UNIVERSITY of RWANDA

Research and Postgraduate Studies (RPGS) Unit

ACEIoT

AFRICAN CENTRE OF EXCELLENCE IN INTERNET OF THINGS

Research Thesis Title:

LANDSLIDES EARLY NOTIFICATION BASED ON INTERNET OF THINGS

A dissertation Submitted in partial fulfilment of the requirements for the award of

MASTER'S OF SCIENCE DEGREE IN INTERNET OF THINGS: EMBEDDED COMPUTING SYSTEM

Submitted By

MUHIRWA Dieudonne (REF.NO: 215018240)

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UNIVERSITY of RWANDA

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LANDSLIDES EARLY NOTIFICATION BASED ON INTERNET OF THINGS

Case study: Kamonyi district, southern province, Rwanda

by:

Dieudonne MUHIRWA
Ref no: 215018240

A dissertation submitted in partial fulfilment of the requirements for the degree of Masters of Science in Internet of Things- Embedded Computing Systems at the African Center of Excellence in IoT (ACEIoT)

Under supervision of:

Dr. MUKANYILIGIRA Didacienne

Dr. NIYIZAMWIYITIRA Christine

DECEMBER 2020

DECLARATION

I MUHIRWA Dieudonne, Master ‘student from African Center of Excellence in internet of things, at University of Rwanda. I declare that this research thesis is my own original work and it has never been presented before anywhere in the world.

MUHIRWA Dieudonne.

Ref: 215018240

Signed:

Date: 30th December 2020

BONAFIDE CERTIFICATE

This is to certify that this submitted Research Thesis work report is a record of the original work done by MUHIRWA Dieudonne (**REF.NO: 215018240**), MSc. IoT-WISNET Student at the University of Rwanda / College of Science and Technology / African Center of Excellence in Internet of Things, the Academic year 2018/2020.

This work has been submitted under the supervision of Dr. Didacienne MUKANYILIGIRA and Dr. NIYIZAMWIYITIRA Christine

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Signature:

Date…..../……/…...

Signature………

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ABSTRACT

Landslides result in the destruction of property. It interrupts public services and also leads to loss of lives. Landslides usually occur in mountain regions having a steep front. These usually occur in form of mud and soil flow together with rock sliding. The biggest problem is that there is no real-time and automated way of notifying population about the event of a landslide. I investigated existing tools currently used in Rwanda to find what are the gaps in landslide detection and prevention. This study aims to deploy an automated landslides early notification system which is able to communicate information of the suspected mountain to the control center and let the right person control some of the parameters remotely. With the help of Internet of Things, it is possible to conduct early monitoring of landslides and mitigate their effects. It allows easy access to information in hard-to-reach regions. This system is made of three sensors, accelerometer which senses the land slope, Soil moisture sensor to sense the soil strain strength, and GPS which helps in monitoring the displacement of land. In case of landslides or sudden shock, the system will directly notify all population in the environment through an alarm buzzer. This system takes KAMONYI as its case study as it is the region with frequent landslides across the country. Based on the research conducted, data analysis and its evaluation, the system proves its effectiveness in facing the problem of landslides in the region.

Keywords: Landslides, Environmental analysis, Internet of Things

LIST OF SYMBOLS AND ACRONYMS

Dr.: Doctor

GPS: Global Positioning Systems

GSM: Global System for Mobile

GUI: Graphical User Interface

HTTP: Hypertext Transfer Protocol

ICT: Information Communication and Technology

IDE: Integrated Development Environment

IEEE: Institute of Electrical and Electronics Engineers

IoT: Internet of Things

LIS: Landslides Information Systems

MCU: Microcontroller Unit

SDM: System Development Model

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CHAP 1: GENERAL INTRODUCTION

