# LANDSLIDE PREDICTION AND EARLY WARNING SYSTEM

Project report submitted in partial fulfillment of the requirement for the

Degree of Bachelor of Technology

in

**Computer Science and Engineering/Information Technology**

By


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to


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# CERTIFICATE

## Candidate's Declaration

I hereby declare that the work presented in this report entitled **" Landslide Prediction and Early Warning System"** in partial fulfillment of the requirements for the award of the degree of **Bachelor of Technology** in **Information Technology** submitted in the department of Computer Science & Engineering and Information Technology, Jaypee University of Information Technology Waknaghat, Solan is an authentic record of my own work carried out over a period from August 2017 to May 2018 under the supervision of **Dr. Vivek Sehgal** (Associate Professor, Department of CSE & IT) and **Dr. Rakesh Bajaj** (Associate Professor, Department of Mathematics).

The matter embodied in the report has not been submitted for the award of any other degree or diploma.

(Student Signature)

**Ayush Jain, 141435**

This is to certify that the above statement made by the candidate is true to the best of my knowledge.

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I also thank our colleagues who have helped me in successful completion of the project.

Date: …../05/2018 Ayush Jain

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# LIST OF ABBREVIATIONS

| Abbreviation | Full Form |
|---|---|
| LMPS | Landslide Monitoring And Prediction System |
| GIS | Geographic Information System |
| IoT | Internet Of Things |
| IDE | Integrated Development Environment |
| OS | Operating System |
| RISC | Reduced Instruction Set Computer |
| NOOBS | New Out Of The Box Software |
| ENIG | Electroless Nickel Immersion Gold |

# LIST OF FIGURES

# ABSTRACT

Landslide is a standout amongst the most incessant characteristic cataclysm and a land risk which happens over and over everywhere throughout the world. It is likewise a standout amongst the most hazardous and abruptly happening regular peril among other common disasters, for example, tremors, violent winds, surges, seaside disintegrations. It is a standout amongst the most deadly cataclysmic event which happens relatively consistently in all the uneven and rocky locales over the world. Mainly happening amid the downpours, it assert gigantic number of lives each year over the world. In India, all the slope areas the nation over are the poor casualty of this regular calamity. The most influenced districts are the Northern region of the nation and the North-Eastern region of the nation on the grounds that for the most part, almost all of these areas are the Himalayan locale of the nation with higher slopes and mountains. In the northern part of the nation Himachal Pradesh is the most and the most exceedingly bad influenced area among all. This district claims immense number of lives each year as the casualty of the hazardous landslides each year principally amid the storms and rainy season and the blustery season amid winters when it rains. The event of an landslide in an area impacts the whole life and environment in the locale making a colossal misfortune to the streets and the railroad arranges in the district separated from the loss of valuable human life.

Because of the harm to the highways and the railroad system of the district, there is a colossal and antagonistic effect on the tourism in the locale. Since tourism is a noteworthy wellspring of monetary development and improvement in the state, negative effect on tourism brings about the colossal budgetary misfortunes separated from the loss of properties in locale. Farming is likewise exceedingly influenced in the area because of the landslides. Horticulture in the state is for the most part either step cultivating or in the valley in the foots of the hills. But when the landslides happen and the tremendous mass of rocks and flotsam and jetsam slips and moves down the slopes and mountains it demolishes everything incorporating crops in the progression cultivating and in addition the developed land at the valley where the whole garbage settles the vast majority of the times. Again, pulverization of agribusiness comes about into enormous budgetary and monetary misfortune since farming being a noteworthy wellspring of financial pay of the area.

Subsequently, anticipating and recognizing the locales and the zones that are powerless and the regions which are vulnerable for the occurrence of an landslide is essential to spare the loss of valuable lives and significant property by taking preventive and prudent steps.

Along these lines, the objective and the primary point of this venture is to devise an landslide expectation display and a comparing steady checking and early cautioning framework to produce an alarm for the approaching threat due a the imminent cataclysmic event of avalanche. With the goal that a legitimate system can be defined to limit the effect of the risky characteristic catastrophe landslide on the general public and the territory in the whole district.

In this undertaking, an exertion has been made to build up a model that can enable us to foresee the event of landslide to a long time before time and furthermore a model that can continually screen the defenseless and vulnerable regions and produce an early cautioning system. This is accomplished with the assistance of physical sensors. Utilizing IOT, a sensor based checking framework demonstrate which can be actualized into an operational landslide observing, forecast and early cautioning at the locales of weakness.

# Chapter - 1

# INTRODUCTION

## 1.1 Introduction

Landslide is a natural geo-hazard which may be defined as the outward and downward movement of huge or small part of a mountain or hill as a response to the force of gravitational pull downwards. It occurs mainly due to the reason that the shear resistance of that part of mountain or hill is exceeded or overcome by the shear stress of that part of mountain resulting in the displacement of that part of mountains forming a slope along with debris mainly due to the excessive moisture content in the soil of that part or the cracks developed overtime due to mining activity in the nearby area or mountains. Apart from these two reasons, there may be other reasons and factors such as various geological, hydrological, topological climate or man induced reasons which may result into the invitation of a landslide. So, more likely we can say that a landslide usually occurs when a mountain slope becomes highly unstable due to various natural and human intervened reasons such as ground water pressure working towards the destabilization of the slope or part of the mountain or hill. Soil erosion is also another important reason behind the landslide as it have direct impact on the binding capacity of the soil. Earthquakes and volcanic eruptions which are itself huge natural geo-hazards and natural calamities are also one of the major reason behind the occurrence of landslide.

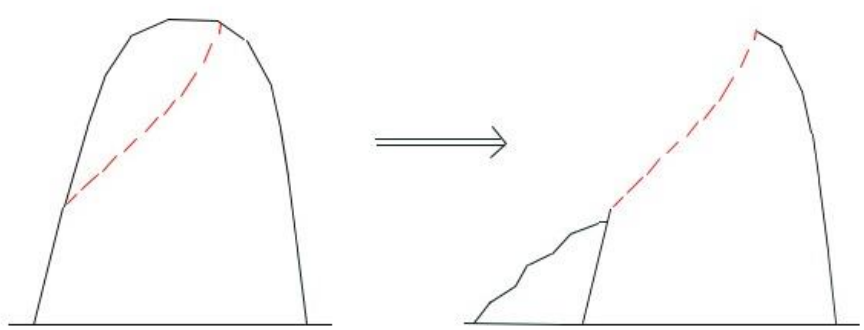

*Fig. 1.1 Depiction of a mountain before and after landslide*

## 1.2 Problem Statement

Landslides are one of the most frequent natural calamity and a geological hazard that happens again and again every year all over the world. It is also one of the most dangerous and suddenly happening natural hazard among other natural disasters such as earthquakes, cyclones, floods, costal errosions. It is one of the most fatal natural disaster which happens almost every year in almost all the hilly and mountaineous regions across the world. Mainly occurring during the rains, it claims huge number of lives every year across the world. In India, almost all the hilly regions across the country are the poor victims of this calamity. The most affected regions are the Northern part of the country and the North-Eastern region of the country because mainly all these regions are the Himalyan region of the country contained with high hills and mountains. In the Northern region, the state of Himachal Pradesh is the most affected and the worst effected part among all the rest. This region has recorded huge and one of the highest number of lives every year mainly during the monsoons and also during the heavy rains occurring during the season of winters. The occurance of a landslide in the effected parts impacts the entire life and habitat in that region which also results into heavy losses to the roads, the railways and the entire transportation system of the region leaving aside the loss of precious lives of the humans living in that area.

Due to the damage to the roads and the railways which constitutes major part of transportation network of the area, there is a huge and negative impact on the tourism in the area. Due to the fact that tourism is a major source of economic growth and development in the region, adverse effect on tourism industry flourishing in the area result in the heavy financial losses apart from the losses to the properties in the area. Agriculture and farming is also highly effected in the region due to the natural hazardous landslides. Agriculture in the region is mostly either step-farming or in the valley in the lower area of the mountains. But when the landslide occur and the big parts of the rocks and debris slips and rolls down the hills and mountains it destroys everything including crops in the step farming as well as the harvested land at the valley where the entire debris settles. Again, destruction of farming results to heavy financial losses and economic downfall being a major source of income of the area.

## 1.3 Objective

Prior prediction and identifying the regions and the areas that are vulnerable and the areas that are highly probable of a landslide occurance is important to save the loss of the precious lives and valuable property by taking preventive and precautionary measures.

So, the objective i.e. the major goal and main aim of this project is to devise a landslide prediction model and a corresponding constant monitoring and early warning system to generate an alert for the impending danger due to the forthcoming natural disaster of landslide so that a proper strategy can be formulated to minimize the impact of the hazardous natural calamity – landslide on the society and the habitat in the entire area.

## 1.4 Methodology

In this project, an effort has been made to develop a model that can help us to predict the occurance of a landslide well before time and also a model that can constantly monitor the vulnerable and susceptible areas and generate a warning well on time. This is achieved with the aid of physical sensors. Implementing IoT, a sensor based monitoring system model which can be implemented into an operational landslide monitoring, prediction and early warning at the sites of vulnerability and danger.

In this project, the model designed and implemented is mainly using IoT. The sensors primarily used in this project are - the soil moisture sensor and the ultrasonic sensors. Just due to the reason that this is merely a model and not an actual implementation of the methodology used in this project, we have used ultrasonic sensors to make the model more economical and less costly. In actual scenario, the ultrasonic sensors may be replaced by proximity sensor or to obtain a more actual and accurate result, strain gauge may be used.

The entire model that is built in this project utilizing IoT is based on the analogy that the occurance of a landslide is most of the times during the seasons of rain where the mountains and the hills are majorly consisting soil as one of its contents of formation. The second major finding taken into consideration during the building of this project is that landslides also occur frequently at or nearby the places where some type of mining activity is being prevailed. For e.g. mining for minerals like limestone which are found in abundance in several parts of the state of Himachal Pradesh also referred to as ”the hilly state”.

Also taking into consideration, the study of previous works done in this field suggests that the happening of a landslide is not an instantaneous event but an outcome of a gradual process taking place for quite some time as long as about two years with an exception to the occurance of a landslide as a tailing effect of an earthquake in the mountaineous and hilly areas.

Occurance of landslide happens most of the times due to the rains. This is because the soil in that part of mountain gets excessively wet and starts flowing down in the form of a debris. This is because soil have a certain limit of binding capacity and also a limit upto which it can absorb and hold water after which it starts setting itself loose and develops a tendency to flow down as debris. But this moisture retaining capacity of the soil or the water retaining capacity of the soil changes with the change in soil and tropographical area. So, there is no fixed threshold of the binding capacity of the soil and no constantly fixed threshold of the moisture retaining capacity of the soil. Due to this, the threshold value has top be found using experimental results of the soil of that area. This is done using soil moisture sensors. Soil moisture sensors are installed in that area to keep a constant check on the moisture content of the soil.

Also, landslides occurs in the Rocky Mountains and rocky hills but again it is not an instantaneous event but a result of the cracks developed over a long period of time. The development of these cracks can be detected well on time to generate an early warning of the impending danger be installing sensors that can detect the widening of the distance between two points of the same mountain. In our model we have used ultrasonic sensors but in actual scenario, strain gauge is more preferred.

The two different types of sensors that are discussed above are not installed separately but a sensor strip is made on which both types of sensors are put and then these sensor strips are installed at the sites of vulnerability.

## 1.5 Organization

### 1.5.1 Arduino IDE

Arduino IDE is basically a customized environment for the building and development of projects utilizing Arduino circuit boards. It consists of a text editor which is used to write the codes. It also contains a separate area for messages called as – “message area”. There is also a toolbar which contains clickable buttons for some simple and prevalent functions and a list of menu and a text console. It is basically used to connect the Arduino hardware to help uploading the programs and then communicating with them.

The programs that are written utilizing the Arduino IDE are usually known as “sketches”. We write these sketches into the text editor discussed above and then save these programs (now being called as “sketches”) with a file extension – “.ino”. The editor contains various functionalities that allows us to cut and paste the text and also provides the facility to search or replace the text. The feedback is displayed in the message area which is given during the time we save and export. The message area also show the errors.

The console displays text output by the Arduino Software (IDE), including complete error messages and other information. The bottom right-hand corner of the window displays the configured board and serial port. The toolbar buttons allow you to verify and upload programs, create, open, and save sketches, and open the serial monitor.

