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IoT Based Landslide Detection and Monitoring System

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Abstract*: Landslide is a natural disaster and it occurs due to natural or manmade activities. A landslide is defined as the movement of a mass of rock, debris, or wide range of ground movement. Landslides are a type of "mass wasting," which denotes any down-slope movement of soil and rock under the direct influence of gravity and it damaging the social life every year. India also faced the loss of humans due to landslides which occurred last few years during monsoon in Kerala. The aim of the proposed system is to detect that condition which leads to the occurrence of landslide and notify it well before time. And necessary steps can be taken to reduce or save the human loss. The system uses soil moisture and accelerometer sensors. Soil Moisture sensor measures the moisture content in the soil whereas accelerometer monitors the movement of land. The readings crossing the defined thresholds give an alarm to local citizens in the form of message through GSM. The sensed data are also transmitted via MQTT protocol to the Raspberry Pi (Rpi) used in the monitoring station. Raspberry pi is interfaced with a laptop to display the SAFE, MIDDLE and DANGER zones. All the readings from Rpi are also uploaded to IoT cloud for future analysis. The system takes only less time to collect data from sensors and transmit it to Rpi and also to upload data from raspberry pi to IoT cloud.

***Keywords*: Soil moisture sensor, Accelerometer, GSM, Raspberry Pi, IoT cloud, MQTT protocol.**

1. Introduction

A landslide is movement of a mass of rock, debris, or earth down a slope. In monsoons the rain water percolates and develops hydraulic pressure which exceeds the elastic limit of the soil or rocks. Due to this the strain gets accumulated which forces the soil and rocks to loosen their adhesive strengths entailing landslides [1]. Landslides can also be said of “Mass Wasting”, which refers to any down slope movement of soil and rock due to gravity. It causes property damage, injury and death. Also, it adversely affects a variety of resources such as

Water supplies, fisheries, dams and roadways for years after a slide event. The landslides occur when the slope changes from a stable to an unstable condition. This change in the stability of a slope can be caused by many factors together or alone. The natural causes, such as, ground water pressure acting to destabilize the slope, erosion at the bottom of a slope by rivers or ocean waves, earthquakes adding loads to barely stable slope, earthquake caused liquefaction destabilizing slopes. The manmade causes such as, deforestation and construction which destabilizes the already fragile slopes, vibrations from machinery or traffic. Landslides occur in rocky mountainous regions like Himalayas, konkan railways [2], lonavala Ghats and marshy regions of Kerala in India. Landslides are hazards all over the world. Hillsides with steep slopes are prone to landslides. In the last few years Kerala also faced the loss of human landslide. Mainly landslide season in Kerala starts with the onset of the south-west monsoon every year. Landslides include debris flows, rock slides and mud slips. Apart from claiming human lives it destroys hills and vast tracts of agricultural lands, buildings, roads, economic and infrastructure.

Researchers are still doing different case studies on landslide prediction, detection and monitoring. Landslide detection can be done by using diverse methods like visual inspection using image processing [3], digital aerial photographs [4], and laser projector [5], using statistical methods. Landslide detection can also be based on data driven approaches using wireless sensor networks (WSN) [6]. The main objective to study the landslide detection is to prevent the natural calamity by detecting its early movement and this will reduce or save the human loss caused by the landslide. Also, the objective is to find a certain way in which the sensing elements should respond quickly to rapid changes of data and send this sensed data to data analysis center. The proposed Internet of things (IoT) based landslide detection and monitoring system is a low cost, robust and delay efficient.

2. System Architecture

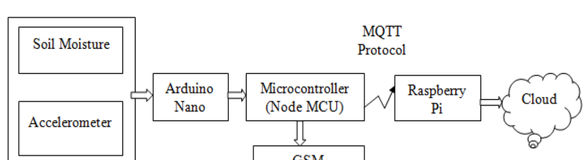

Fig. 1. Block Diagram

Fig. 1. shows the basic architecture of the system. It shows

the soil moisture sensor [7] and accelerometer sensor [8] which measure movement of land and moisture content in the soil. The collected data from the sensors is given to the microcontroller through Arduino Nano. The controller accepts the data from sensor nodes. If these sensed data cross threshold values, it gives an alert to local citizens by using the GSM. Apart from giving alerts to the local citizens, controller also transmits all the sensed data towards the monitoring station. The sensed data are also transmitted from NodeMCU to the Raspberry Pi (Rpi) used in the control room via MQTT protocol. The Raspberry pi is interfaced with a laptop to display the SAFE, MIDDLE and DANGER zones. All the readings from Rpi are also uploaded on IoT cloud to analyze them and give alert to the rescue team.