1.1 INTRODUCTION

Landslides are natural disasters that occur when gravity overcomes friction displacing layers of rocks on a slope. The ground we stand on is made of layers of different rocks of the materials, and a weak layer like a scale can form a failure plane, at the same time disturbance can cause the upper layer to slide away. Heavy rain is one of the common causes of landslide since it adds to the quantity of water in soil hence weakening the ground structure, Deforestation on the mountain slopes also weakens the ground structure and increases landslide risks. Earthquakes are one of the causes of landslides which cause the ground to shake and given the sloppy nature of these mountains, it leads to landslides or another natural disaster like floods. On the other hand, improper housing in urban areas and mining activities in those mountain regions can lead to higher risks of landslides [2]. Rwanda, a country often referred to as the thousand hills country [3] has experienced several landslides leading to damage of lives [4] destruction of property like crops and disruption in transport activities especially in the western side of this country where we found high mountains, mines operations and high population growth after main capital of the country. In December 2017, an entire valley covered with maize and sorghum fields in Kamonyi district was eroded and covered with water and land debris [5]. In March 2018, in the neighboring district of Muhanga, a tantalite mine collapsed and buried 5 miners, after only 10 months on 21st January 2019, heavy spots of rain trigger the collapse of a hill near the mining site in the eastern province, killing 14 workers [6]. In January 2018, the road to Northern Province a hill failed and buried the main road linking Kigali to Musanze district [7] [8]. The same as what was happened in august 2016 on this road on the side of Gakenke District and more than 20 peoples killed by landslides with floods [6]. It is possible to support unstable ground and large bolts that can be used to secure upper layers of materials but it will not be easy because some landslides happen very slowly over many years due to flooded rivers around the mountain areas. The high cost of traditional landslides monitoring technologies calls for finding alternative technologies that are affordable and can look beneath the terrain's surface. Between 1974 and 2018 heavy landslides occurred five times that killed about 117 people and had a devastating effect on about 11,949 people and cost the country of Rwanda loss of $ 28 million[9] on the other hand, the $ 19.1 million earmarked for the three years from 2017 to 2019 of disaster risk reduction (DDR) in Rwanda is estimated at $ 8 million spent on mitigation and prevention, response, recovery, and reconstruction due to landslides and floods while most floods are caused by landslides The good news is that we can mitigate the negative impact caused by landslides and other disasters by using the Internet of things (IoT) based solutions. Landslide Early Notification Based On the Internet of Things, will help the government to analyze data according to past accidents with the present situation which will come up with fully monitor mountains in the district of (Kamonyi). This research will also save the lives and environments especially by alerting the district for the danger ahead of time. The alert will reduce the budget spent on visiting physical verification which is usually high due to protection equipment that individuals must carry.

1.2 BACKGROUND AND MOTIVATION

People's lives are in danger because they are not well protected and their activities such as agriculture are also not going well due to the old methods of fighting and collecting landslide information therefore government is losing a lot in rescuing and repairing landslide damages due to insufficient information to help the government protect the people and inform them about the status of the landslide early to reduce the problems caused by it.

A system that will help the government or the right person to easily monitor the suspected mountain where the landslide can occur and assist in providing real-time information anywhere at any time so the proposition of landslide early notification should be a good fit.The system would be one of the most important roles in human lifetime and government for its efficiency, time, and money-saving.

1.3 PROBLEM STATEMENT

After qualitative research and understanding, big environmental and natural resources management issues need to be addressed in an improved and effective way to make this region as well as the world a better place to live.

- According to the different activities related to the environment like mining for individual companies in this region of high mountains, it is very easy for landslides accidents to occur, while there is no efficient tool that will fully monitor mountains and these activities.
- Because of heavy rain in this region and according to the fact that the major problem of this continent is climate changes, it is not easy for agricultural activities in this region however, ¾ of the population in this region are cultivators and farmers [10] , it is very easy for the water to flows from the mountains into their field crops because a big part of agriculture’s activities is founded in the swamps [6] , this problem arises because they don’t use to know when this will happen and prepare

for them earlier so that there is no early detection system which is used to support early notification for this cultivators, farmers and other population in general.

- It is also very difficult for peoples to analyze data according to past accidents with the present situations by their minds while there is no monitoring system and there are no data analysis methods technologically.
- Landslides causes the Rwandan government to spends a lot of money on repairing damages and rebuilding after the landslides not forgetting the loss of human lives. After all, there is no efficient and reliable way to notify people before a landslide accident.

1.4 STUDY OBJECTIVES

1.4.1 GENERAL OBJECTIVES

The general objective of this study is to make automated landslides early notification which can communicate the information of the suspected mountain to the control center and let the right person control some of the parameters remotely whenever it is required and alert people by using buzzer. This will be a system made up of IoT devices such as sensors, microcontrollers, and network devices to help interaction between the local system and remote server.

1.4.2 SPECIFIC OBJECTIVES

In practice this study has the following specific Objectives:

- Development of the system which will be able to monitor soil moisture, displacement of the suspected slope by using accelerometer sensor and development of a portable system by fixing all components in a single kit, and this system will be able to save power as required in IoT devices.
- Support in analysis and investigations of other landslide accidents by using data stored on the cloud.

1.5 HYPOTHESIS

Employment and IoT for soil monitoring can be used to remotely alert upcoming landslides.

1.6 STUDY SCOPE

This system will locally process all the data from soil moisture and accelerometer sensors then monitor that information in case of crossing the limit. the information will be simultaneously sent to the cloud, where someone in charge can control everything remotely with real-time information and notify residents around the suspected mountains if a landslide is going to happen and the system itself can alert the public with a buzzer and E-mail notification when necessary, which is why it is important to control it from near or far.

1.7 SIGNIFICANCE OF THE STUDY

Natural disasters like landslides and floods bring life in danger worldwide. This Landslide Early Notification Based On the Internet of Things, will help the government to analyze data according to past accidents with the present situation which will come up with fully monitor mountains in the district of (Kamonyi). This research will also save the lives and environments especially by alerting the district for the danger ahead of time. The alert will reduce the budget spent on visiting physical verification which is usually high due to protection equipment that individuals must carry.

