

Real Time Slope Failure Prediction System

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Abstract— Slope failures are most prominent in hilly regions facing heavy downpour of water. This leads to blockage of roads, loss of life and economy, etc. This can be detected prior to its commencement by using an array of sensors integrated with a microcontroller by precise programming and calibration. But implementation of such a system in real world is extremely difficult due to unpredictable conditions. This paper focuses on predicting failure of slope in a controlled environment. This reduces errors and difficulty in experimental setup. We were successful in predicting failure of the designed slope under conditions maintained with the help of Arduino and Moisture sensors. Telemetry program was used to plot data on graph.

Keywords— Slope failure, Arduino, Moisture sensor, Failure prediction, Geo-Slope, Telemetry Viewer, Landslide prediction system, Slope failure prediction system.

I. INTRODUCTION

Slope failure / mass wasting / landslides / avalanche all refer to the same engineering problem i.e., sliding of land which are triggered due to increase in moisture content: excessive rainfall, addition of excessive weight above the slope, unstable slope: digging at mid or foot of slope, surface and toe erosion, induced vibrations: earthquakes and due to man-made activity: construction activity etc. Slope failure on average costs hundreds and millions to any country for its mitigation, repair or study. Not only economy but life also suffers due to this natural disaster. Thus prevention or early knowledge of landslides will help in preparing for such event and in some cases prevention too. Thus development of an early warning system which predicts or is capable of monitoring such an event is of prime importance. With the help of modern technological advancements, it is possible to implement a chain of information communication system device to monitor natural conditions with the help of sensors, event detection equipment, etc. and calculate the possibility of a landslide far before it actually happens. Thus it would provide officials with ample time to take preventive measures such as slope stabilization or measures such as evacuate people to safer places etc. to reduce the effects of landslides in the adjoining area.

Moisture, one of the major causes of slope failure can be measured by using moisture sensors. At a certain moisture content, the slope tends to fall under the effect of gravity. Similarly, movement of earth is also the reason for failure or is accompanied once slope fails. This moisture content and earth movement can be known by collecting and analysing the data of prior landslides in nearby area. By installing sensors which measure these limiting values an alarm can be triggered right before the slope fails. This can be achieved by programming Arduino (Fig 1) with an array of moisture sensors (Fig 2) and accelerometers / vibration sensors. A sign board or LCD (Fig 3) showing Danger Ahead or Stop sign can be installed at least 5 km prior to the site of landslide for a buffer zone to react accordingly.

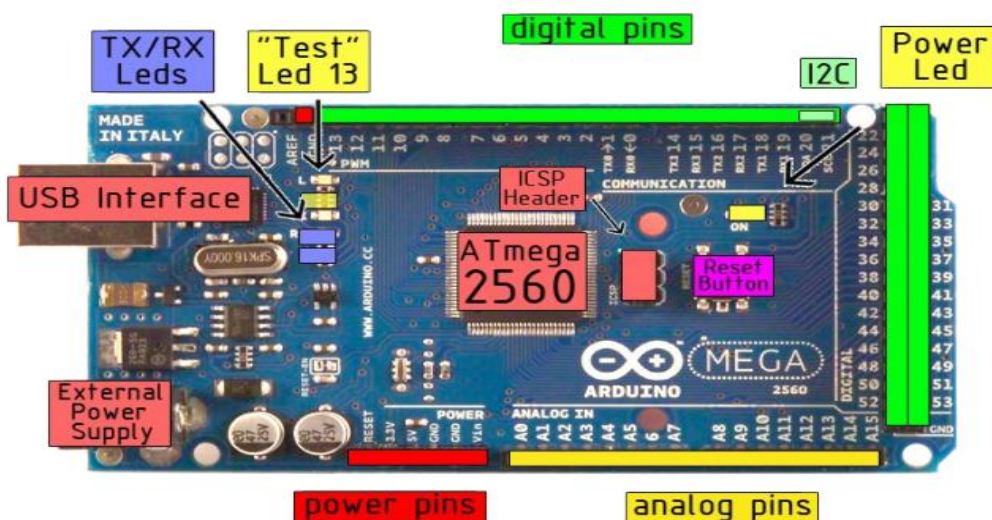


Fig 1: Arduino mega 2560.