3. Component Description

A. Soil Moisture Sensor

Soil moisture sensor measures the volumetric water content in the soil. Since the direct gravimetric measurement of free soil moisture requires removing, drying, and weighing of a sample, soil moisture sensors measure the volumetric water content indirectly by using some other property of the soil, such as electrical resistance, dielectric constant, or interaction with neutrons, as a proxy for the moisture content.

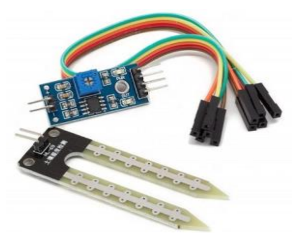

Fig. 2. Soil Moisture Sensor

The fork-shaped probe with two exposed conductors, acts as a variable resistor (just like a potentiometer) whose resistance varies according to the water content in the soil. This resistance is inversely proportional to the soil moisture:

- The more water in the soil means better conductivity and will result in a lower resistance.
- The less water in the soil means poor conductivity and will result in a higher resistance.

The sensor produces an output voltage according to the resistance, which by measuring can determine the moisture level.

B. Accelerometer

An accelerometer is a device that measures proper acceleration. Proper acceleration, being the acceleration (or rate of change of velocity) of a body in its own instantaneous rest frame, is not the same as coordinate acceleration, being the acceleration in a fixed coordinate system.

ADXL335 is used, it is a triple axis accelerometer with extremely low noise and power consumption. It measures acceleration within range ±3 g in the x, y and z axis. The output signals of this module are analog voltages that are proportional to the acceleration. It contains a polysilicon surface-micro machined sensor and signal conditioning circuit. This structure is suspended by polysilicon springs. It allows the structure to deflect at the time when the acceleration is applied on the particular axis. Due to deflection the capacitance between fixed plates and plates attached to the suspended structure is changed. This change in capacitance is proportional to the acceleration on that axis. The sensor processes this change in capacitance and converts it into an analog output voltage.

It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration.

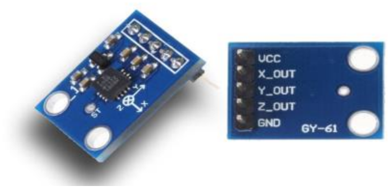

Fig. 3. Accelerometer

C. Arduino Nano

Arduino Nano is a small, compatible, flexible and breadboard friendly Microcontroller board, developed by Arduino.cc in Italy, based on ATmega328p (Arduino Nano V3.x) /Atmega168 (Arduino Nano V3.x). It comes with exactly the same functionality as in Arduino UNO but quite in small size. It comes with an operating voltage of 5V, however, the input voltage can vary from 7 to 12V.Arduino Nano is a surface mount breadboard embedded version with integrated USB. It is a smallest, complete, and breadboard friendly.

Fig. 4. Arduino Nano

It has more analog input pins and onboard +5V AREF jumper. The Nano automatically sense and switch to the higher potential source of power, there is no need for the power select jumper.

D. Node MCU

NodeMCU is a low-cost open source IoT platform. It includes firmware which runs on the ESP8266 Wi-FiSoC from Espressif Systems, and hardware which is based on the ESP-12 module. The term "NodeMCU" by default refers to the firmware rather than the development kits. The firmware uses the Lua scripting language. It is based on the eLua project, and built on the Espressif Non-OS SDK for ESP8266.

Fig. 5. Node MCU

It uses many open source projects, such as lua-cjson and SPIFFS.

E. ESP8266 Wi-Fi Module

ESP8266 is low cost microchip with full TCP/IP stack and microcontroller capability. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor. ESP8266 is already pre-programmed with a set of AT commands.

Fig. 6. ESP8266

F. GSM

GSM stands for global system for mobile communication. It is a mobile communication modem and it is widely used mobile communication system in the world. The GSM was developed at Bell Laboratories in 1970. It is an open and digital cellular technology, it used for transmitting mobile voice and data services and operates at the 850MHz, 900MHz, 1800MHz and 1900MHz frequency bands

Fig. 7. GSM

G. Raspberry Pi

The Raspberry Pi is a low cost, credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It is a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python. It's capable of doing everything you'd expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games.

Several generations of Raspberry Pis have been released. All models feature a Broadcom system on a chip (SoC) with an integrated ARM-compatible central processing unit (CPU) and on-chip graphics processing unit (GPU). Processor speed ranges of Pi 3 Model B+ from 700 MHz to 1.4 GHz and on-board memory ranges from 256 MiB to 1 GiB random-access memory (RAM). Secure Digital (SD) cards in MicroSDHC form factor (SDHC on early models) are used to store the operating system and program memory. The boards have one to five USB ports.