1.8 STUDY ORGANIZATION

This research is organized as follows.

Chapter One gives the introduction of the research which includes a short background Problem statement, objectives, and the summary of the study.

Chapter Two discusses related researches that were carried out before, the gaps, proposed solutions as part of this research.

Chapter Three is the research methodology. This gives an overview of the research methods and system design.

Chapter Four presents a system analysis and design that includes all the theory that was used.

Chapter Five provides results by interpreting data using charts.

Chapter Six finalizes the research with a conclusion and suggests recommendations for future work.

CHAP 2: LITERATURE REVIEW

The following is a summary of the literature review and the gaps vis a vis this system. The Landslide Early Notification Based on the Internet of Things required with the help of these sensors (**soil moisture sensor, accelerometer sensor, with GPS systems**), microcontroller, and network Gateway. All the work of this system is automated and it is also easy to monitor landslide accidents remotely for emergency help from other locations. Also, Computer and smartphone are added to allow the end-users to monitor and control remotely landslides information, in this system Arduino platform can be configured as a remote server or customer through ease and other hardware settings. Design of the background for this Landslide Early Notification Based On Internet of Things is also implemented with the real-time monitoring solution for measuring the water in the soil, displacement of the suspected slope, heavy deforestation, and a decision support system for data storage, monitoring, analytics, and sending the right information to the right persons involved at the right time. The sensor node from this system sends the data to the central monitoring station. The monitoring process of this system was done by analyzing those data with logic to check whether the threshold level is violated or not according to the sensors readings therefore in case of emergency decides to send information to the control stations also agree to notify residents around the suspected slope by using a buzzer. Solar-powered with chargeable battery also was deployed in this system for energy-efficient (reference) the following are the summary of conducted studies.

- The work described in [11] Anomaly detection and visual perception for landslide monitoring based on a heterogeneous sensor network, closely resembles the system and it deals with similar challenges. But the work is limited only to sensors network and does not provide adaptive streaming and remote administration of the sensor networks, our proposed system will be able to be controlled remotely and accessed by anyone with the required credentials.
- The system in [12] a robust wireless sensor network for landslide risk analysis, uses the geological sensors along with camera sensor nodes. At whatever time the sensor node value signs a specific threshold, the camera sensor is activated and the sensor rate with the images are transmitted to a distant center. But in this system, the sensors are deployed using the borehole method and buried 30 or 20 m deep inside the soil with an array of sensor columns tubes. Therefore, the accuracy of measurements for pore pressure and underground movement is increased without the need for a camera but this system is more expensive for developing countries.

- The other recent work on designing a wireless sensor system to monitor the slope movement is presented in [13] Open-source wireless sensor system for long-term monitoring of slope movement. In this work, they focus on building a low energy system but do not deal with network related issues.
- The work in [14] Reliable network connectivity in wireless sensor networks for remote monitoring of landslides, looks exactly like this system provided and solves similar problems. But the job is limited to the remote management of the sensors site. it doesn't matter if the system itself can warn the people on the site in the event of a sudden shock or emergency time but the proposed system can manage all of those events.
- The work in [15] utilizing crowdsourcing to enhance the mitigation and management of landslides. This work presents a new landslide information system (LIS) comprising a smartphone app and an administrative interface and database. The information provided by the smartphone owners is collected and a decision is made based on that information. The proposed system in [15], requires smartphone to collect data and use that information to predict the risk of landslides however it can only be used in developed countries. In less developed countries, the number of people with smartphones does not reach the desired level to be able to make the proper prediction using the data collected from those few, and landslides can occur in rural areas. This affects the local population near the site of the uninhabited mountains where landslides can occur. Therefore, the system does not have enough information on these uninhabited hills Because in this system information is extracted from people without the use of IoT technologies. This would put people's lives at risk but this system is designed to process and extract information from anywhere whether unoccupied or occupied.

CHAP 3: RESEARCH METHODOLOGY

It highlights the methods and approaches used and shows how the analyzed results were presented throughout the whole project and he prototype research approach was used.

3.1 METHODS

In order to know what the Rwandan government is doing in the prevention and control of landslides in general and clearly identify specific areas and mountains that face severe consequences due to landslides, I used the data collected by government of Rwanda institutions (REMA,MIDIMAR) and reports, big conferences reports locally and internationally, internal and international media reports, review of previous researcher's work dealing with the same problems and all of this research related data are available online except requesting for the data collected by government institutions and to analyze those data, I used discourse analysis.

3.1.1 PROTOTYPE

At the first, the idea came with the objectives, problem statement, and the proposition of the solution based on IoT applications.