Fig 2: Moisture sensor and buzzer.



Fig 3: 20x4 LCD screen.

II. LITERATURE REVIEW

Y. Srinivas in his paper used various sensors such as angle sensors for measurement of movement, liquid level sensors for collecting depth of water and temperature sensors for changes in temperature for studying the occurrence of landslide. All these sensors were connected to LPC 2148 ARM processor for collection of data with a GPS to give latitude and longitude and all the readings are transferred to a receiver side by using zigbee and displaying on an LCD at receiver station or by SMS. This can be used to alert people, save lives and property.

Gunarathna W. A. S. R in his paper tried to implement a system capable of predicting possible landslides in a given area and issuing a warning to aid in risk management. It is a low-cost, sustainable early warning system to send alerts via an SMS. They also claim to utilize data mining for identification of most dangerous areas for landslide and install sensors at those locations. Thus generate a warning alarm at the most critical point and issue warning such as sirens, SMS or via android application.

Mohamed Omar Kebaili in his paper used WSN to gather data even in hazard data to bridge the physical world for intensive monitoring the environment. When integrated with Web of Things and Big Data(MongoDB) database, the WSN offers a promising way to sketch an online picture of the monitored site. The developed prototype reads and observes precipitation, soil movement and soil moisture data and plots using telemetry viewer. All of this is implemented in a Tunisian Landsliding high risk zone which triggers alerts when bounded values are reached.

Frieda Lange in his paper studied mountainous landscape of Norway, which pose a considerable risk to its population, property and infrastructure. Among these mountains are a few shallow glacial till (properties similar to clay) sediments which overlay impermeable bedrock. Most significant triggers are precipitation or snow melts (leads to increase in water content), saturation and pore water pressures. Which causes destabilization of slope making it vulnerable to failure. A landslide early warning system based on metrological parameters has been active and working since 2013 at Norway. Problems such as frost and its effects on soil strength prevail. Thus design and development of a model which considers frost as a critical parameter in Early Warning System shall be verified.

III. METHODOLOGY

In hilly areas, slope failure / landslide is a major problem during monsoons. The most significant factors that trigger these landslides are moisture and vibration. These parameters can be measured by using moisture and vibration sensors respectively. Implementation of such a system which efficiently and precisely predicts slope failure is extremely difficult

in real life. Thus, designing a controlled environment such that all the parameters can be restrained easily is of prime importance.

Thus, for designing a slope, a soil whose properties can be easily determined is to be used. Considering this, beach sand seems to be the most obvious and preferable choice. Other parameters which affects the stability of a slope such as slope-angle, pore-water pressure are designed to create the most critical slope.

The slope is designed on Geo Studio such that the factor of safety of the slope is < 1 as shown in Fig 4. The red point with value of 0.399 shows the factor of safety (0.399) with the point of radius of slope failure. The experimental setup is prepared accordingly.

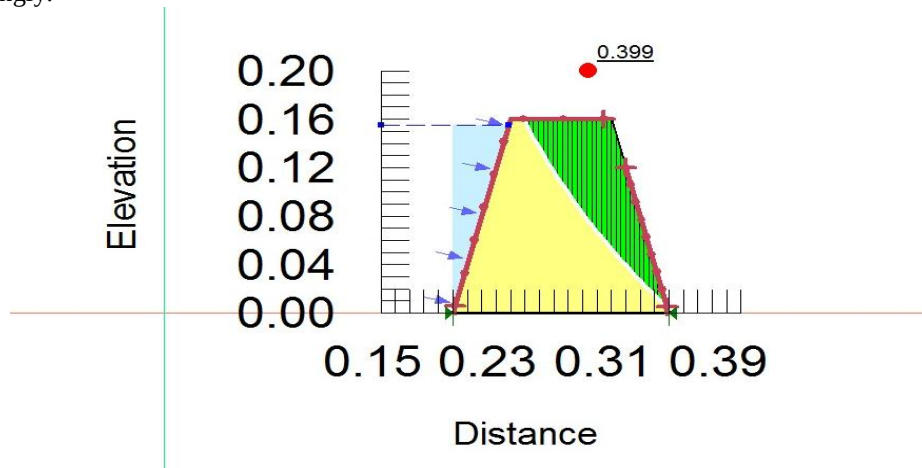


Fig 4: Slope designed in Geo Slope.