For video output, HDMI and composite video are supported, with a standard 3.5 mm tip-ring-sleeve jack for audio output. Lower-level output is provided by a number of GPIO pins, which support common protocols like IC. The Raspberry Pi 3 model B+ has an 8P8C Ethernet port and have on-board Wi-Fi 802.11n and Bluetooth.

Fig. 8. Raspberry Pi 3 B+

4. Module Description

The proposed system is divided into three modules

1. Sensor Module
2. Controller Module
3. Data Module

1) Sensor Module

Several sensor nodes are needed to cover certain area. All these sensors collect the landslide monitoring parameters such as landslide displacement, soil moisture, and tilt angle. Here, the system consists of soil moisture sensor and accelerometer sensor.

Soil Moisture Sensor is used to measure water content of soil.

It has two plates which measure the water content in the soil. The electric current through the plates is proportional to the amount of water content.

The accelerometer used for vibration sensing (slope displacement measurement) is ADXL335 which contains a polysilicon surface-micro machined sensor and signal conditioning circuitry. The basic structure of accelerometer has a fixed plate and a moving plate. The moving plate deflects due to the acceleration which in turn unbalances the differential capacitance and gives the output voltage proportional to the accelerations. ADXL335 accelerometer provides analog voltage at the output X, Y, Z pins which are proportional to the acceleration in respective directions i.e. X, Y, Z. The collected data from the sensors is given to the controller module through Arduino nano.

2) Controller Module

The collected data from the accelerometer and soil moisture sensors is given to the controller through Arduino Nano This is done because the controller used here is NodeMCU (esp8266) which has only one analog input pin and in-build Wi-Fi module which is required for transmission of data towards monitoring station. The controller accepts the data from sensor nodes. If these sensed data cross threshold values, it gives an alert. The entire data range is divided in three classes; SAFE zone, MIDDLE zone and DANGER zone. Alert is given for the DANGER zone. When the system is powered up, the NodeMCU configures itself to the Wi-Fi and the MQTT server. After making these connections successfully, it initializes arduino nano. Then, it starts accepting readings from soil moisture and accelerometer sensors. If these sensed data cross threshold values, it gives an alert to local citizens by using the GSM. Alert about the danger zone is passed in the form of message to the local citizens by using the GSM. Apart from giving alerts to the local citizens, controller also transmits all the sensed data towards the monitoring station. The Raspberry pi is interfaced with a laptop to display the SAFE and DANGER zones.

3) Data Module

Data module consists of raspberry pi and IoT cloud. The sensors are placed in the soil and the readings are collected and transmitted over MQTT to raspberry pi. Later the information is transmitted to IoT cloud. The monitoring station does the work of monitoring and analyzing of data. The sensed data is communicated to monitoring station via NodeMCU using MQTT protocol. For collecting data from MQTT, python programming is used in raspberry pi. The data reception and transmission by raspberry pi towards cloud is done using python script.

5. Result and Discussion

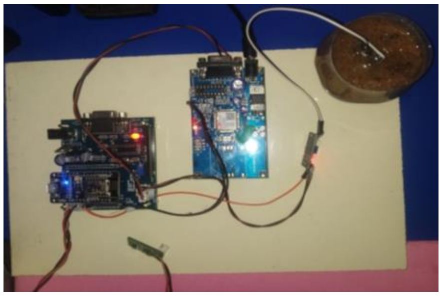

Fig. 9. Base Station (Landslide site)

The landslide detection system is successfully implemented as a prototype. All the sensors and other stuff works as per the expectations. The sensors effectively sense the surrounding conditions and give the readings. Based on readings, the prediction of landslide is achieved successfully. The system senses data and transmits it continuously. The system takes only less time to collect data from sensor and transmit it to raspberry pi over MQTT and also to upload data from raspberry pi to IoT cloud.

6. Conclusion

Real-time monitoring of landslides is one of the challenging research areas available today in the field of geophysical research. The IoT based landslide detection system is to detect those conditions which lead to the occurrence of landslide and notify it well before time and able to save the human loss. The current landslide detection systems are less accurate. Here the proposed system is a real-time monitoring system and more accurate too. It is also very easy to set up. All the current systems are not completely automatic. They all require human interaction at some point. Here the proposed system is completely free of human interruption. The system is a robust and delay efficient system. It predicts occurrence of landslide at early stages thereby reducing the fatalities due to landslide.

7. Future scope

Continuous improvement and work on remaining problems is continuing and will be approached in the near future. By applying machine learning accuracy can be increased. In the future, this work will be extended to a full deployment with increased spatial variability. Field experiment will be conducted to determine the effects of density of the nodes, vegetation, and location of sensors for detecting rainfall induced landslides, that may help in the development of low cost system. Machine learning can be implemented in the system through python programming in future work.

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