Landslide Early Warning System

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***Abstract*—Landslide is one of the catastrophic disasters that cause hundreds of fatalities and millions worth economic losses in landslide-prone areas. So, a proper landslide risk assessment should be done to develop the relationship between triggering parameters and the dynamics of mass movement of soil under gravity and finally apply innovative engineering techniques to develop landslide early detection and warning system. To alert the local community about the probable landslide and initiate mass evacuation to avoid human casualties and minimize economic damages, landslide early warning system remotely senses environmental behaviors like rainfall, soil moisture, crack elongation in real time. The required sensors are being made for high precision and cost efficiency. Rain gauge, soil moisture sensor, and extensometer sensor are interfaced with core controller Arduino MEGA to detect the parameters. Data are displayed on LCD and stored on SD card for future access. When the sensor values go beyond the threshold value, a siren is enabled to alert people for evacuation and SMS is sent to multiple concerned people who might be responsible for immediate disaster assessment or rescue operation.**

***Keywords*— Rain gauge, Extensometer, GSM module, soil moisture sensor, Hall effect sensor, Potentiometer, RTC**

I. INTRODUCTION

Landslide is defined as the movement of a mass of rock, soil or debris down a slope under the influence of the gravity. The frequency of the occurrence of this disaster in Nepal, where more than 64% of the total area comprises of the hilly region, is more. The natural causes like seismic activities, heavy rainfall, etc. lead to the geological fragility of the soil causing it to slack and slide. Similarly, human activities like mining, clear-cutting, deforestation, etc. alter the natural slope stability aiding landslide. Every year a large number of landslides occur across the country causing hundreds of human fatalities and millions worth economic and infrastructural damages. One big factor causing landslides in Nepal is the summer monsoon. The occurrence of landslides is high in July with slightly lower but still notable towards August and September. During these months, landslide buries hundreds of houses, takes lives of people, displaces families, blocks roads and rivers and causes serious havoc. So, the steps should be taken to check the human causes aiding landslides and also minimize the damage caused due to it.

Landslide early detection and warning system should be deployed in landslide-prone areas to remotely monitor the environmental behavior and alert the respective community about the potential landslide. Proper development of landslide early warning system has become a world-wide challenge and introduced systems are not effective. The existing systems are available in terms of monolithic terms. They are very costly considering installation, operational and personal expenses.

For example, close-range photogrammetry has low monitoring accuracy and GPS is not cost effective under high accuracy requirements. Being cost-intensive, regular maintenance of the system is avoided which leads to disturbance of the flow of information in case of emergency.

This work aims for the systematic development of real time monitoring and early warning system to minimize loss of human life and infrastructures around landslide-prone areas. It is an improvised system of classic early warning systems which is cost-effective, flexible and reliable. This system analyses environmental changes around such areas and alerts as needed. Our system includes extensometer, soil moisture sensor and rain gauge for sensing environmental behaviors. Tipping bucket rain gauge and borehole extensometer are being designed using their working principles to make them highly accurate, cost effective, flexible and easily applicable for the work. Arduino MEGA is used as a core controller that processes measured data to display on LCD in the deployment site and stores those data taken at specified intervals on SD card. GSM/GPRS module is also used to send information.

Siren is automatically enabled as soon as threshold values are reached. Landslide Early Warning System (LEWS) is all about detecting probable landslides as soon as possible to avoid or at least to minimize human casualties.

II. LITERATURE REVIEW

Zhang Wenlong, Guo Quing and Liu Baoshan [1] designed the landslide warning system based on the wireless sensor networks using ZigBee protocol. They designed this system mainly relying on the role of two sensors, liquid level sensors and angle sensors. They set up some vertical holes along the mountain and deploy liquid level sensors and angle sensors in the different depths of the hole. These sensors are used to monitor water level and slope angles of the mountain. When the landslide occurs, the sensors sent the data by the wireless sensor networks to the monitoring canter. Wireless network sensor is made of all kinds of nodes, including terminal nodes, routing nodes and coordinator nodes. Terminal nodes collect data about the mountain and send them to the router, the router is also responsible to collect data of mountain and act as a routing role. Eventually, these data are sent to coordinator where it establishes a network and test the received data and transfer the data to the GSM and GSM module send the data to the remote monitoring center where the data are displayed on the screen.