The developed idea will have sensor nodes embedded with an accelerometer sensor, and moisture sensor to collect data related to mountain displacement, vibration, and soil information to ease monitoring. Specifically, the work is split into four parts:

- Design of prototype
- Implementation of prototype
- Evaluation of the prototype

The design of the prototype is based on the prior research and knowledge gained from a clear Literature study, thus giving an optimal architecture and evaluating the best-suited sensors and protocols for this application. The implementation of the prototype follows the rules and guidelines specified in the study site. The result of this design should be a prototype that could be implemented to address potential changes in requirements due to the addition of new requirements or a deeper interpretation of the needs that arise. Regarding the evaluation of the system prototype, testing procedures should consider the end to end performance to find out if there are any problems concerning the system's functionality or scalability.

3.1.2 SYSTEM DEVELOPMENT MODEL

In the research process of this project, the preferred system development model was the Prototyping model of a system development model (SDM) in which to build, test, and reuse where necessary until finally the acceptable type in which the complete system or product can now be built [15].

3.1.2.1 THE PROTOTYPING MODEL

The general prototyping model is described in Fig. 1 as shown below:

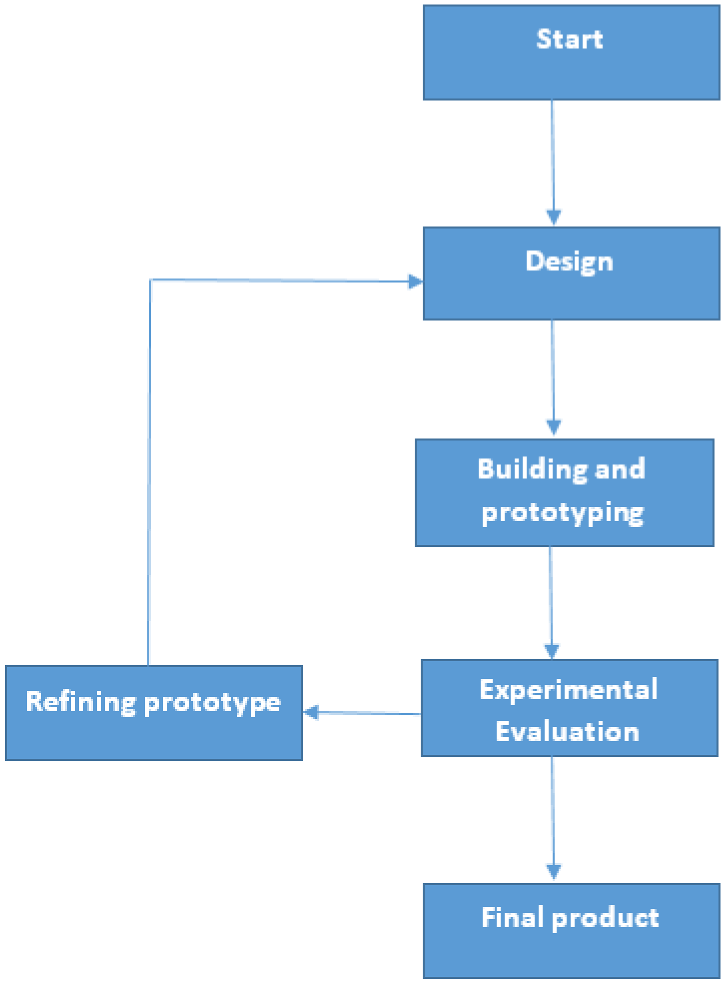


Figure 1: prototyping model of the system

- **Building and prototyping:** All the Information gathered from the quick design phase has been modified to form the prototype which represented the working model of the required system. It is in this phase where also the simulation tools stated to be identified and are used.
- **User evaluation:** Next step was to present the prototype to the user evaluation of the prototype to recognize its strengths and weaknesses such as what is to be added or removed.

  Comments and suggestions were collected as more simulations were being made.
- **Refining prototype:** After evaluating the prototype and if the Government of Rwanda is not satisfied, the current prototype was refined according to the requirements or comments or suggestions from the first presentation.

- **Final prototype:** Once the requirements were completely met, the user has accepted the final prototype.

3.1.3 SYSTEM REQUIREMENTS

3.1.3.1 Functional Requirements

In software engineering, a functional requirement defines a system and its component. Landslide Early Notification Based on Internet of Things has some functional requirements such as:

- Sensing soil parameters through the sensors
- Sending sensed data to cloud for storage
- Analyzing and visualizing data
- Notify around people by using buzzer and email by depending on the location.

3.1.3.2 Non-Functional Requirements

A non-functional requirement defines the quality attribute of a system. Landslides early notification owns the following non-functional requirements:

- Consistency: gives output for the desired time duration in certain environmental conditions.
- Usability: Everyone with knowledge of ICT can use this system.
- When something is wrong in the system, it is easily recoverable.

3.1.4 SYSTEM REQUIREMENTS

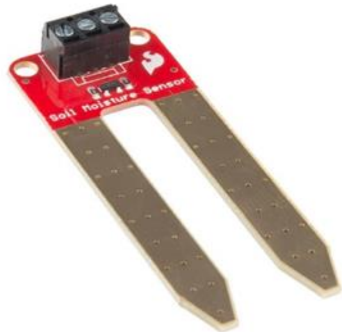
3.1.4.1 Sensors and actuators requirements Specifications

A **sensor** converts the physical gesture into electrical signals and do different works. Whereas, the **actuator** is responsible for the conversion of an electrical signal to mechanical work. **Sensors** measure discrete as well as continuous process variables [16].