### 1.5.2 Embedded C for Arduino

Arduino IDE (Integrated development Environment) is absolutely furnished with usefulness of an immense and parts numerous number of libraries, and as that of programming and composing the code for the equipment – "Arduino UNO", Embedded C dialect is utilized as a part of this task due to the reason that Arduino IDE is productive and fit for incorporating the "Arduino code" and furthermore the "AVR standard code".

Due to the reason that a large portion of the codes that are composed in "Embedded C" are open-source and the running and execution of these codes on the Arduino is likewise simple and proficient, so the every one of the codes identified with the "Arduino UNO" utilized as a part of this task are composed in "Embedded C".

The codes that are composed to take the contribution from the sensors – "Soil Moisture Sensor" and "Ultrasonic Sensors" and to give the coveted yield are altogether composed in "Embedded C".

### 1.5.3 Python 3.6 Programming Language:

Python 3.6 is the most up to date significant arrival of the Python programming language, and it contains numerous new highlights. It is utilized in this venture or project to compose the code to create an email warning of the early caution of the approaching peril of Landslides.

# Chapter – 2

# LITERATURE SURVEY

In [1], a distributed sensor system has been designed and implemented with the sole aim and only goal to predict landslides in the hilly and mountainous regions of western India. The occurrence of landslides in this region is mainly due to heavy rainfall during monsoon rainy season and rains during the winter season which results into significant damage to precious human lives and valuable property. At present there are some existing solutions which can detect the occurrence of landslides in this region but in this system - senslide, the major aim is to predict the occurrence of this dangerous natural hazard. Instead of using a lesser number of sensors but costly sensors, the model proposed and implemented in the senslide system utilizes a huge number of cheaper sensor nodes that are connected to each other via a wireless network. The software designed in this system is in such a way that in an event of sensor failure or system failure, the less costly and inexpensive components may encompass. The senslide system is implemented and test in the laboratory environment using sensors on a testbed. The results obtained from this test trial on the testbed are motivating enough to setup a simulation model with 400 sensors on the testbed. Again, the results were encouraging enough to implement a real time field test of this system during the rainy season in that region.

Landslides are mainly occurred due to increasing strain because of rain that filters through the porous surface of the rocks gradually in the rock fissures in the highly rocky region of the Konkan coastal hillsides. This causes fractures in the rocks and due to the cracks developed, the rock mass becomes vulnerable and there is an increased probability that the rock may slide down the slope. The present solution are majorly related to landslides detection and not the prior prediction of the hazard before its occurance. In the earlier solutions to the problem to detect this natural calamity, a trip wire is setup across the side of the railway track adjacent to the hills in all the landslides prone areas of the region. And in the event of occurrence of a landslide, the trip wire breaks as the rocks and debris falls on the wire breaking it and as a result triggering an alarm. Of Course, this is a very economical and low cost solution method but it is ineffective to predict the impending danger due to forthcoming landslide and provide an early warning which could at least save valuable lives if not the immovable property. A better and more efficient alternative is using sensors that predict landslides before their occurence.

Giving adequate cautioning time before the approaching landslide permits taking careful steps, limiting the harm caused by the landslide. The careful steps could run from land fortifying of the rough surface, covering the slope with a work to keep the stones from falling, clearing individuals, ceasing trains, and so forth. Typical sensors utilized for checking incline steadiness are multi-point borehole extensomters, tilt sensors, displacement sensors, and volumetric soil water content sensors. These require penetrating 20-30 meter gaps into the surface, and requiring talented work. Besides, a portion of these are costly sensors, making wide scale arrangement infeasible. Introducing a solitary sensor for checking a whole slope side isn't adequate as the properties of the stones change each 100-200 meters. Rather than existing settled single-point approaches, an in a general sense new way to deal with measure incline strength is by consolidating perceptions from an expansive number of disseminated reasonable sensors. Senslide utilizes a variety of reasonable single-hub strain measures associated with shabby hubs. The utilized sensors make point estimations at different parts of a stone, yet make no endeavor at estimating the relative movement between rocks. The system depends on the straightforward perception that stone slides happen in view of expanded strain in the stones. Hence, by estimating the reason for the landslide, one can foresee landslides as effortlessly as though we were estimating the early relative development of rocks. Geologists comfortable with our territory appraise that sensors can be isolated by 30– 40 meters. This would suggest that around 600– 900 sensors are required for each square kilometer of slope encompassing the railroad track. This accumulation of sensors is known as a sensor patch, which is our essential unit of scale. The sensor patch contains just an unassuming number of sensors that we can sensibly anticipate that our answers will work at this scale. However, the patch is sufficiently expansive that we can copy it helpfully to cover the extends of the railroad track that are most inclined to landslides. In the present plan, each patch is free of different patches; for every down to earth reason this seems, by all accounts, to be a sensible supposition. The point estimations made by singular sensors are engendered to an arrangement of "base stations" that have GPRS as well as 802.11 network connections to each other. Notwithstanding their enhanced system network, base stations are situated in places with access to ground control, and have more calculation and capacity assets than the sensor hubs. Every sensor patch has 3–

6 base stations, both for expanded adaptation to non-critical failure also to limit bounce tally between sensor hubs and base stations. There are a few favorable circumstances to utilizing basic strain sensors. The strain sensors can work at low profundities (25– 30cms); the requests of size lower profundity of task influence strain to measure arrangement significantly less expensive and more advantageous without particular hardware or an advanced work constrain. The little size, minimal effort, and remote network permit denser scope over a bigger territory without fundamentally expanding the trouble or the cost of implementation.

A potential issue with utilizing little, modest sensors is that failure will probably happen and system programming needs to remunerate to keep the system practical. Correspondingly, the bigger number of sensors suggests that the system programming must be adaptable. It is likewise trusted that as sensor systems turn out to be all the more generally sent in brutal conditions where disappointment is normal, and power and system availability is inconsistent, our outline methods will turn out to be progressively more relevant. As far as anyone is concerned, however there have been sensor organize frameworks conveyed in unfriendly situations (e.g., volcano monitoring), normally these frameworks have not concentrated on adaptation to internal failure or adaptability. Subsequently, they can experience the ill effects of system blackouts and low information yield because of the disappointment of framework parts. In attempting to outline a framework to fathom the requirements of our application, we experienced a few difficulties, which we quickly identify beneath. We utilize appropriated frameworks calculations and in addition strategies from machine figuring out how to give answers for these difficulties. The blend of these arrangements makes our plan one of a kind, which guarantees adaptation to internal failure at each level of the framework and expands the lifetime of the framework.

**1. Noisy sensor data:** Generating an alarm established on sectionally specimened unprocessed sensor data would head towards a huge count of untrue positives and negatives. Therefore, the sensor signal should be stabilized before further processing.

**2. Fault Tolerance:** The system is not supposed to be consisting of single points of failure, and ought to consequently adjust to nodes, base station failures and communication links.

**3. Spatial summary of sensor data:** Despite the fact that information from each sensors is smoothed, single sensor reading values are inadequate to anticipate a landslide; information from a few spatially distributed sensors must be consolidated to recognize peculiarities demonstrative of a landslide. Without due care, such joining of information could prompt unreasonable communication.

**4. Uneven energy dissipation in the network:** The protocol utilized to route the packets from the each sensor hub to base station ought to dodge the arrangement of hotspots in the network. Hot-spots heads towards uneven power dissipation at few hubs because of the raised power necessity for sending and receiving packets. Nodes which are power dissipated may result into network segregation.

**5. Equity amid rare event detection and periodic data collection:** Landslides are almost occasional accidents. Hence, one would most likely preserve energy and at no time send data uptil a landslide is embryonic. This saves life of the power source in the network, but tha might head towards a huge count of inaccurate and untrue alerts and also beat the aim of gathering the seismic data timely.

**Gathering Rock Information:** The essential rock properties we think of is the stress-strain conduct. The sort of rocks that are present in the Konkan locale of India are delegated volcanic molten, which are a kind of "fragile" rock. The stress-strain bends of molten rocks show direct conduct until there is a distortion. This close perfect conduct makes the landscape especially appropriate to the proposed procedure. Shockingly, not every single molten rocks of a similar sort have a similar stress-strain conduct. Singular varieties in the crystalline structure and in addition plainly visible variety in synthetic organization and physical attributes prompt recognizable contrasts in their conduct to stress.

**Prediction Algorithms:** In the most straightforward case, if the base station has strain values from all the sensor hubs, it can without much of a stretch foresee if a landslide is probably going to happen.

**Threshold Based Prediction:** In this plan, the base station gets strain readings from every one of the hubs. It utilizes the normal stress-strain graph to estimate the pressure on each point in the rock. It at that point calculates the mean pressure and contrasts it and the pressure that is known to cause a rock breakage. In the event that the figured normal is over a specific threshold, it forecasts a landslide. Practically, it is unrealistic to expect that the base station gets readings from all hubs.

In [2], the real spotlight is again laid on the occurance of the landslides because of the precipitation in the monsoon season. Higher dangers of landslides in the Indian sub-landmass and particularly in the Himalyan locale are talked about. Topographical information administration and spread for relief exercises in case of such calamities can be dealt with adequately utilizing GIS innovation and physical sensors. With parallel computing power accessible, models can be controlled by shifting parameters to reproduce diverse landslides situations. Application to the entire provincial region over a dense computational grid can go for the improvement of an ongoing framework to create landslides hazard situations in view of forerunner information. The proposed Landslide Monitoring and Prediction System (LMPS) depends on the standards of landslides material science and thus a sensor-based checking of the antecedent factors will prompt an operational landslides observing and expectation framework, consolidating the qualities of mathematical modeling and GIS.

Primarily, the landslide scenario of Sikkim is taken into consideration. Physical models depend on numerical administrators (also considering the empirical methods), which mull over some physical parameters, such as soil thickness, pore weight, and so on. They figure parameters like leftover strength and shear on the soil layers. Different observational strategies have been attempted and tried by researchers for different areas around the globe, yet a framework for India requests for one of a kind prerequisites regarding rise information accessibility, security concerns, propelled mapping and monitoring tools, network facilities to send documented information, and so forth. With parallel computing power accessible, models can be controlled by shifting parameters to mimic diverse landslide situations. This will be helpful to understand the landslide antecedents, important parameter readings and make mindfulness among those living on these susceptible areas.

For solving the purpose, a three dimension model can be utilized that backs on the stability of the slope. In this model, there are various different parameters such as angle of the slope, strength of the soil, depth of the soil, Factors like slope angle, soil depth, soil strength, the depth at which ground water is obtained etc. are taken into consideration. The "degree of landslide" is asserted as the "factor of safety F". This "factor of safety" is "ratio of the forces that prevent a slope from failing over those that try to make a slope fail".

**"Factor of Safety (F) = Resisting Force / Driving Force"**

The experimental landslide model is measured to show the conduct of pilot study area. The general landslide model performs on the equity in the criteria defining the weight of the piece of hill or the mountain and the force of resistance which is opposing and counteracting to the force of gravity. When the water due to the rain in the region oozes in the soil or the pores of the rock, it occupies the space in the vacant minute holes and as a consequence, there is an "increase in pore-pressure" that is measured by the "Pore Water Pressure Sensor". A considerable and constant rise in the pressure of water in the pore-holes is normally measured well before a landslide occurs. These readings must be correlated with the reading obtained from the strain gauge to find the creation of "slip surface". The "slip surface" is defined using the values obtained from the strain gauge.

Moreover, "GIS-based modeling techniques" could be implemented for generating a "physically-based system" that has the capability to enhance the performance of the system in all aspects. Parameters such as the amount of the rain fallen in the region, content of moisture in soil and various properties of the slopes are taken into consideration. A linear relation can be drawn in the condition of the moisture in the soil and the threshold value of the rainfall that have to be derived from the data which is obtained from the satellite.

In the system proposed, a specimen part of the region is chosen on the basis of the details such as the aspect area, longitude, latitude and other important properties of that area. There are various other factors that tells a lot more in details about the rocks in the considered area or the region such as the altitude of the region and the weather prevailing in the region also conveys a details about the methods of utilization of the land which is considerably significant information, the sub-surface properties of the rock can be determined by the area's geology. Historical information of the previous landslides that occured in the region also are of great use in predict any future calamity or disaster. Good quality images obtained from the satalite also helps in implementing a "monitoring and early warning system".

In [3], the event of landslide is administered by different climatic and spatial components, for example, hydrogeological conditions, geography, geology, cultivation, and precipitation. It makes landslide vulnerability evaluation troublesome, on the grounds that differing and a lot of spatial information must be obtained from the local territory and considered in the examination system.