Maneesha V. Ramesh, Sangeeth Kumar, and P. Venkat Rangan [2] published this detection system in the conference paper of 2009. Here, a sensor such as Geophone, Pore pressure transducer, dielectric electric sensor and strain gauge are used to sense the occurrence of the landslide. The initial slope failure of sloppy land can occur due to the increase in pore pressure and soil moisture content, under heavy rainfall, which necessitates the inclusion of geophysical sensors for detecting the change in pore pressure and moisture content with the warning system developed for landslide detection. So, the system discussed in this paper also includes geophysical sensors such as pore pressure transducer and dielectric moisture sensor for capturing the in-situ measurements. After the slope failure, the subsequent transport of the material happens that will generate slope gradient change, vibration, etc. which has to be measured and monitored for the effective issue of warning. So, the warning system includes strain gauge and tiltmeter. Along with them, geophone is used for analyzing the vibration.

AghusSofwan, Sumardi, M. Ridho, Abdul Goni and Najib [3]designed Wireless Sensor Network for Landslide Warning System in IoT Architecture. This system implements machine-to-machine communication, which may not need human interaction into the system. The proposed system considers three domains, which are sensors node domain, communication domain, and user access domain. Each node consists of a coordinator and four sensors, which are a temperature sensor, humidity sensor, slop sensor, and soil moisture sensor. Data comes from sensors are collected by a single-chip microcontroller, which is Arduino Mega 2560. They used a cellular network in the communication domain which provides internet services. Data from a node then are transmitted using GSM modem in the gateway. Each node is equipped with the solar cell that supplies power for its operation.

Terzis. Andreas., Anandarajah. Annalingam., Moore. Kevin., Wang. I-Jeng. [4], “Slip

Surface Localization in Wireless Sensor Networks for Landslide Prediction” discusses the topic of slip surface localization in wireless sensor networks, which can be used for landslide prediction. A durable wireless sensor node has been developed, which can be employed in expandable wireless sensor networks for remote monitoring of soil conditions in areas conducive to slope stability failures. In this paper, real time deployment of a heterogeneous network in India for landslide detection has been discussed. This study incorporates both theoretical and practical knowledge from diverse domains such as landslides and geomechanics, wireless sensor, Wi-Fi, and satellite networks, power saving solutions, and electronic interface and design, among others, which paved the design, development, and deployment of a real-time landslide detection system using a wireless sensor network.

Leonardo Zan, Gilberto Latini, Evasio Piscina, Giovanni Polloni and Pieramelio Baldelli [5] developed Landslides Early Warning Monitoring System in Campo Italy. The system is composed of a series of sensors, of easy and rapid installation which measures seismic noise, ground displacements, piezometric level, and rainfall. Thus, the sensors used are laser diastimeter, groundwater level gauge, geophone and rain gauge. The sensors are linked by means of a data acquisition card to a personal computer capable of processing data and emitting alert and warning signals whenever the established threshold is exceeded. By means of a GSM system, this instrument transmits alert signals to the operators in charge of monitoring. The system receives the signals, the digitizes and stores them in specific files for each sensor, and permits their download by means of computer storage media. The warning signals are provided by the means of SMS technology.

PraptiGiri, Kam Ng, and William Phillips [6] designed Wireless Sensor Network System for Landslide Monitoring and Warning. Remote monitoring and warning of landslides are made possible by the advancement of technologies, including radar systems robotic total station but they used WSNS due to real-time data collection, processing, and transmission allowing effective remote monitoring and warning. Here, they divided the system in hardware and software part. The hardware for the landslide monitoring and warning system consists of three main components: capture server, sensors, and power sources. The capture server is comprised of an Internet connection, sensor communication devices, data storage devices, and an advanced reduced instruction set computing machine processor. BNO055 absolute orientation sensor device by Bosch was selected for meeting the requirement of this study with a three-axis accelerometer and a three-axis gyroscope. The sensor device with a minimum of accelerometer and gyroscope sensors allows movement detection and failure type determination. For software for this system is Node-RED. The Node-RED flows are created to control the sensors in the WSNS for start-up and end of data collection into the database, monitor the change in motion of sensor devices based on live graphing, and send warning signal(s) to the authorized personnel via e-mail or text messages.