The following are specifications of sensors and actuators used in this research:

- **Moisture sensor** with Op range -4^{o} C-85^{o}C, accuracy of ±1^{o}C,7mA,3.5V-20V

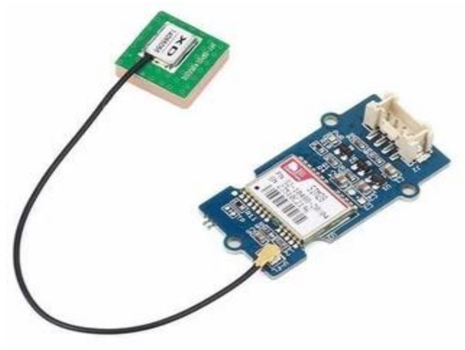
  Soil moisture is the content of water in the soil. Soil moisture sensors measure the amount of water in the soil. Groundwater content is a variation of the earth's surface defined as water contained in a saturated soil that is not saturated. Measuring soil moisture is important for Landslides detection applications [17].



- **Accelerometer**

An accelerometer is a dynamic sensor capable of a vast range of senses. Accelerometers are available that can measure acceleration in one, two, or three axes [18]. They are usually used in one of three methods:

- As an inertial measurement of position and velocity;
- As a sensor of inclination, tilt, or orientation in 2 or 3 dimensions, as taken from the acceleration of
- gravity (g = 9.8m/s^2);
- As a vibration or impact (shock) sensor.
- **GPS**: Global Positioning System



The Global Positioning System (GPS), originally Navstar GPS, is a satellite-based radio navigation system, It is one of the global navigation satellite systems (GNSS) that provides geolocation and time information to a GPS receiver everywhere on or close the Globe.

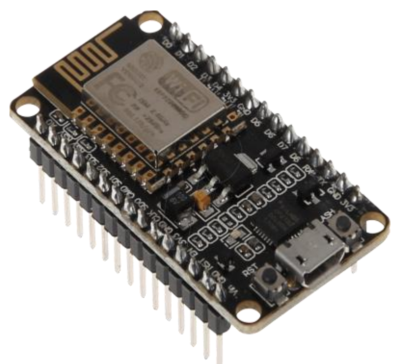
- **Power supply**: Monocrystalline solar panel with model: PWM Buck charge: 28.8V Float charge: 27.4V USB output: 5V/3A Working current: 10A

- **LED:** Led is in charge of providing headlights when there is a serious problem to help people who are unable to hear but who find themselves able to escape.
- **BUZZER:** buzzer is responsible for making noise when there is a problem but it is urgent for my people or to fix it if possible. to find out more by following this reference [19]

3.1.4.2 Communication Technology Requirements

The Internet of Things gateway is a visual tool or software program that serves as a point of communication between the cloud and controls, sensors and smart devices. All data sent to the cloud or vice versa enters the gateway, which may be a dedicated hardware device or software program. The IoT portal provides a complex representation of the conditions. The main tasks the IoT gateway perform are Data forwarding, Gateway management, Device management, Data analysis, and Diagnostics [14]. In Smart Soil Monitoring Application, **ESP8266 WiFi Module** is Gateway and **WiFi** as Communication Technology.

The ESP8266 WiFi Module is a self-contained SOC with an integrated stack of TCP / IP protocols that can give any microcontroller access to your WiFi network. ESP8266 is able to host an application or download all Wi-Fi communication activities from another application processor. Each ESP8266 module comes pre-configured with AT command set firmware, which means, you can simply integrate this into your Arduino device and get as much WiFi capability as the WiFi Shield. This module has sufficient processing and storage capacity of the board which allows it to be integrated with sensors and other device-specific devices using its GPIOs with fewer advanced upgrades and fewer loading during operation. The following figure shows the ESP8266 12-E chip pinout.



3.1.4.3 Cloud and IoT Analytics Platform requirements

In the simplest terms, cloud computing means storing and accessing data and programs over the internet instead of your computer's hard drive. The cloud is also not about having dedicated network-attached storage hardware or server in residence, it's as a service. Cloud computing is intelligent. With all the various data stored on the computers in a cloud, data mining and analysis are necessary to access that information in an intelligent manner [15]. Thing speaks an open source Internet and Things and API Internet application for storing and extracting data from HTTP and MQTT protocols online. It's an IoT analytics platform service that allows you to aggregate, visualize, and analyze data streams in the cloud [16].

3.1.4.4 Microcontroller Requirements and Specifications

The development of Landslide early notification requires a microcontroller Arduino Nano. Arduino Nano board based on ATmega328 (Arduino Nano 3.x). The Arduino Nano Pinout contains 14 digital anchors, 8 analog anchors, two reset anchors and 6 power anchors. Each of these Digital & Analog anchors is supplied with many functions but its main function is to perform as an input or output.