The evaluation of the vulnerability of a landslide is largely dependent on various features and the analysis of the "spatial distribution" of the considered features. Amongst all the methods used for the evaluation of the vulnerability of the landslides, these methods utilized for the assessment and evaluation can be defined and differentiated from the other method as data driven methods which is based on physical methods and is quantitative in nature or as knowledge driven method which is qualitative in nature.

In [4], the vulnerability of the occurance of a landslide in the susceptible regions of Sri Lanka are discussed. Koslanda being the most susceptible and vulnerable area in the country is taken into consideration. Efforts are made to produce a model that can predict the occurance of a landslide utilizing "bivariate and multivariate statistical analysis". Again, the basic information such as "topographical, hydrological, land cover and various soil factors" of the vulnerable area are taken into consideration. The level of prediction is differentiated and classified into four levels namely, “very low, low, moderate and high".

In the methodolgy used in this model, "hydrological, topographical, geological and soil" are the major properties and features which are taken into account. These factors are evaluated on the basis of certain parameters. Topological factor is assessed on the values of the evaluation, aspect and slope. Soil is evaluated on the basis of its "topological wetness index" and "soil moisture index". Hydrological factor is dependent on the distance of the susceptible region to the water bodies.

In [6], an early warning system is set up for the landslides in the susceptible regions of Italy that occur due to the rainfall in the region. The entire system is setup on the factors such as the threshold for the time duration of the rainfall, real-time data about the rainfall obtained from an automated network of rain gauges that are installed in the region. Also, the data regarding the forecast of the rainfall collected from the local system. The system is established in a "WebGIS" to make it easier to use and obtain results from it. The system is capable of forecasting the data from about 48 hours of the future as well as monitor the real-time data of the present.

In [11], generation and the concepts of building a early warning system for the management of natural and environmental crisis is discussed. At present times, any early warning system is an application and implementation of a data driven IoT system. So, the concept of IoT can also be utilized and implemented for natural disaster prediction and generating an early alert for it. In this, easier sensors are used and the data which is analyzed is more of a dynamic meta-data. Efforts are made to practically deploy a "semantic early warning system" which is necessary for the exchange of a scalable and time sensitive data. The designed model is an IoT based early warning system established on the multisemantic model of representation. Both heavyweight semantics and lightweight semantics are used for the model. Heavyweight semantics are utilized for the top level web related models which describes the workflow orchestration, a decision support system that is driven on semantics and multilevel knowledge related to it.

# Chapter - 3

# SYSTEM DEVELOPMENT

## 3.1 Hardware and Software Components

There are various important hardware component as well as software constituents which had been used to develop this project. Following are the various hardware and software components of the model developed for this project:

1. Raspberry Pi
2. Arduino UNO
3. Raspbian OS
4. Soil Moisture Sensor
5. Ultrasonic Sensor

### 3.1.1 Raspberry Pi

The Raspberry Pi is a debit card-sized computing device primarily devised for education and research. A Raspberry Pi is a very little and a low-cost affordable computer that can be availed to imbibe programming using pleasant, practicable projects. It was primarily designed with a goal to make a inexpensive and affordable gadget and device that would upgrade coding skills and hardware knowledge at the pre-university level. Due to its meager size and accessible valuation of cost, it was quickly accepted by tinkerers, manufacturers, and electronics fanatics for projects that require more than a primitive and principal microcontroller such as Arduino devices.

The Raspberry Pi is lackadaisical than a contemporary present-day laptop and desktop but is still a outright Linux computer and can contribute all the expected conventional capabilities that works at a low-power dissipation level. The Raspberry Pi is open hardware, with the exclusion of the elementary chip on the Raspberry Pi, the Broadcomm System on a Chip, that runs many of the prime segments of the board–CPU, graphics, memory, the USB controller, etc. A lot of the projects made with a Raspberry Pi are open and well-documented as well and are things you can frame, constitute, produce, revise and transmute on your own.

The Raspberry Pi was devised for the Linux operating system, and a lots many operating systems based on Linux are now having a variant improved and enhanced for the Raspberry Pi. Two of the most trendy and prominent choices are - Pidora which is established on the operating system Fedora and Raspbian which is established on the operating system Debian. For newcomers, either of these two work really good. Also, which one amongst the two, one prefers to use is just a matter of secluded choice. A better habitude might be to select and opt for the one which most intently relates and corresponds to an operating system that one is acquainted with, in either a server or laptop.

If you would like to try and have a hands on experience with more than one Linux operating systems and are not sure about the one you want, or you just desires to have an easier acquaintance in a situation where something erroneous happens, try NOOBS, which is an acronym for New Out Of Box Software. When one boots for the first time from the SD card, one will be given a list from which the person could choose one among multiple distributions counting in Pidora and Raspbian. If the person decides to give a try to a particular one, or if something erroneous happens with the system, one could ingenuously press the Shift key for booting to go back to the menu and start fresh again. There are for sure, a lot of other options to choose from. RaspBMC and OpenELEC are two good operating system distributions that are established on Linux and both of them are aimed towards utilizing the Raspberry Pi like a center of media. Also, there are some systems which do not run on linux such as RISC OS, that runs on the Pi. Some fanatic geeks have even used the Raspberry Pi to master on the operating systems by developing their own.

Raspberry Pi is not the only cramped and modest computing gadget out there. In fact, there are many more options present than one could think of and list up. Some of the options have been considered and evaluated before but there are some of the others that one may not be knowing of before. An Arduino is one other connoisseur board, that is equipped and aimed for those desiring to design and build IoT based projects. But, because the Raspberry Pi is a totally working computer based on Linux, the Arduino is just a microcontroller. Hence, it implies that Arduino does not helps functioning an operating system, and instead, executes very particular, small chunks of program coded by the developer or programmer using the device. There are various add-on boards that give it a lot more potential but apart from it, it is not much ready to use than a Raspberry Pi. Other choice is the Beaglebone boards series that are much alike to the Raspberry Pi but somewhat more dominant and potent, and also somewhat more costlier. One of the benefits of using the Raspberry Pi on some of its other substitutes is the strength of the community. In case a person has a query related to a project he/she is working upon, there are lots of people in the community who may be willing to lend an aide to the person and able to do so due to the huge availability of the community.

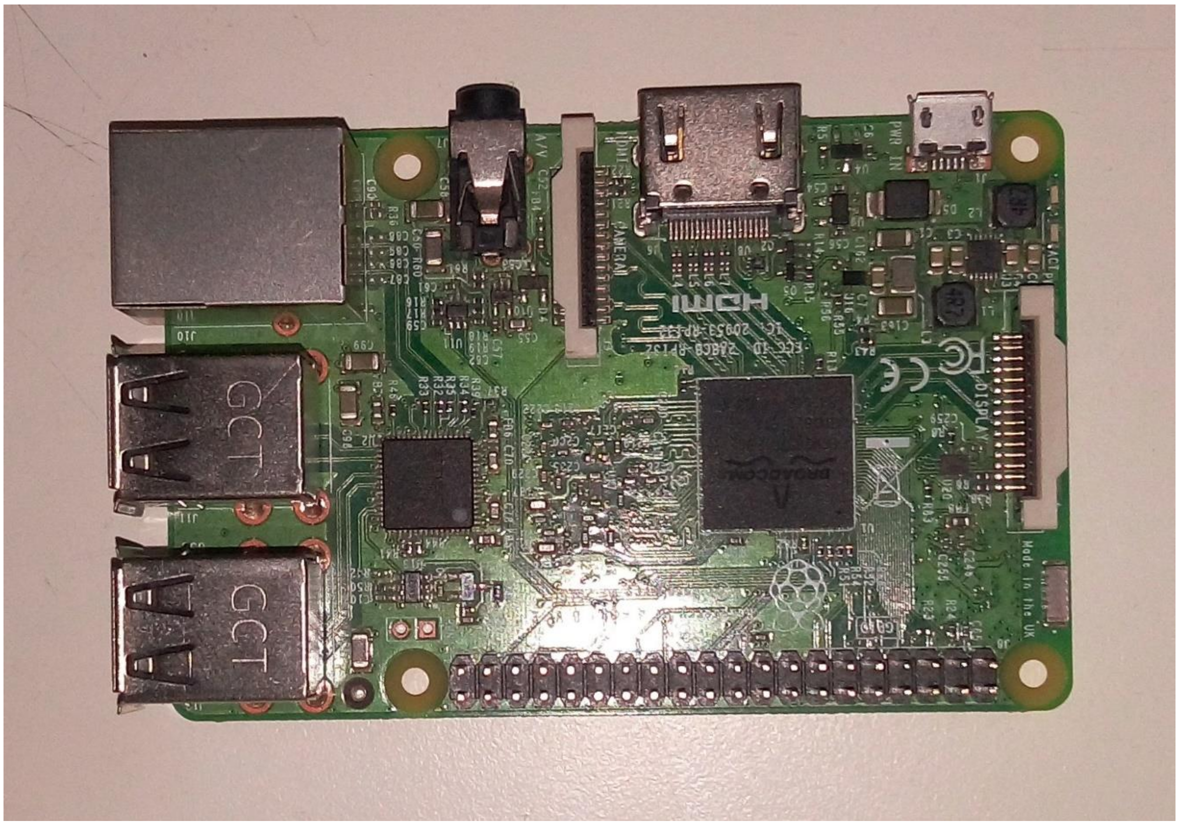

*Fig. 3.1 Raspberry Pi*

### 3.1.2 Arduino Uno

An Arduino Uno R3 is a hardware device board - microcontroller which is based on a detachable and double inline package (DIP) ATmega328 AVR microcontroller. It contains a total of 20 digital input/output pins of which 6 pins are utilized for PWM outputs and other 6 pins are used for taking analog inputs. Out of the total 20 pins for the purpose of input and output, 14 pins are for digital input or output usage further out of which 6 are used for obtaining PWM outputs and 6 of the pins are utilized for taking analog inputs. It also contains an oscillator that is made up of 16 MHz crystal, a port to make USB connections, a power jack, a button for reset, and an in-circuit system programming abbreviated as ICSP header. All the programs can be loaded on to the board from the easily usable program for Arduino computing gadget. The Arduino has an pervasive backing online associations and forums, which makes it a really effortless means to get started working on embedded electronics. The R3 is the third and the most recent version of the Arduino Uno.

Arduino Uno is equipped with all the things required to assist and aid the microcontroller; planely connect it with a computer or most suitable wall power adapter with a USB cord or provide it power with a AC-to-DC adapter or a power source such as battery to start it.

The Uno different and unique from all previous boards that it does not utilize the FTDI USB-to-serial driver chip. Instead, it countenance an ATmega16U2 coded as a USB-to-serial converter. This ancillary microcontroller contains its personal USB bootloader, that allows further level users to program it again as per the changing needs and requirements.

The Arduino accomplishes the possibility to develop a lots many enjoyable elementary prototypes of projects in IoT.

*Fig. 3.2 Arduino UNO*

### 3.1.3 Raspbian

Raspbian is an open-source operating system. It can be easily downloaded and used freely because it is the one which is officially available at free of cost at the official website. It is a system which is established on Linux platform - Debian and is developed to enhance the working capability on the computing and processing gadget - Raspberry Pi. As everyone knows that an operating system is the most basic and rudimentary set of code and functionalities that allows us to use the hardware more efficiently and easily and in this case, the hardware is Raspberry Pi. Raspbian is not just purely an operating system but much more than a proper operating system. Debian is a very lightweight operating system and it is the best option for Raspberry Pi. The Raspbian contains all armours to surf and browse easily, compile the codes written in python programming language and also provides a Graphical User Interface for the hardware desktop or laptop.

The Raspbian operating system provides a computing and processing desktop environment that is also known popularly by the phrase "Lightweight X11 Desktop Environment" and is abbreviated as LXDE. It contains a very alluring and interactive user interface which is developed by utilizing the software - X Window System and also it is a very familiar and popular interface with point and click.

Raspbian is fully armed and equipped with more than 35,000 packages and bundles of the softwares that are pre-compiled in a very neat and good format that makes possible the installation of Raspbian operating system on the hardware gadget - Raspberry Pi very easy.
Because of the reason that the initially developed module of Raspbian consists of more than 35,000 Raspbian packages, it makes it possible to achieve best performance on the hardware - Raspberry Pi. Raspbian being a software and a operating system is even at present under development to further improve the stability and increase the performance of as many as possible packages of Debian.