III. METHODOLOGY

A) Requirement Gathering and analysis

All the electronic modules and sensors were collected after the immense research on them according to the required conditions. Arduino MEGA is used as a microcontroller that is based on AT mega 2560. For GSM, we selected SIM 900A module. Being the most popular and cost-effective solution, we decided to go with this module. Variants of SIM 800 modules could be used. Those modules offer Bluetooth and FM features that are insignificant to our system. SD card module, 4×3 Keypad, and 16×2 LCD module were introduced to our work that basically acts as I/O components. Real Time Clock (DS3231) and normal piezoelectric buzzer were also introduced. We chose resistive soil moisture sensor over capacitive soil moisture sensor. Dealing with resistive soil moisture sensors are simple, yield successful results and are economical. I2C module was added to reduce the complexity in the connection between Arduino and LCD module. We needed to select the best type for designing the rain gauge. Various popular types of rain gauge are available, namely: non-recording type, recording type, weighing bucket type, tipping bucket type, and floating type. Tipping bucket rain gauge was found to be best suited for our work. Tipping bucket measures the rainfall data directly and displays it on the interfaced program software. This makes us easier since the observer doesn't need to go to the instrument field. Also, the main character (i.e. light, medium or heavy) can be obtained easily. Tipping bucket is not limited to rainfall capacity and its output data can be observed wirelessly in long range, thereby being the best alternative as it requires less maintenance too. The idea of wire extensometer was taken in light. Being the major component to measure the displaced land length, we had to design a better instrument. For these, laser displacement sensor, non-contact displacement sensor or extensometer was selectable. We found wire extensometers easier to use and they have a relatively low cost. Most importantly, they are usable and some extensometers do not require special instrumentation. A multi-step potentiometer with 10 turns and 10K Ohms was taken for our extensometer. Moreover, the Hall Effect sensor US1881 was also taken. Using this sensor, it was simpler to interface with the rain gauge and the program. Alternatively, Reed Switch could also be used instead. Hall Effect sensor was concluded to be the best sensor to use in our rain gauge since it's more convenient and makes the working mechanism of rain gauge much easier.

B) Design

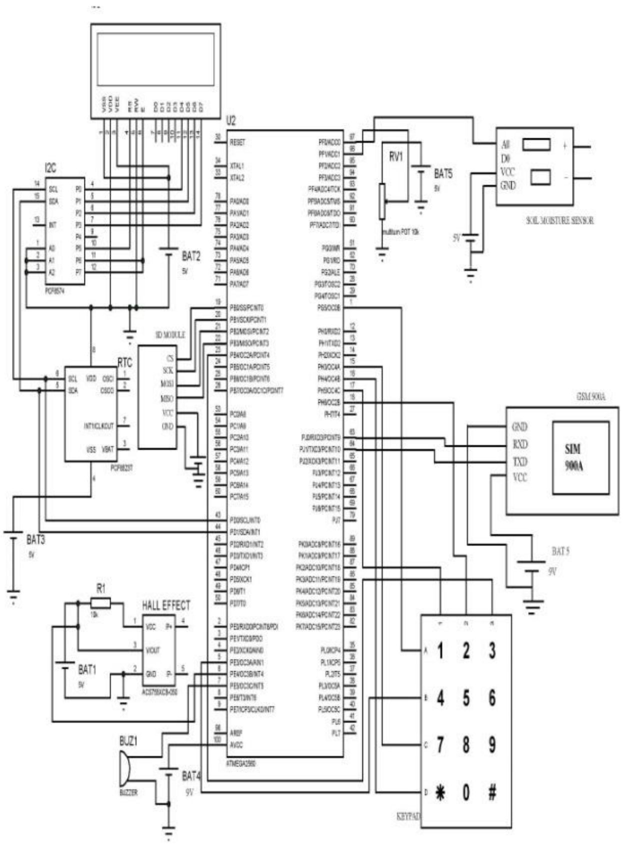

Fig. 4. Block diagram of the system

C) Flowchart

The flow chart of the system is shown in Fig 2.