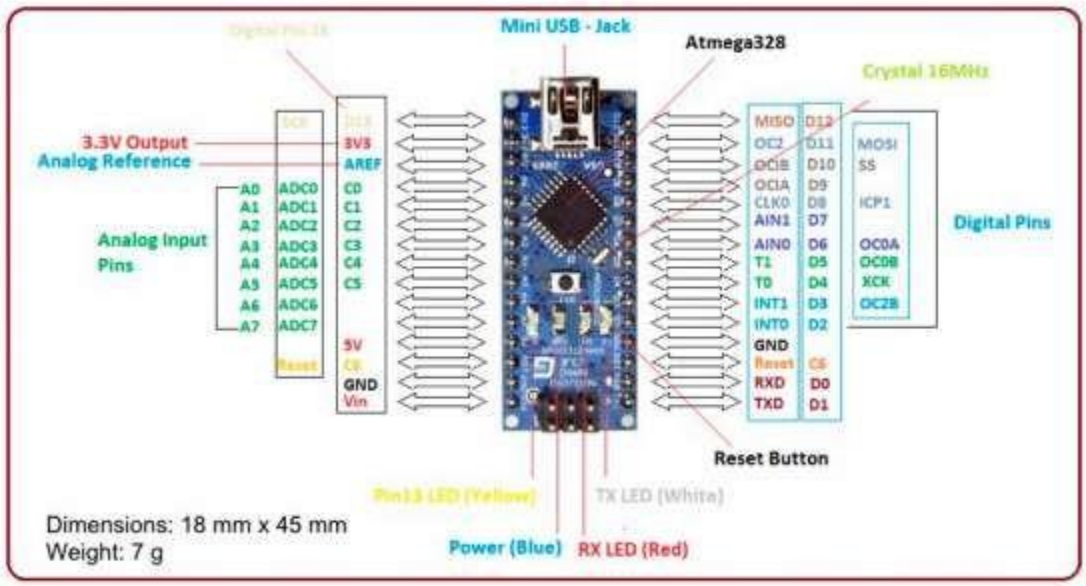


Figure 2: Arduino Nano

3.2 Design process

To develop Landslide Early Notification Based on the Internet of Things a Hardware-Software Code design approach is used. Software and Hardware circuit were developed separately then after an integration of both to produce an effective system. The following is a design process of the landslides early notification.