### 3.1.4 Soil Moisture Sensor

The Soil Moisture Sensor is a sensor or an electronic gadget that is utilized to gauge the substance of water volumetrically in the dirt or soil like issue. The Soil Moisture Sensor utilizes capacitance to gauge the water substance of soil (by estimating the dielectric permittivity of the dirt, which is a component of the water content). Basically embed this tough sensor into the dirt to be tried, and the volumetric water substance of the dirt is accounted for in percent. Soil Moisture Sensor is a basic breakout for estimating the dampness in soil and comparative materials. The soil dampness sensor is truly direct to utilize. The two huge uncovered cushions work as tests for the sensor, together going about as a variable resistor. The more water that is in the dirt means the better the conductivity between the cushions will be and will bring about a lower protection, and a higher SIG out.

To get the Soil Moisture Sensor working all you will require is to associate the VCC and GND pins to your Arduino-based gadget (or perfect advancement board) and you will get a SIG out which will rely upon the measure of water in the dirt. 0ne normally known issue with soil dampness sensors is their short Iifespan when presented to a soggy situation. To battle this, there is a PCB covered in Gold Finishing (ENIG or ElectroIess NickeI ImmersionnGoId). We prescribe either a basic 3-stick screw stick terminal or a 3-stick jumper wire get together to be fastened onto the sensor for simple wiring.

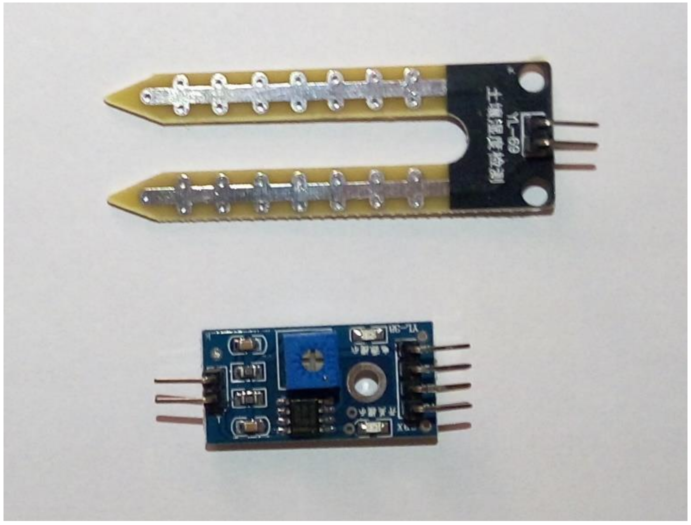

*Fig. 3.3 Soil Moisture Sensor*

### 3.1.5 Ultrasonic sensor

An Ultrasonic sensor is a device that can measure the distance to an object by using sound waves. It is measuring the distance by the simple technique of sending out the wave of sound at some very specific frequency and then listening to that sound wave for being bounced back. By recording the elapsed time between the sound wave being generated and the sound wave bouncing back, it is possible to calculate the distance between the object and the sonar sensor.

An optical sensor has a transmitter and receiver, on the contrary an ultrasonic sensor used a single ultrasonic element for both reception and emission. In the reflective model ultrasonic sensor, the single oscillator is emiting and receiving ultrasonic waves alternately. This enables miniaturization of the sensor head. In our project, due to the unavailability of strain gauge and due of lack of actual environment, the ultrasonic sensor is used as a replacement or as an alternative for strain gauge to detect the movement of soil mass.

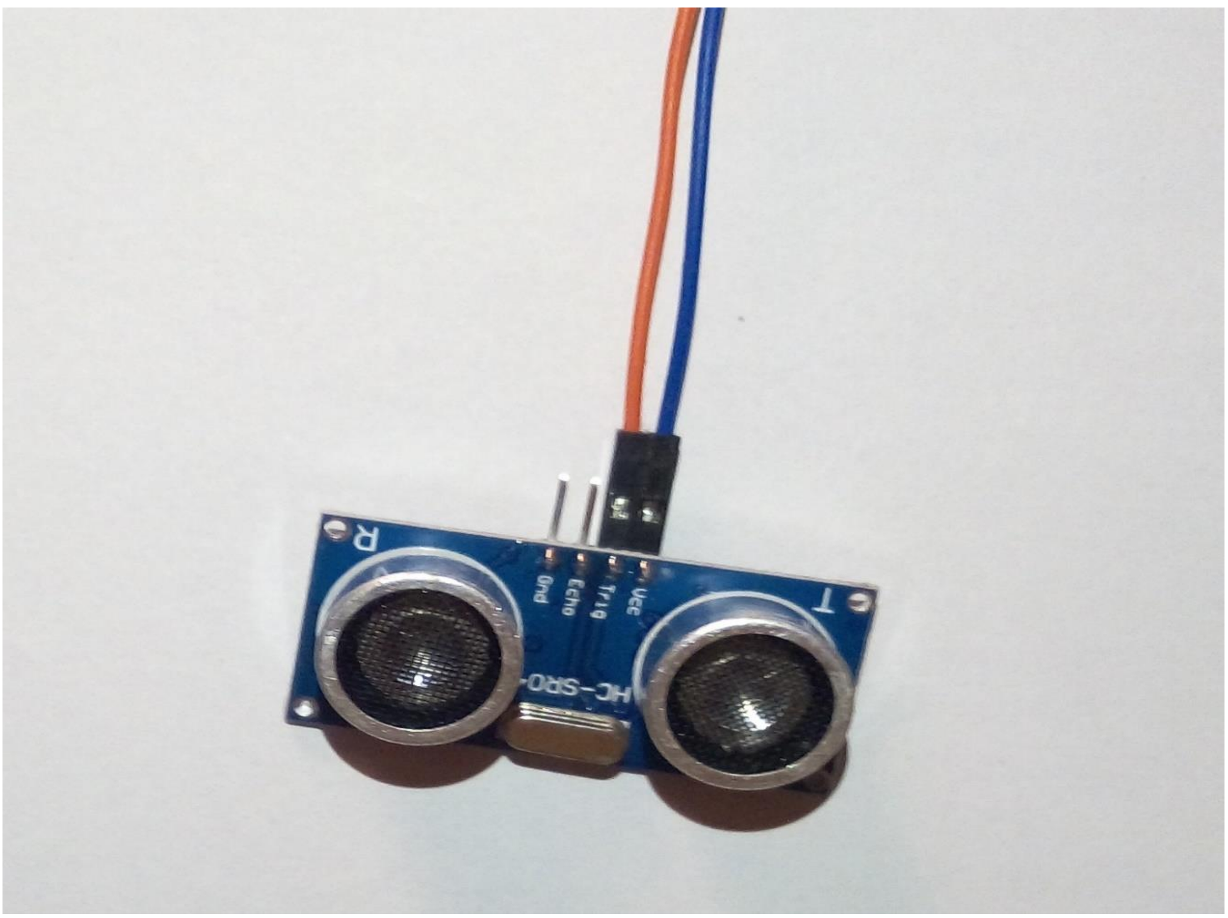


*Fig. 3.4 Ultrasonic Sensor*

### 3.1.6 Strain Gauge

A Strain measure additionally here and there called as a Strain gage as its other name. It is a sensor in which the protection is constantly shifted with connected power. What it does is that "it converts tension, force, weight, pressure, etc., into a change in electrical resistance" which is then estimated. At the point when outside powers are connected to a stationary question, anxiety are the outcome. Stress is characterized as the question's inward opposing powers, and strain is characterized as the relocation and disfigurement that happen.

The strain gauge is a standout amongst the most vital sensor of the electrical estimation strategy connected to the estimation of mechanical amounts. As their name shows, they are utilized for the estimation of strain. As a specialized term "strain" comprises of tractable and compressive strain, recognized by a positive or negative sign. Thus, strain measures can be utilized to get extension and additionally constriction. The strain of a body is constantly caused by an outer impact or an interior impact. Strain may be caused by powers, weights, minutes, warm, auxiliary changes of the material and so forth. On the off chance that specific conditions are satisfied, the sum or the estimation of the impacting amount can be gotten from the deliberate strain esteem. In test pressure examination this component is broadly utilized. Test pressure examination utilizes the strain esteems estimated on the surface of an example, or basic part, to express the worry in the material and furthermore to anticipate its wellbeing and perseverance. Unique transducers can be intended for the estimation of powers or other inferred amounts, e.g., minutes, weights, increasing velocities, relocations, vibrations and others. The transducer for the most part contains a weight delicate stomach with strain checks clung to it.

### 3.2 System Architecture

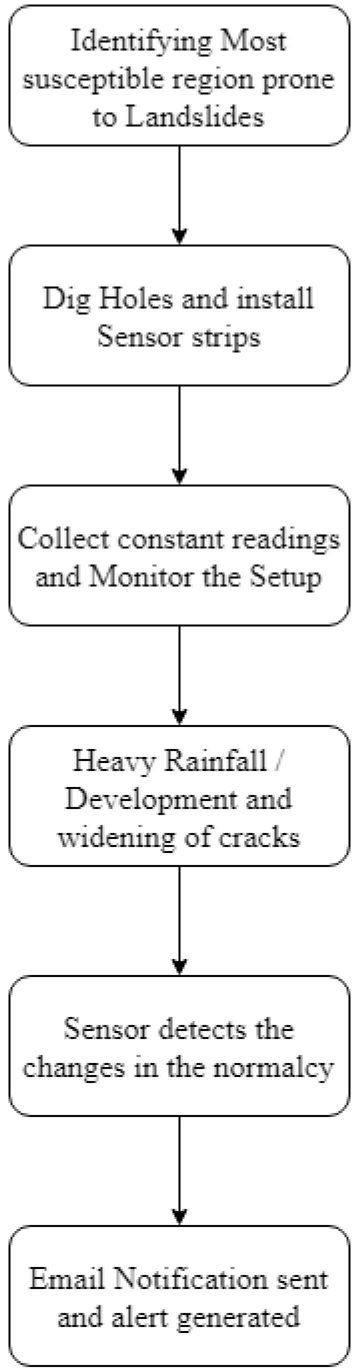


*Fig. 3.5 System Architecture*

In the project the basic concept used on the basis of the study of the previous work done in this field (mentioned in literature survey) is that we have to identify the regions which are more susceptible and prone to the occurance of landslides utilizing the already available geological data.

After the most probable sites for the occurance of a landslide are identifies, deep holes are to be dug so that the sensor strips could be installed into the holes. These holes are supposed to be at the least about 90 feet to 100 feet deep i.e. about 20 meters to 30 meters beneath the surface of the mountains or the hills. This is done to extract the exact information about the rock or the soil of the mountain or the hill where the holes are being dug and the sensor strips are being installed. Also, the holes are not to be dug just at one place only but several holes are supposed to dug at various places because the properties of the rocks of which the mountains are formed, changes after the distance of every 200 meters to 300 meters. So, we have to dig holes after every several meters in all the directions across the area of vulnerability. This is also important to dig several holes across the mountain or the hill and install the sensor strip within the holes because the ultrasonic sensors are being installed within this setup with the line of thought that it will constantly measure the readings with respect to the adjacent ultrasonic sensors and any change in the distance between any two ultrasonic sensors means that the cracks had been developed.

After the holes have been dug and the sensor strips had been installed, the sensors are connected to the hardware and gadgets outside and the sensors start working and measuring the readings constantly after every fixed hiatus of time as being setup by the programmer in the system code of the Arduino written in embedded C. The soil moisture sensors start taking the readings of the moisture content in the soil and the ultrasonic sensors keep on taking the readings of the distance between them and their adjacent sensor strips embedded in the mountains and hills. This distance under ordinary and regular conditions and usual circumstances must remain constant as it was at the time of its installation and any change in this distance for sure means danger of the occurance of a landslide.

Now, consider the event of occurance of a heavy rainfall in the susceptible area where the chances of the happening of a landslide is really high. In this event, the moisture content in the soil is expected to rise for sure and if this value of the moisture in the soil crosses the threshold reading value for that area, the increased moisture value is recorded by the soil moisture sensor and the corresponding next step is initiated. Also, if at some point of time the value of the distance between the sensor strips anywhere in the vulnerable area is increased and the same is recorded by the ultrasonic sensors on the sensor strips, then it simply implies that some cracks had been developed in the specific area where the sensor strip shows varied values of distance and that particular mass of rock or that piece of hill or the mountain is more likely to detach from the larger mass of the mountain and fall down making the destruction in the area where it falls in the ways which have been discussed earlier in this report.

Because of the reason that the sensors are constantly working and recording and providing us the real-time information about the situation in the area where the entire setup is established, any change in the situation from that of what is expected and the one which is known to be normal and usual triggers an alert. Hence, we have an early warning system that can intimate us about the soon to happen natural calamity. In our model, we had used an LED as a way to show the alert which blinks if the readings are different from the normal. In real-time scenario, a traffic light can be installed at some places away from the sites of danger that is connected to the monitoring system. Also, an email notification is generated to the concern authorities so that they can take control of the situation well on time and take the necessary actions and implement the required measures to reduce the impact of this geo-hazard and natural calamity.