D) Implementation

The designed model will be installed on the site where there is a high probability occurrence of translation landslides. After the installation, the test will be performed to ensure the communication between the microcontroller, sensors, and modules used in the system. Test data will be sent from the sensors to the Arduino which will be displayed on the LCD module.

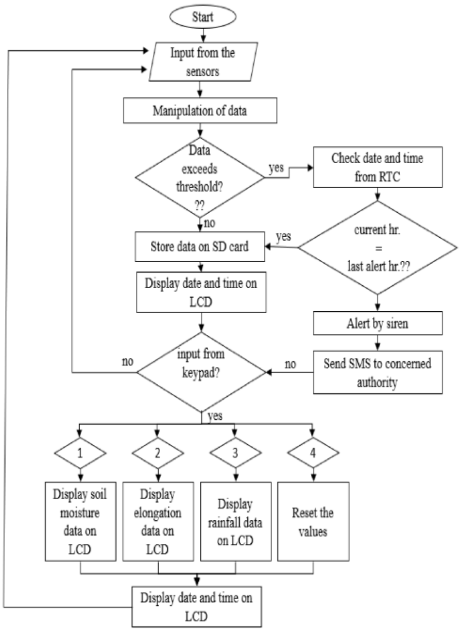

Fig. 5. Flowchart of the system

E) Testing

Arduino IDE was used to compile and upload the programming code into the required modules. Each module were tested multiple times as required and After the fabrication of different modules and sensors with Arduino MEGA, the code was optimized using the software where all the commands for the operation were coded according to which the all the devices in the system was operated. After completion of optimization of the codes, the system was tested multiple times to learn about the real time problem that could occur after the implementation.

IV. Results and Discussion

Individual parts of the system have been interfaced with Arduino to produce their respective output. GSM module was successfully interfaced to send a message to multiple mobile numbers. An RTC and SD card module were combined to save the data with the current date and time in the following format: “DATE: 10.06.2019 TIME: 18:29:02 Soil moisture: 81 % Crack elongation: 250 cm Rainfall: 0.00 mm” LCD module was interfaced to display the data. Hall Effect sensor detected the change in the magnetic field which can be mounted in the rain gauge to count the tip of the tipping bucket and measure the amount of rainfall. Soil moisture sensor was interfaced to measure the moisture content in the soil. A 4×3 keypad was interfaced to control the display of data on LCD. Piezo buzzer, which works on the principle of piezoelectricity, was able to produce sound when the value exceeded the defined limit. A multi-turn potentiometer has been interfaced to calculate the length of crack on the land. Following results were seen while testing the system:

Table I. Data from Sensors

Sensors	Extensometer	Soil moisture	Rain gauge
Values	250 cm	81%	29.5mm

V. Conclusion

The system concludes to be an effective implementation for landslide detection at vulnerable regions and thereby being a feasible system to avoid the losses possibly caused due to the landslide. The work is a complete system that measures rainfall, crack elongation and soil moisture of the area where the system is installed. The system includes a rain gauge, extensometer, and soil moisture sensor respectively. The corresponding values can be displayed on LCD manually via the keypad. With the help of the SD card module and RTC, these data are stored on the SD card and updated automatically every 60 seconds in real time. Arduino MEGA, as the core processor analyzes the data which when exceed the threshold values activate the GSM module and message is sent to authorize people. For evacuation, residing locals are alerted via siren. This system has been developed for the effective detection of landslide since Nepal has crucial regions that are vulnerable to landslides. The installation and implementation of our system are possible with affordable budget. Although limited instruments and sensors are used in our work, future enhancements can be made for better reliability.

VI. Recommendation

Due to system’s flexibility, new updates can be done to produce a better-optimized system. Sensors like accelerometer can be added to measure the vibration of the land. Other sensors such as geophones, laser diastimeter, and ground-level gauge can be used to measure various parameters such as seismic noise, ground displacements, and piezometric level respectively. Other modules like pore pressure transducer, Strain Gauge, wireless probe, etc. can be applied to the existing model. The system can be enhanced by applying the IoT concept where real-time data can be displayed on a website via the internet and those data can be stored in the cloud.

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