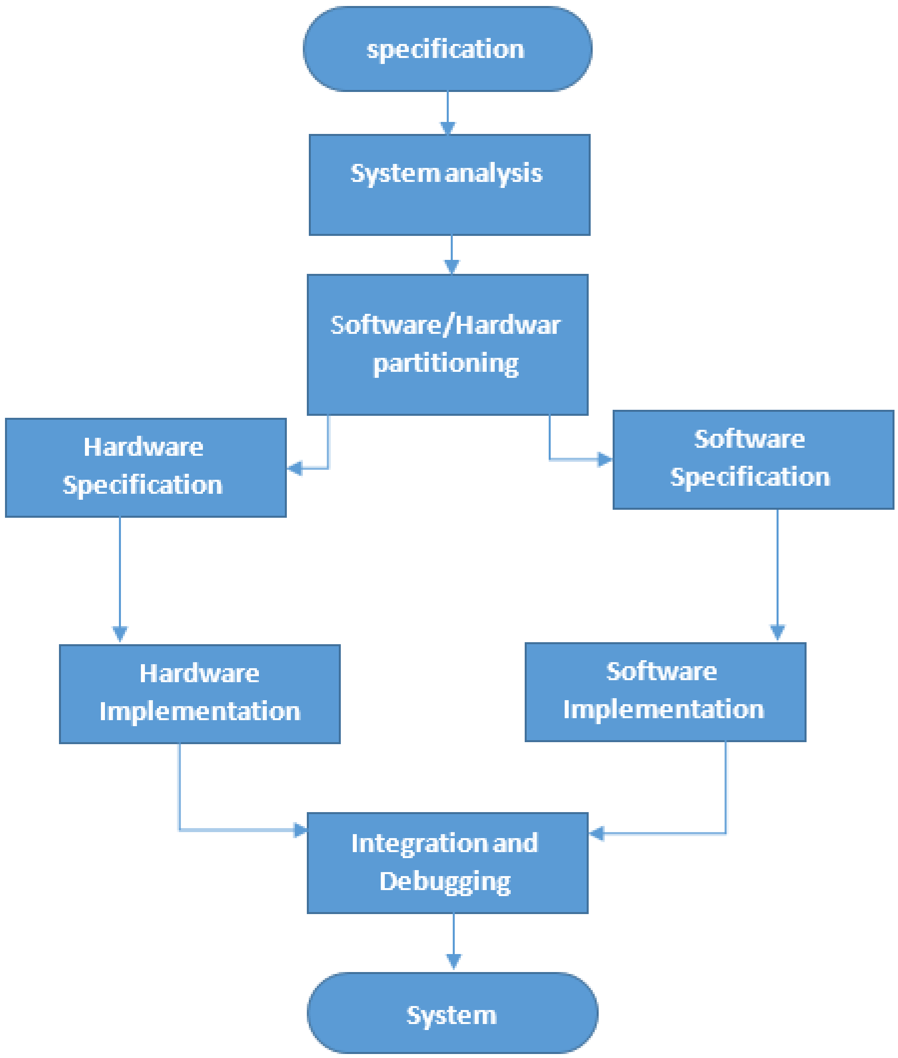


Figure 3: Design process

CHAP 4: SYSTEM ANALYSIS AND DESIGN

4.1 INTRODUCTION

This stage presents the purpose of designing the Landslide Early Notification Based on the Internet of Things. Also, systems analysis and design are used to analyze, design, and implement a prototype. This chapter demonstrates how people and administration of the system will interact with the system and shows the working process of the designed system for collecting the data from soil moisture and accelerometer as it will help then to notify the population.

4.2 SYSTEM MODEL

The Landslide Early Notification Based On Internet of Things system model discusses the monitoring of soil moisture and displacement by using soil moisture sensor and accelerometer sensor. Also, Landslide Early Notification Based on Internet of Things notification can be monitored on the cloud through the protocols such as HTTP and MQTT. This system must be deployed on the suspected mountain. Sensors collect data and send them to the system administration local storage or cloud then to notify the people around that suspected mountain. The following flowchart highlight the proposed system.