### 3.3 Concept and Model Implementation:

### 3.3.1 Model Outline:

Almost all the high standing and lofty hills and mountains have a line of bevel and abruptness on the either side of their slopes which forms the susceptible surface that may slide down the slope due to the occurance of the landslide.

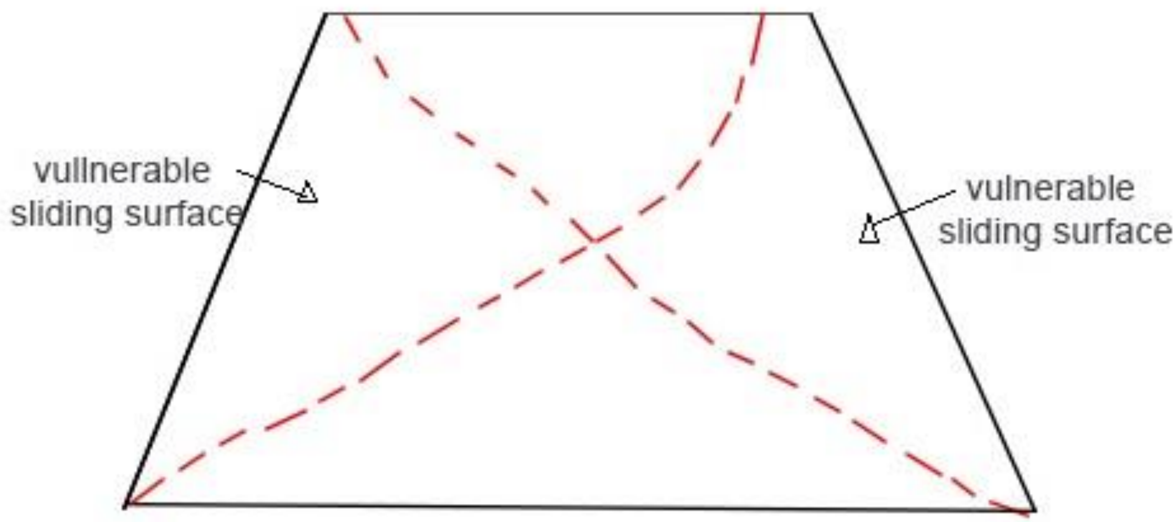


*Fig 3.6 Susceptible sliding surface of a mountain*

The piece of mountain or the hill may break and slide down from either slide which depends of various other factors but majorly upon either the huge rainfall or the nearby mining activities.

The trapezium shaped object in the above figure 3.2 depicts a mountain which is susceptible to the occurance of a landslide. the dotted or the dashed red line shows the possible line of abruptness and slope that may form after the landslide has happened i.e. the mass of the rock or the piece of the mountain on the outer side of the dashed red line is more likely to be detached and fall apart from rest of the mountain or the hill. Hence, this portion of the mountain or the hill may be considered as the vulnerable slipping exterior of that mountain or the hill.

Similar trapezium shaped diagrams have been used to depict the mountain or the hill taken into consideration for implementing the model.

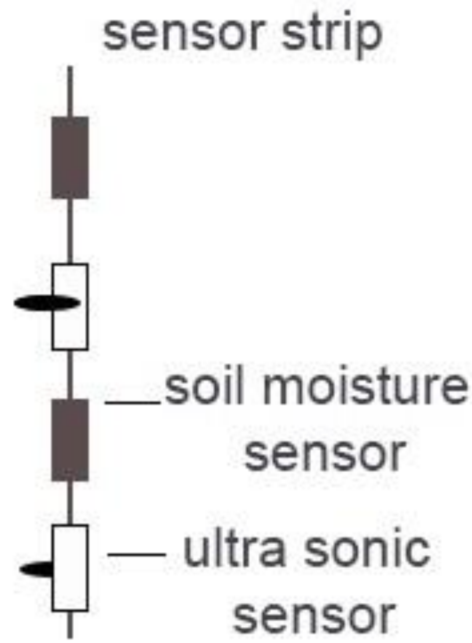


*Fig. 3.7 Sensor strip*

As deliberated earlier we will make a “sensor strip” which will consist of a flexible but relatively hard cable or similar equipment. On this cable or similar equipment we will attach “soil moisture sensor” and “ultrasonic sensor” alternatively. Also, we will not just attach one “soil moisture sensor” and one “ultrasonic sensor” but a considerable number of these sensors reckoning on the depth of the hovel and the need of the geographical area where these “sensor strips” are supposed to be embedded. Figure 3.3 depicts one such “sensor strip” with two “soil moisture sensors” and two “ultrasonic sensors” placed alternatively.

Again not one but several such “sensor strips” will be prepared to be put into the holes at the probable site of amenability.

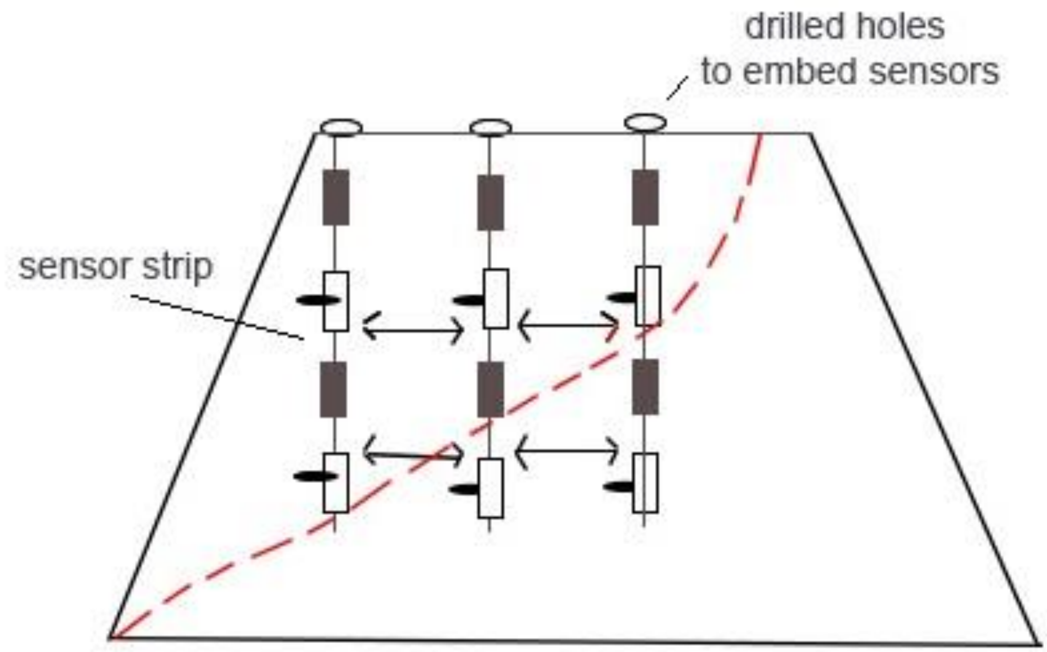


*Fig 3.8 Depiction of installation of sensor strips in holes at susceptible area*

After the most probable sites for the occurance of a landslide are identifies deep holes are to be dug so that the sensor strips could be installed into the holes. These holes are supposed to be at the least about 90 feet to 100 feet deep i.e. about 20 meters to 30 meters beneath the surface of the mountains or the hills. These holes are dug without taking into attention the probable line of abruptness and slope. So, these holes are on both the sides of any such line and may even cross through it. This is done to extract the exact information about the rock or the soil of the mountain or the hill where the holes are being dug and the sensor strips are being installed. Also, the holes are not to be dug just at one place only but several holes are supposed to dug at various places because the properties of the rocks of which the mountains are formed changes after the distance of every 200 meters to 300 meters. So, we have to dig holes after every several meters in all the directions across the area of vulnerability. this is also important to dig several holes across the mountain or the hill and install the sensor strip within the holes because the "ultrasonic sensors" are being installed within this setup with the line of thought that it will constantly measure the readings with respect to the adjacent "ultrasonic sensors" and any shift or revision in the distance between any two "ultrasonic sensors" means that the cracks had been developed.

After the holes have been dug and the sensor strips had been installed, the sensors are connected to the hardware and gadgets outside and the sensors start working and measuring the readings constantly after every fixed hiatus of time as being setup by the programmer in the system code of the Arduino written in embedded C. The soil moisture sensors start taking the readings of the moisture content in the soil and the ultrasonic sensors keep on taking the readings of the distance between them and their adjacent sensor strips embedded in the mountains and hills. This distance under ordinary and regular conditions and usual circumstances must remain constant as it was at the time of its installation and any change in this distance for sure means danger of the occurance of a landslide.

Since the holes are dug on both sided of the probable line of abruptness and slope, and holes even cross through such line. If there is development of some cracks, the fixed distance and the alignment of the sensor strips embedded across the area gets distorted and the "ultrasonic sensor" triggers the alert.

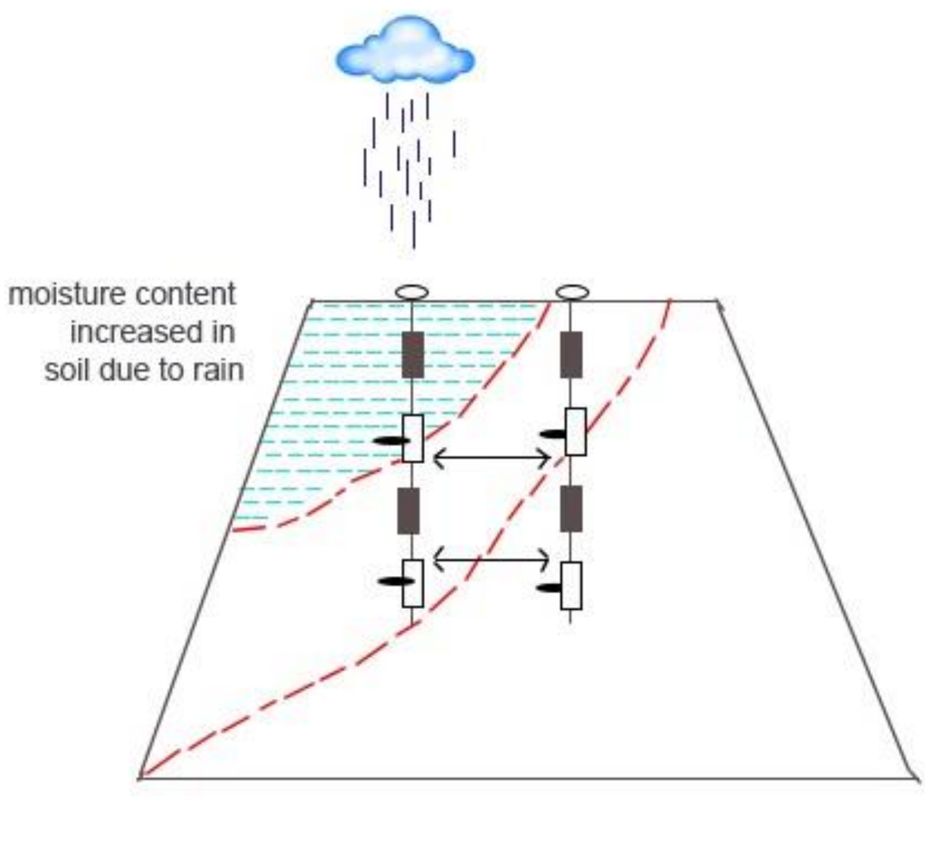


*Fig 3.9 Increase in Soil Moisture due to rain in the susceptible area*

Consider the event of occurance of a heavy rainfall in the susceptible area where the chances of the happening of a landslide is really high. Figure 3.5 shows the huge rainfall in one part of the susceptible area and the corresponding in raise in the moisture content. In this event, the moisture content in the soil is expected to rise for sure and if this value of the moisture in the soil crosses the threshold reading value for that area, the increased moisture value is recorded by the soil moisture sensor. When the moisture value exceeds the threshold, clearly there are increased chances of the occurance of the dangerous geo-hazard. The landslide may happen or may not happen but as and when the value exceeds the threshold, the alert of the danger will be generated so that the preventive measures could be initiated.