During experimental setup, the slope so constructed is similar to the slope which we made in Geo Studio. Moisture sensors are used to get the water head value. The moisture value in the sensors increases as the water head increases. These values can be plotted directly on graph by using telemetry viewer. Other than moisture sensor, buzzer, LCD screen, kill switch is also used. A microcontroller (Arduino) is used to make all the components to work together in sync for their programming.

There are various steps involved while preparing and testing slope. They are as follows:

1. Preparation of soil slope.
2. Programming and coding of Arduino.
3. Initial testing for Sensor calibration.
4. Placement of calibrated sensors.
5. Test run.

A. Preparation of slope

Soil is prepared by adding 7.5% of water by weight of sand. It gives us the required steep slope and easy workability. The dimensions are maintained as designed in GEOSLOPE. Soil is compacted in three layers 25 blows for each layer as shown in Fig5.

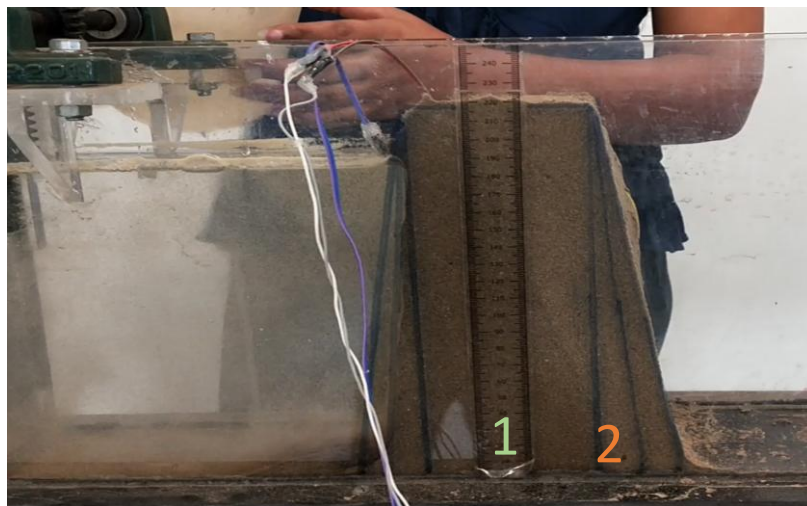


Fig 5: Slope Designed same as Geo Slope.

B. Programming and circuiting of Arduino

Arduino is programmed on Arduino IDE, using JAVA programming language. Which is based on two basic functions, main () and loop (). Where the variables are initiated and linked with the sensors attached. This allows Arduino to talk with the sensors and read analog signals. Which can then be exported to excel and useful data and be studied. Circuiting of Arduino is done as shown in Fig 6.

