On This Research

The addition of Long Range Wide Area Network (LoRaWAN) communication to the system shows great potential for improvement. LoRaWAN technology can transmit data over long distances, making it suitable for both urban and rural areas. Its communication range can extend up to 15 kilometers(over one particular district), which can benefit remote and hard-to-reach regions. LoRaWAN also allows for direct user monitoring, transferring the responsibility from government agencies to end-users. This shift empowers individuals and communities to take proactive measures and receive immediate alerts when environmental conditions exceed defined thresholds. By doing so, it encourages a more responsive and resilient approach to landslide detection and mitigation. This not only makes the system more effective but also promotes local engagement and disaster preparedness.

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