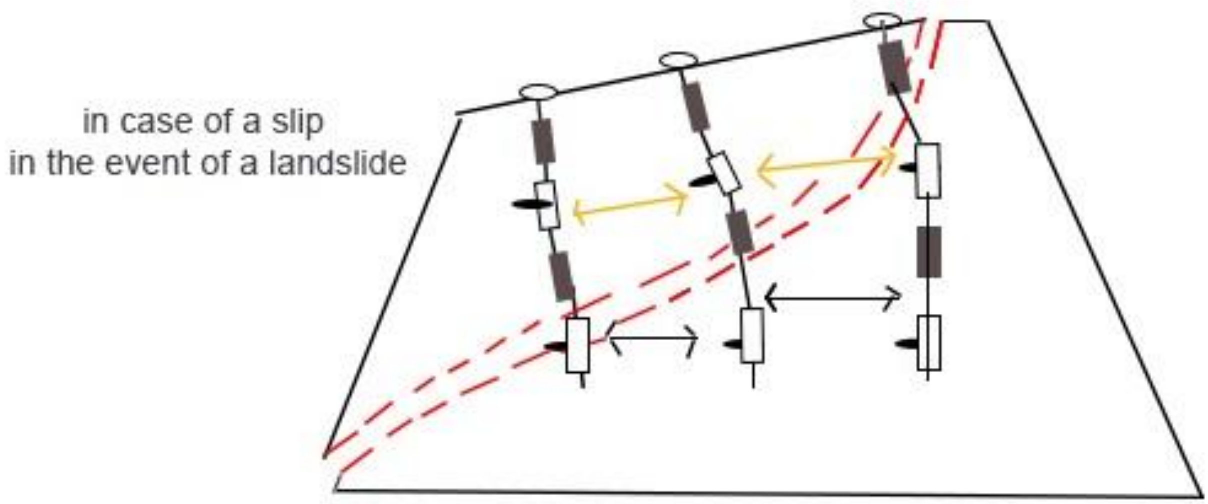


*Fig 3.10 Distortion of sensor strip alignment due to slip*

If at some point of time the value of the distance between the sensor strips anywhere in the vulnerable area is increased and the same is recorded by the ultrasonic sensors on the sensor strips, then it simply implies that some cracks had been developed in the specific area where the sensor strip shows varied values of distance. This is largely the result of the distortion of the alignment of the “sensor strips”. Figure 3.6 depicts such scenario where the cracks are developed and the alignment of the “sensor strips” is distorted. Hence, that particular mass of rock or that piece of hill or the mountain is more likely to detach from the larger mass of the mountain and fall down making the destruction in the area where it falls in the ways which have been discussed earlier in this report.

Due to the reason that the sensors are constantly working and recording and providing us the real-time information about the situation in the area where the entire setup is established, any change in the situation from that of what is expected and the one which is known to be normal and usual triggers an alert. Hence, we have an early warning system that can intimate us about the soon to happen natural calamity. In our model, we had used an LED as a way to show the alert which blinks if the readings are different from the normal. In real-time scenario, a traffic light can be installed at some places away from the sites of danger that is connected to the monitoring system. Also, an email notification is generated to the concern authorities so that they can take control of the situation well on time and take the necessary actions and implement the required measures to reduce the impact of this geo-hazard and natural calamity.

### 3.3.2 Circuit Implementation

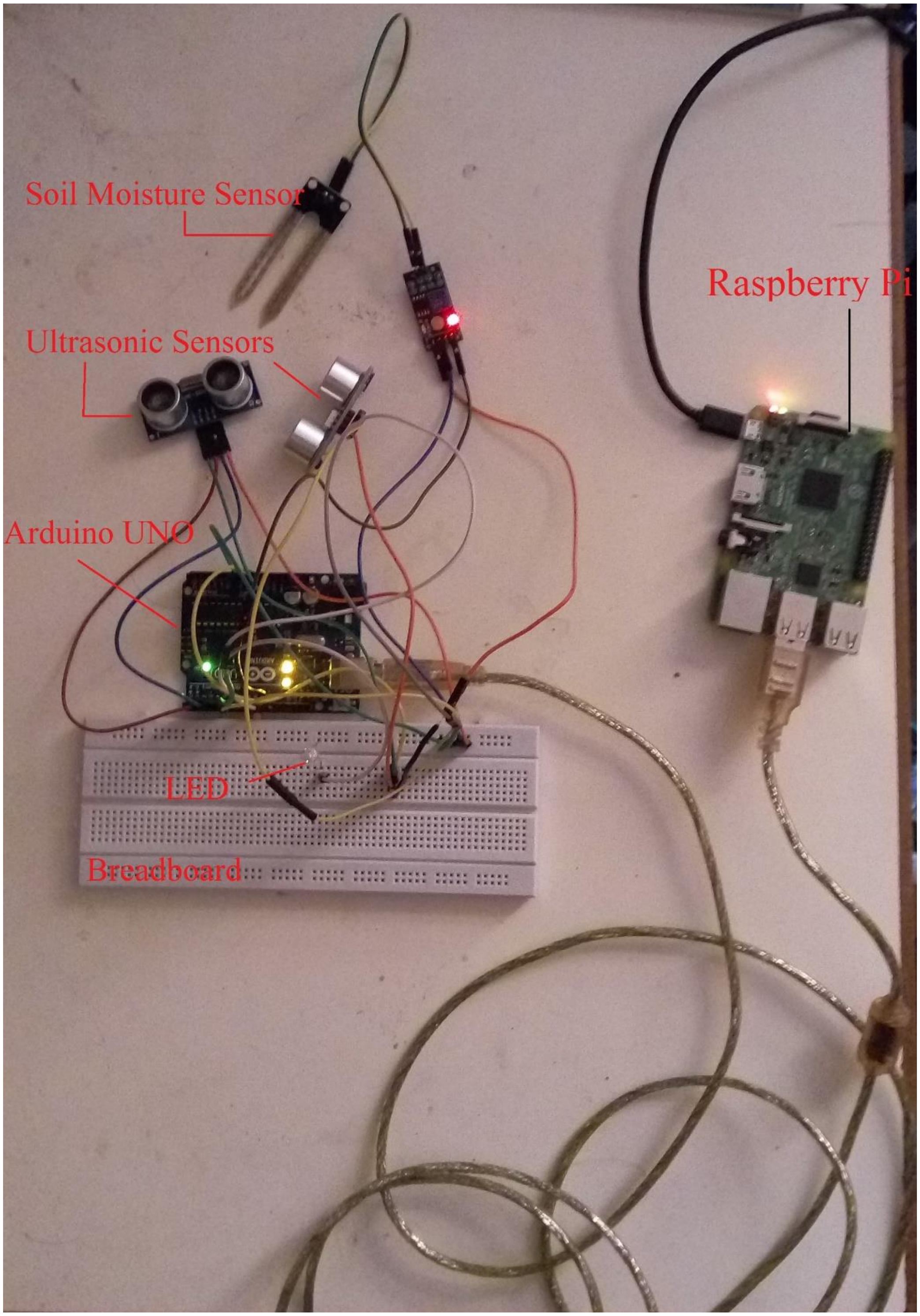


*Fig 3.11 Image of implemented circuit*

To implement the discussed model into a circuit, we have used a mini-breadboard, an Arduino UNO, a Raspberry Pi, an LED, one Soil Moisture Sensor and two Ultrasonic Sensors along with a handful of jumper wires to make the necessary connections.

On the Arduino Circuit Board, we have used following pins for the below mentioned purpose:

Digital Pin 2 connected to the Trig of Ultrasonic Sensor 1

Digital Pin 4 connected to the Echo of Ultrasonic Sensor 1

Digital Pin 8 connected to the Trig of Ultrasonic Sensor 2

Digital Pin 9 connected to the Echo of Ultrasonic Sensor 2

Digital Pin 10 connected to the positive (+ve) terminal of LED

Analog Pin A0 is connected to the Soil Moisture Sensor

All the grounds or the negative (-ve) terminals are connected to a common ground on the breadboard.

All the vcc terminals are connected to common 5V vcc created on the breadboard drawing power from the 5V vcc pin of the Arduino.

The Arduino is connected to the Raspberry Pi containing the Raspbian OS in a micro SD card inserted into it.

The Raspberry Pi is connected to some power source.

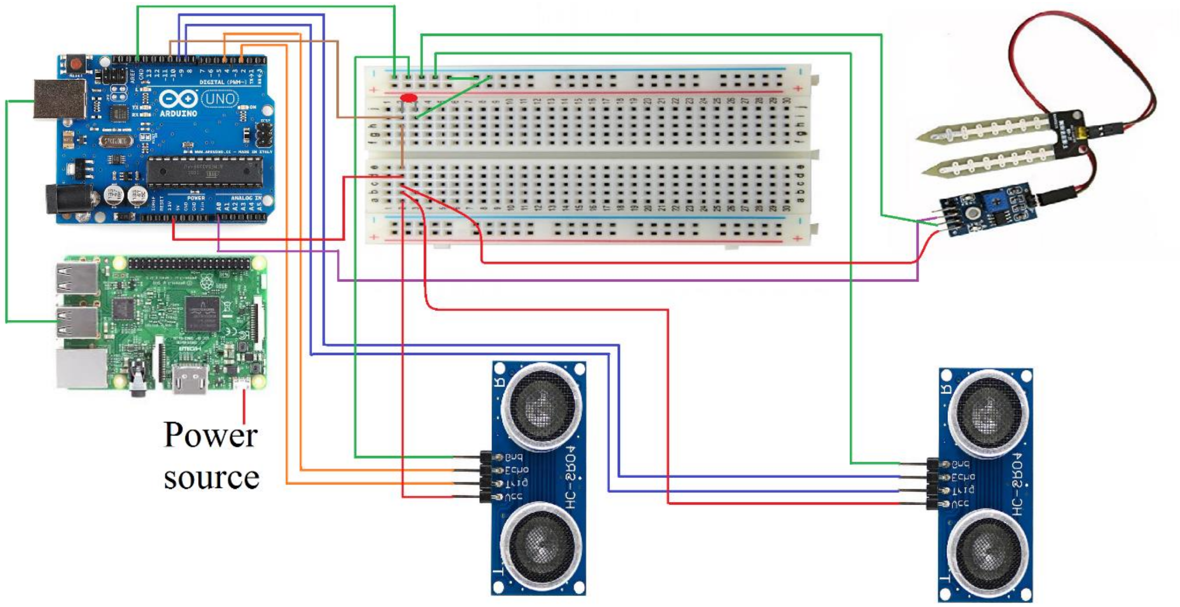


*Fig. 3.12 Circuit diagram with corresponding pin configuration*

## 3.4 Control Flow of the System:

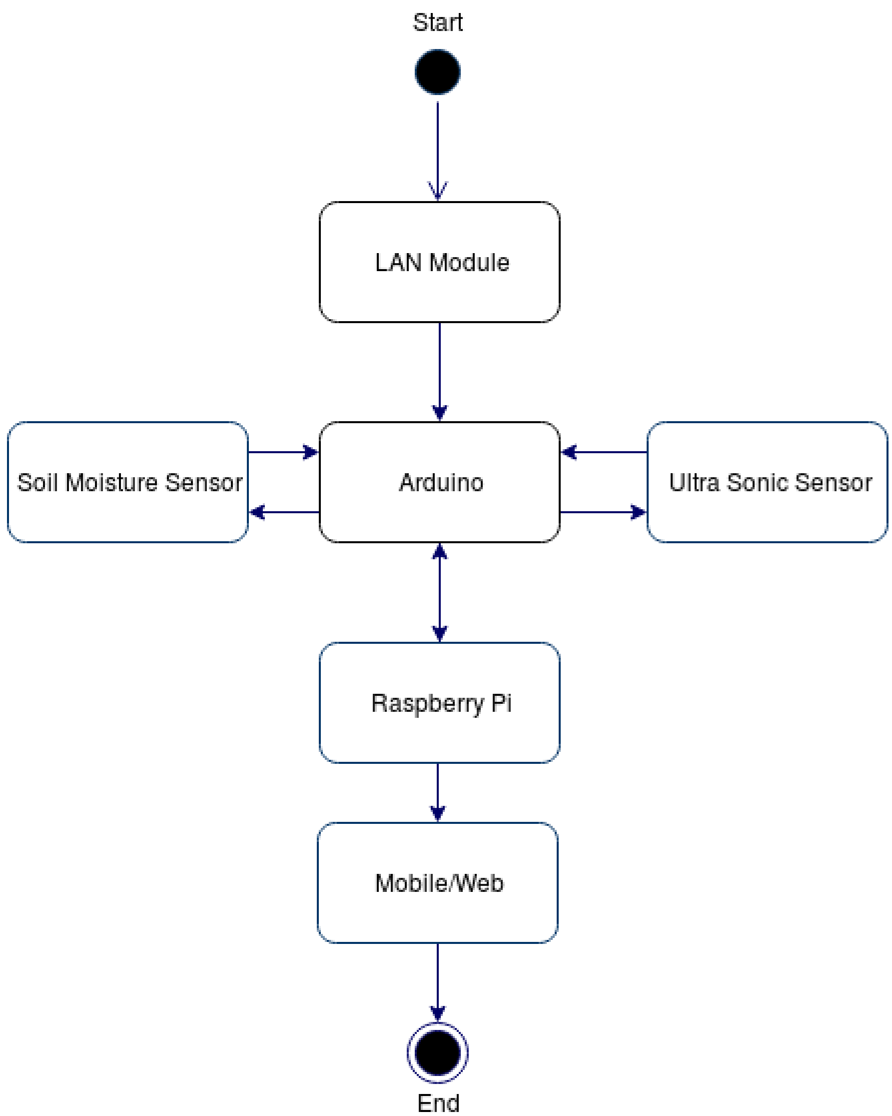


*Fig. 3.12 Control flow diagram of the system*

After the system is started, the "Lan Module" is connected to the "Arduino UNO Circuit Board". The two types of sensors – "Soil Moisture Sensor" and "Ultrasonic Sensor" are connected to the "Arduino" and there is a continuous and simultaneous exchange of input and output between the circuit board and the sensors. The circuit board "Arduino UNO" is connected to the computing hardware – "Raspberry Pi" where the computational decision about the values sent by the sensors is taken and the corresponding action is taken as the notification or alert generation (if required) and the continuous readings are displayed.