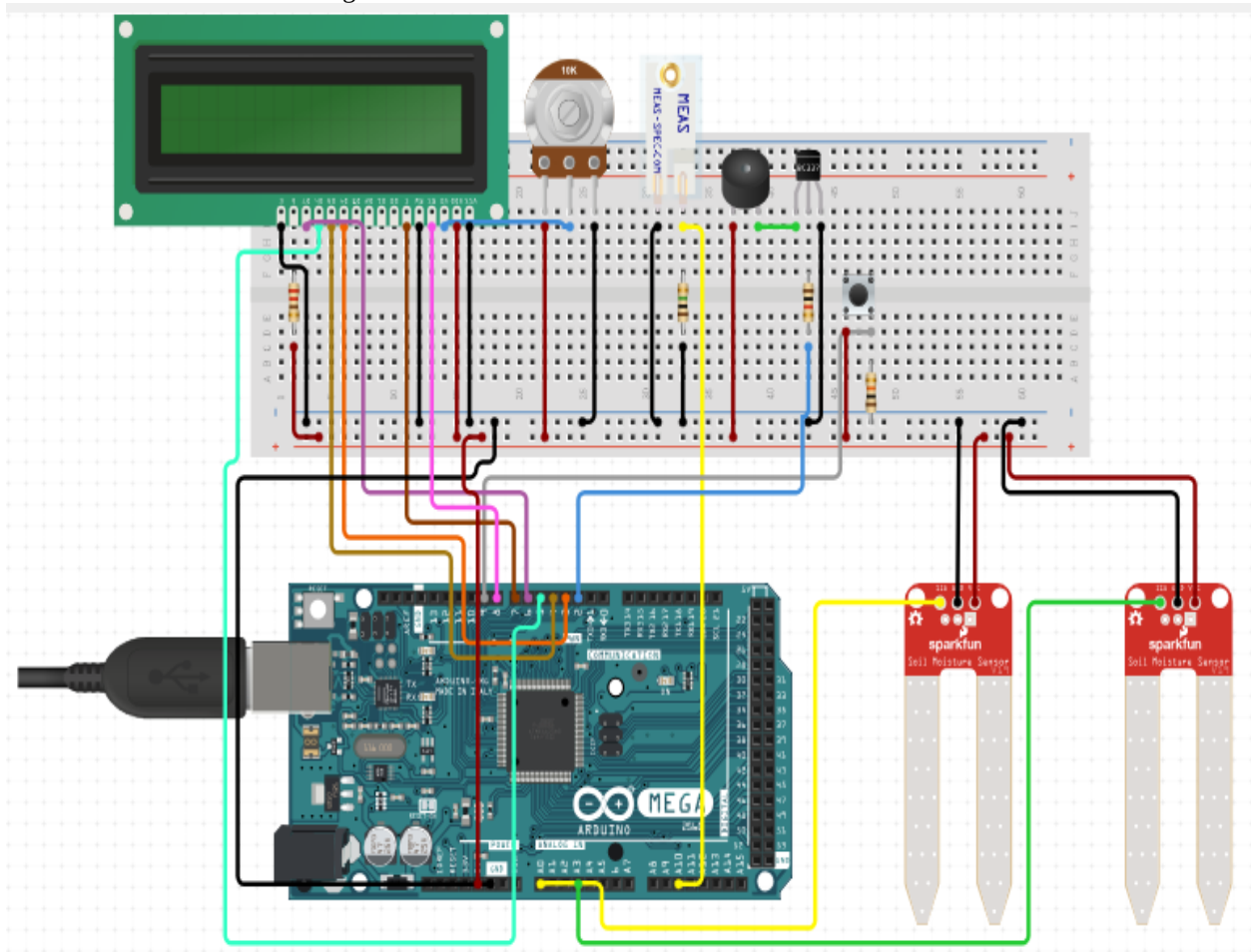


Fig 6: Arduino circuiting with moisture sensor, buzzer and LCD screen.

C. Initial testing for sensor calibration

Since the sensors can be programmed to initiate an alarm at any value programmed and avoid false alarm, a precise calibration is required to initiate an alarm at the most critical point of failure. Thus, a series of tests are conducted in the designed environment. Through the readings obtained with these tests it allows us to study and understand at which moisture value and height of water the slope tends to fail under self-weight.

D. Placement of calibrated sensors

Placement of sensors is the most critical step in setting up the apparatus. As the values of moisture change in all the directions due to increase in pore pressure at different levels in the slope. Thus, each test requires the sensors to be placed precisely at the same location each and every time to ensure proper and reliable data. This also helps to reduce the variations and errors in testing. Two moisture sensors 1 and 2 are utilized for testing which are placed at position 1 and 2 respectively as shown in Fig 5.

E. Test run

Once the programming is completed and sensors are attached, they are then installed in the slope. An initial value of moisture is shown by each sensor, due to presence of water which was added during preparation of soil. Telemetry viewer is then synced with Arduino which provides real-time graphical visualization of sensor data which ease the interpretation of moisture values as shown in Fig 7. Water is then added slowly and the variations of moisture can be observed as water seeps into the slope and recorded by sensors.

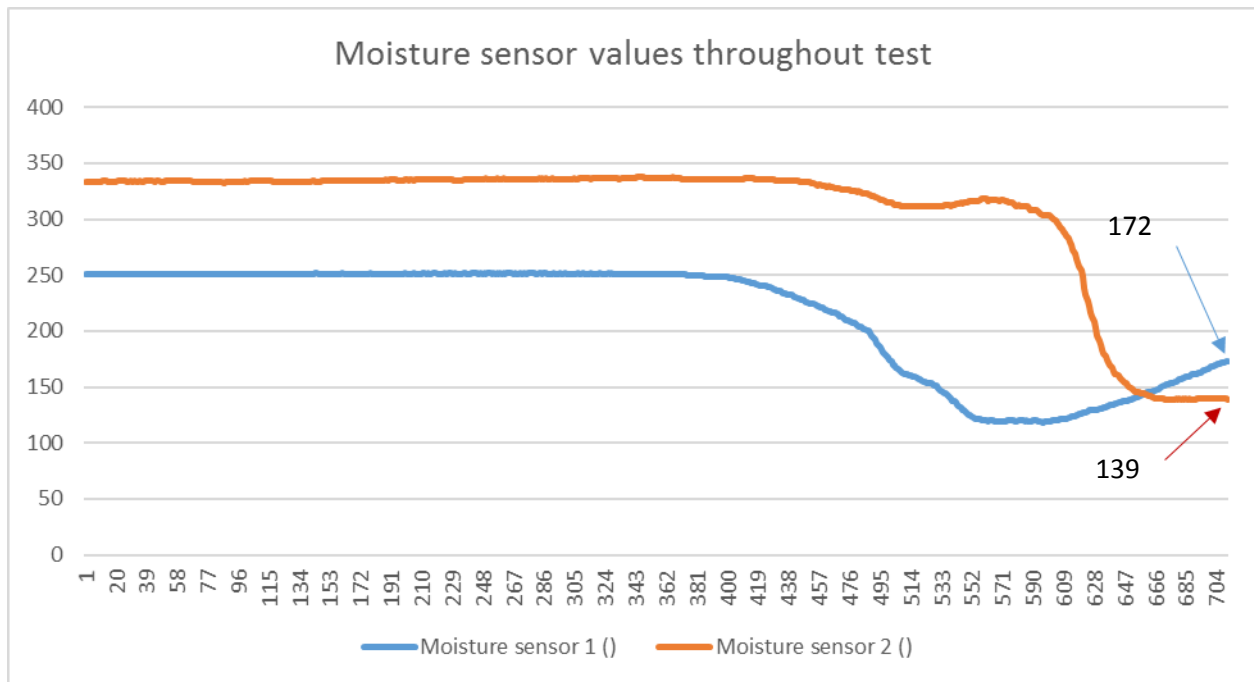


Fig 7: Moisture sensor readings at failure used for calibration.

IV. RESULT

With multiple tests runs, controlled environment and precise calibration. It was possible to predict failure of slope right before it occurs. The values of sensor 1 and sensor 2 were 172 and 139 respectively at the point of failure, i.e. at the moment the slope tends to fail. Thus, the sensors 1 and 2 were calibrated at values 165 and 150 respectively.

The LCD attached displays text such as “Drive Safely”, “Wear your Seat belts”, “Don’t Drink and Drive”, etc. during non-critical point, but as soon as a critical point is reached, the text is changed to “DANGER AHEAD”, “LANDSLIDE AHEAD”, “CAUTION”, etc. Also a buzzer starts to beep at point of failure. Thus, the system was able to perform as expected and predict failure just before it occurs. The time lapse between which alarm is triggered and failure occurs can be easily changed by simply changing the values previously programmed into the sensors.

V. CONCLUSIONS AND LIMITATIONS

Though, it is possible to predict failure to predict in this controlled environment, it becomes very difficult to depict the same in real world. As there are various challenges and variables which get introduced such as unpredictable ground conditions, variations in soil type, cavities, cracks, joints, unconformity, and other geological conditions, and the tough part is, none of them can be controlled or managed or be predicted with precision with today’s technology. But, the fact is, with technological advancement it is possible to develop such a system which is capable of predicting slope failure in real life. Which would save hundreds and thousands of life which are lost at such occurrences.

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