### 3.4.1 Control Flow for Soil Moisture

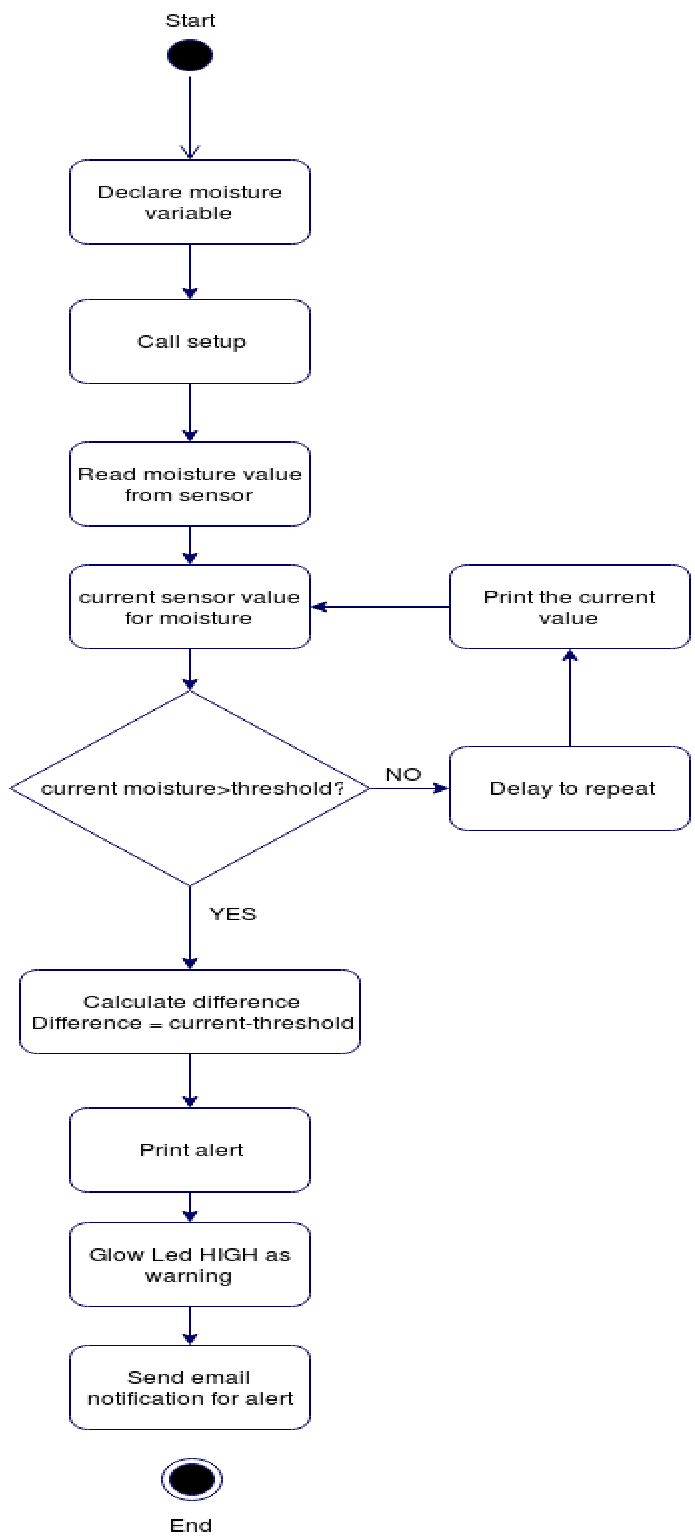


*Fig. 3.13 Control flow diagram for Soil Moisture Sensor*

### 3.4.2 Control Flow for Ultrasonic Sensors

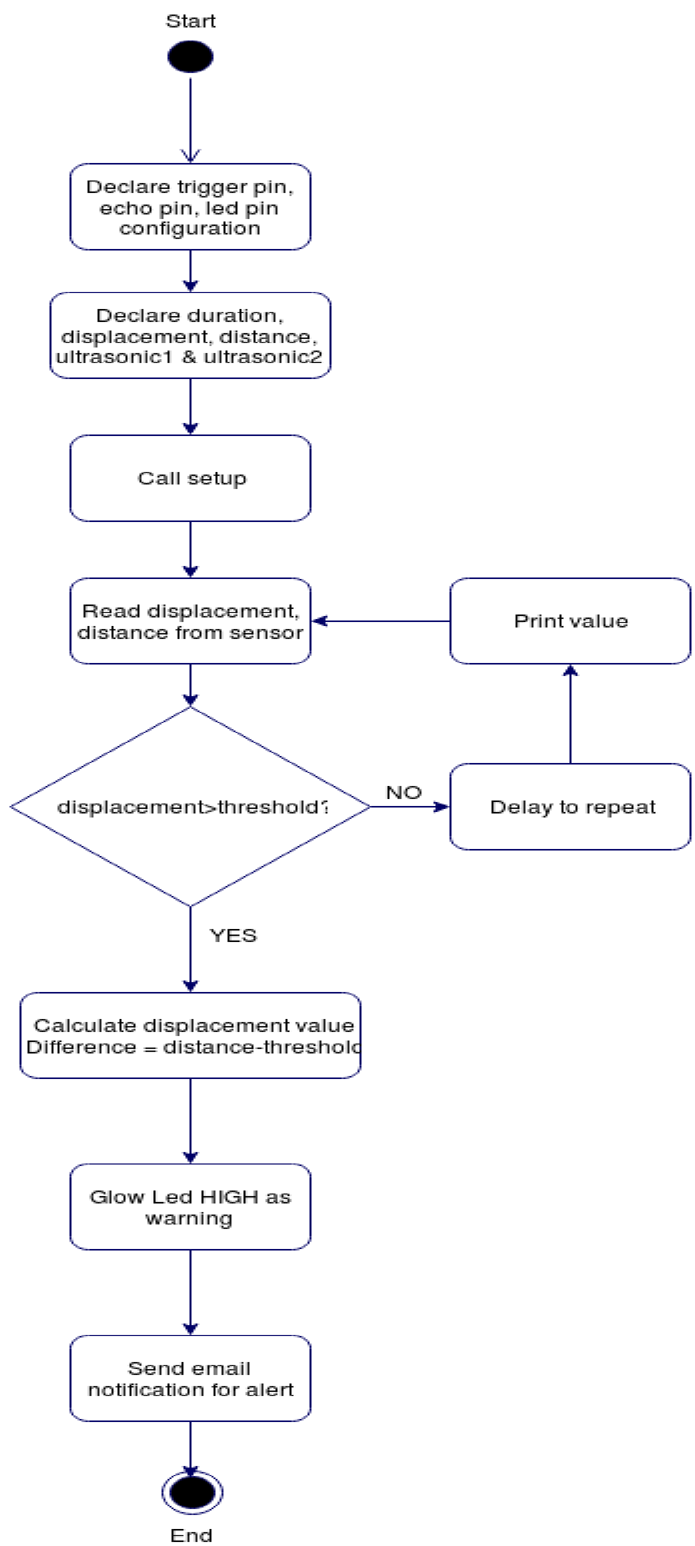


*Fig 3.14 Control flow diagram for ultrasonic sensor*

### 3.4.3 Control Flow for Alert Generation:

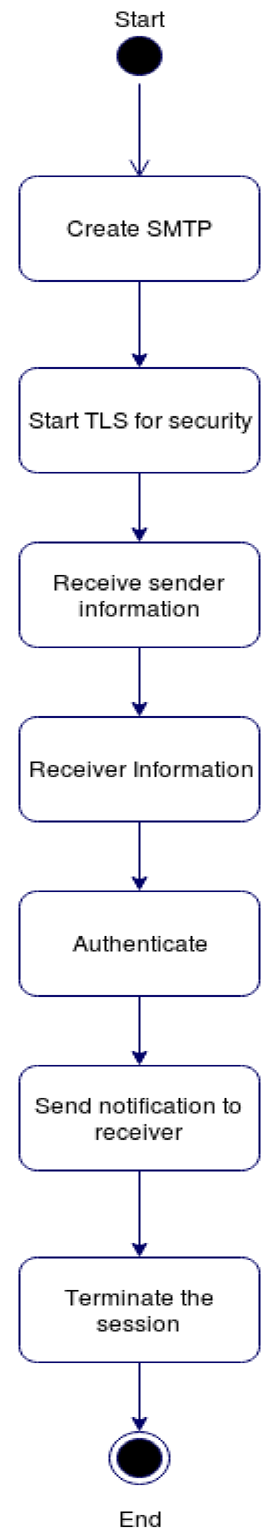


*Fig 3.15 Control flow diagram for alert generation*

# Chapter – 4

## PERFORMANCE ANALYSIS

*Table 4.1 Readings of sensors implemented*

| S. No. | Soil Moisture Sensor Reading | Ultrasonic Sensor 1 Reading | Ultrasonic Sensor 2 Reading |
|---|---|---|---|
| 1 | 815 | 7 | 2 |
| 2 | 829 | 7 | 2 |
| 3 | 825 | 11 | 2 |
| 4 | 822 | 21 | 11 |
| 5 | 832 | 12 | 11 |
| 6 | 464 | 6 | 1 |
| 7 | 544 | 6 | 0 |
| 8 | 157 | 6 | 0 |
| 9 | 154 | 13 | 4 |
| 10 | 509 | 14 | 13 |
| 11 | 207 | 12 | 3 |
| 12 | 223 | 1 | 0 |
| 13 | 192 | 17 | 14 |
| 14 | 1023 | 11 | 129 |
| 15 | 608 | 6 | 7 |
| 16 | 769 | 9 | 6 |
| 17 | 1023 | 10 | 7 |
| 18 | 589 | 9 | 120 |
| 19 | 724 | 9 | 119 |
| 20 | 1023 | 16 | 122 |

The threshold set for the ultrasonic sensors was 10 cm exceeding which alert was generated.

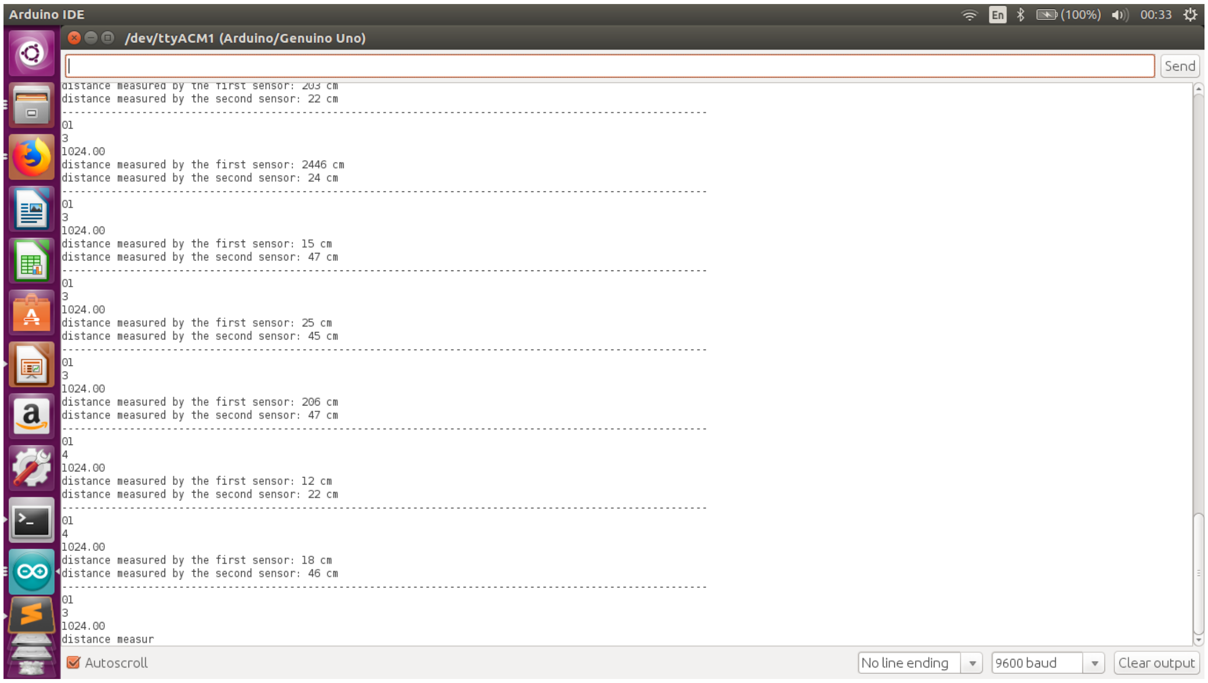

*Fig. 4.1 Screen capture 1 of output of sensor reading on serial monitor*

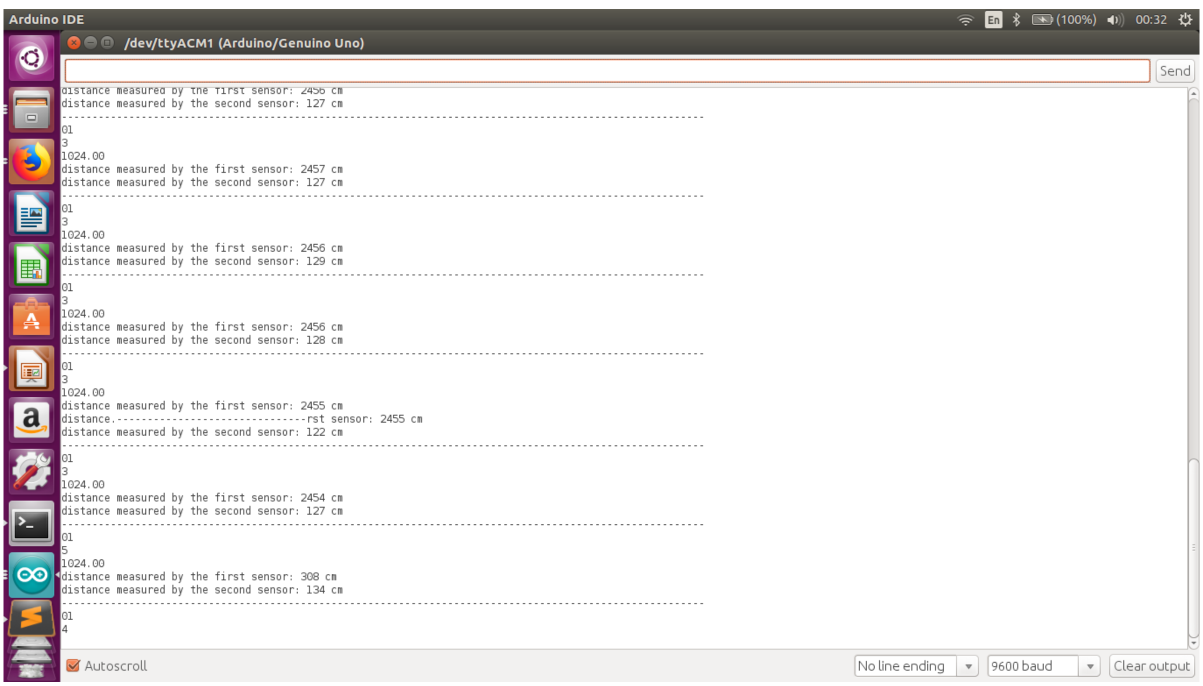

*Fig. 4.2 Screen capture 2 of output of sensor reading on serial monitor*

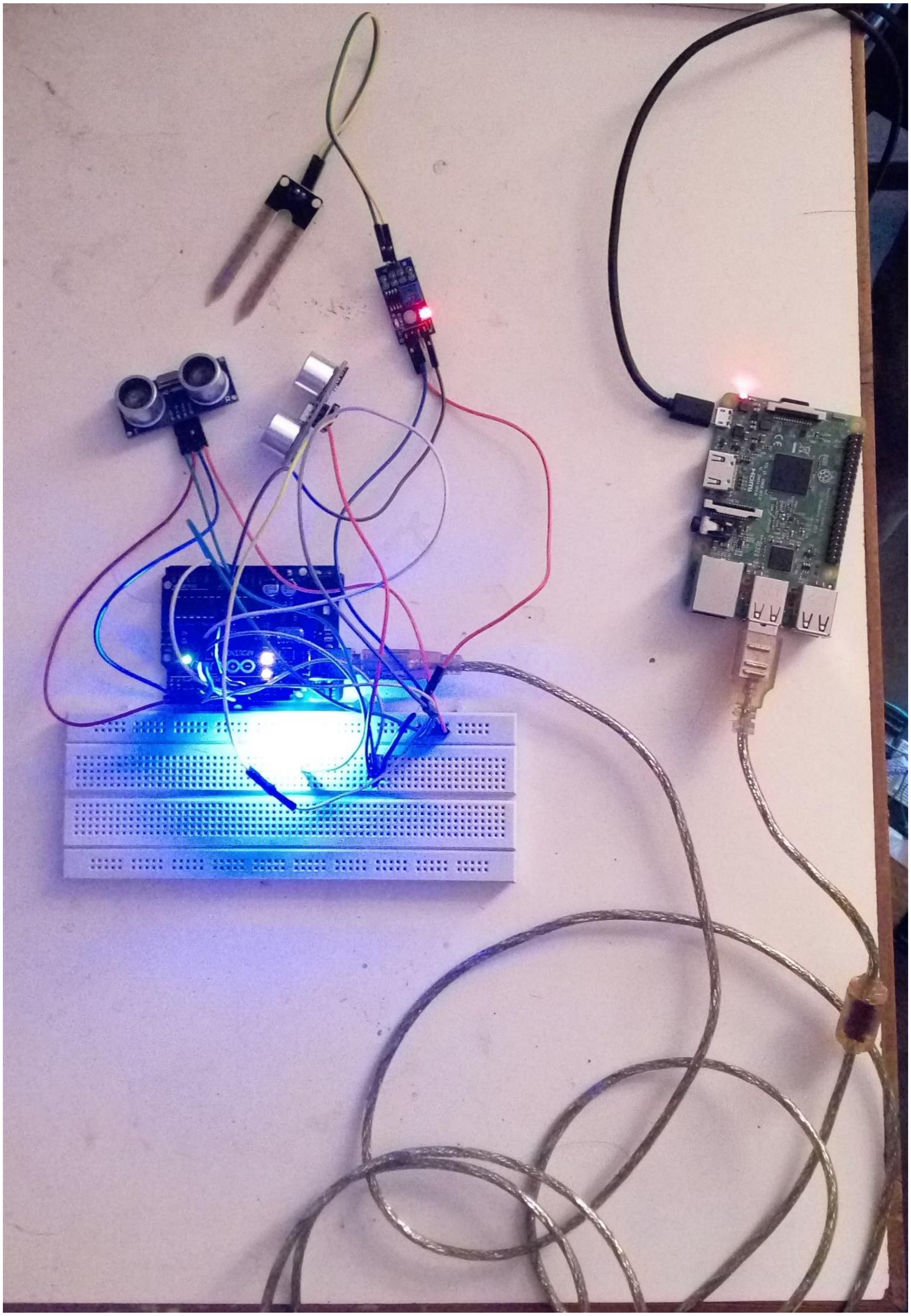

*Fig. 4.3 Blinking of LED for alert generation due to dis-alignment of sensors*

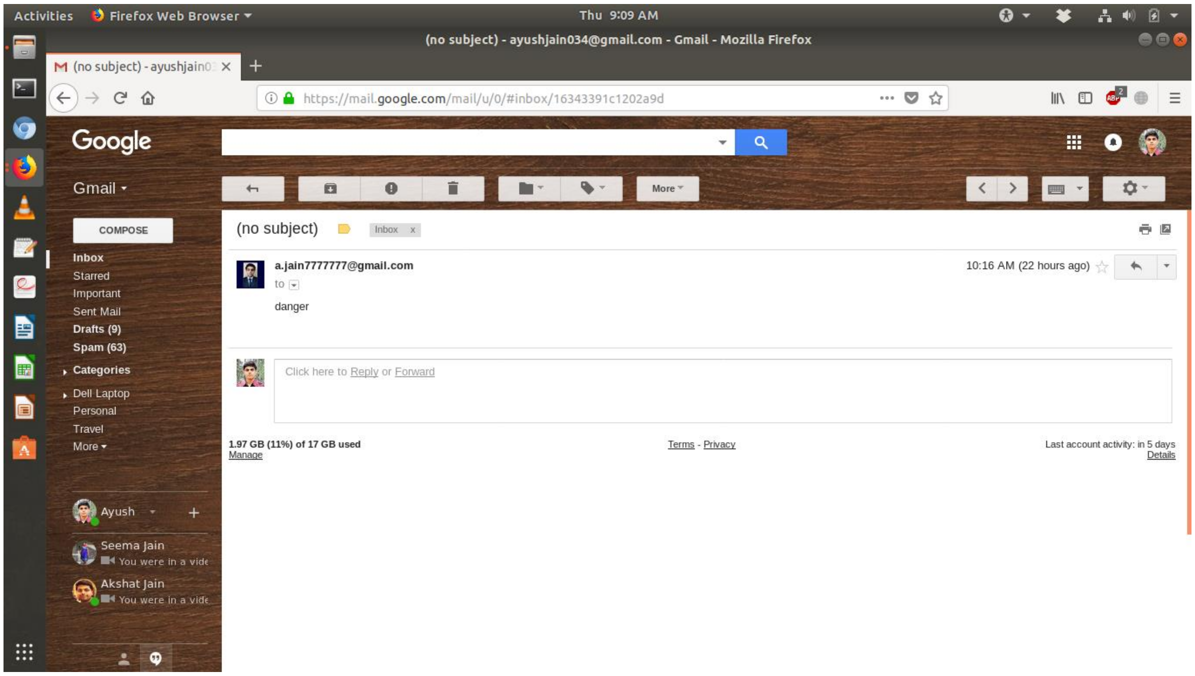


*Fig. 4.4 Screen capture of email notification as a part of alert generation*

# Chapter – 5
# CONCLUSION

## 5.1 Summary and Conclusion:

In this project, an effort has been made to develop a model that can help us to predict the occurance of a landslide well before time and also a model that can constantly monitor the vulnerable and susceptible areas and generate a warning well on time. This is achieved with the aid of physical sensors. Implementing IoT, a sensor based monitoring system model which can be implemented into an operational landslide monitoring, prediction and early warning at the sites of vulnerability and danger. The alert and the warning is being generated in the form of the blinking of an LED and also in the form of an email notification being sent to the concerned authorities so that they can be informed about the impending catastrophe well on time.

### 5.2 Proposal for Future Works:

The present model can be tested in simulation systems and then deployed into a real-time scenario. The existing model can be improved and made more efficient on various fronts. More sensors can be utilized and the Ultrasonic sensor can be replaced with the Strain Gauge at the time of actual deployment. At present there are certain flaws in the system such as the sensors provide the data constantly for the monitoring of the situation but the data is not being stored anywhere. The system can be connected and then synchronized with the cloud and the entire data collected by the sensors can be deposited in a repository which can be utilized in the future for the data driven prediction based on the past data of the specific locations. Also, the alert and the warning system can be made more efficient by developing an android and a web application which can be accessed not only by the authorities but also by the people living in the susceptible area of danger so that a collective effort can be made to minimize the disastrous effects of the calamity.

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