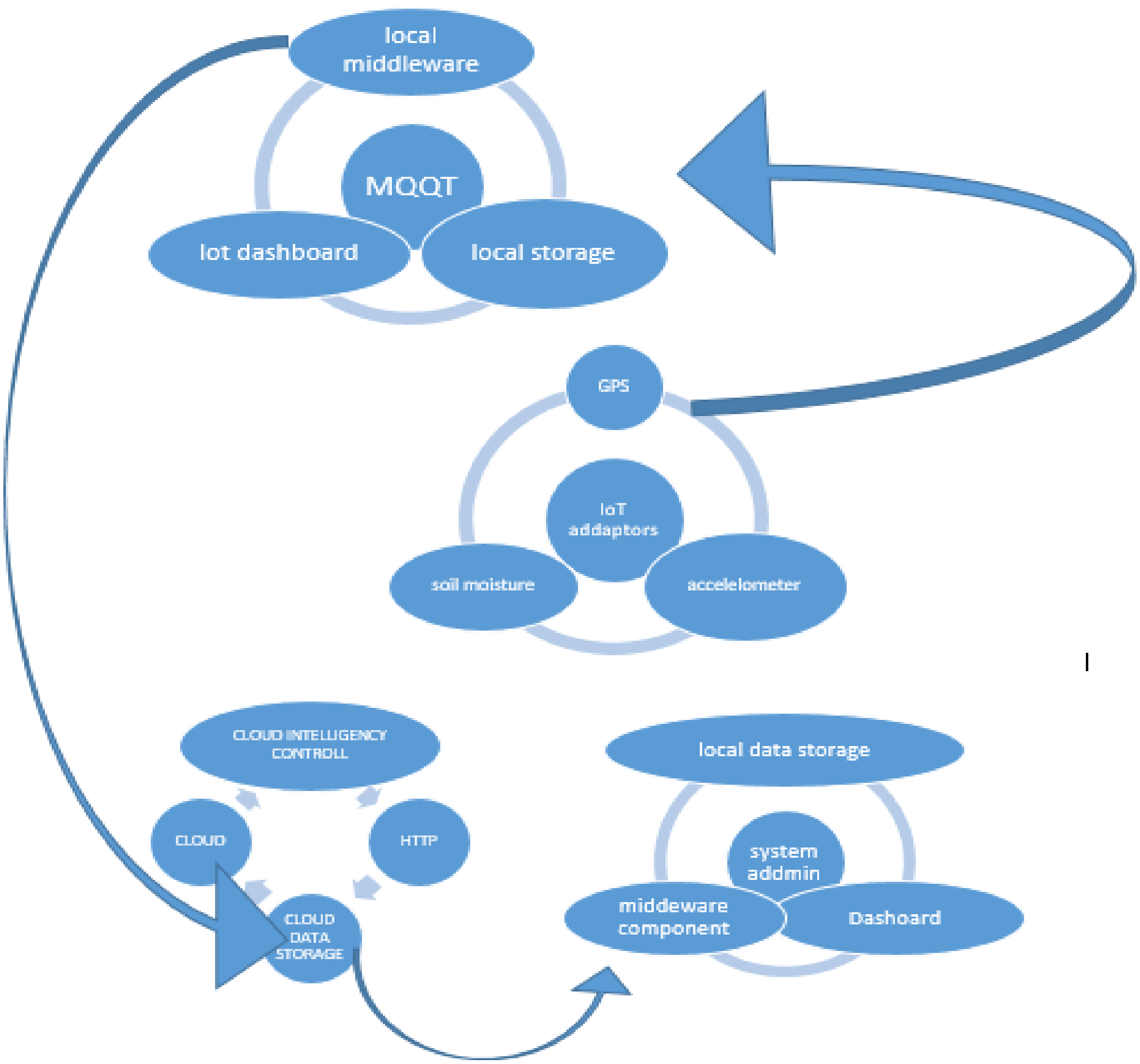


Figure 4: System model

4.3 SYSTEM AND ALGORITHM DESIGN

4.3.1 Architecture Overview

Landslide Early Notification Based on Internet of Things gives an overview of physical objects, sensors, cloud services, actuators, and IoT Protocols.

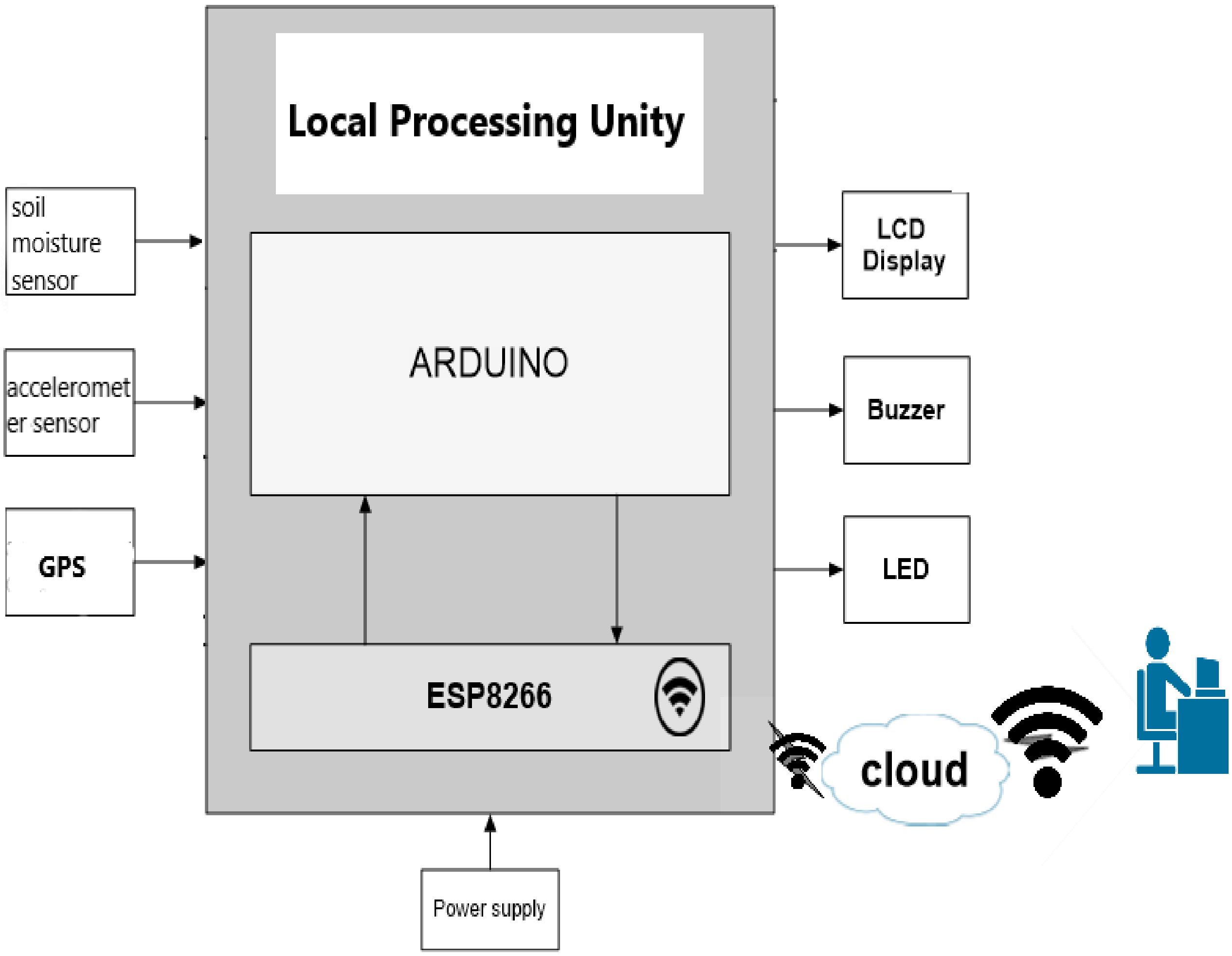


Figure 5: System architecture

4.3.2 Flowcharts Design

The following diagram indicates the flow of information from sensing data from sensors up to the end-users.

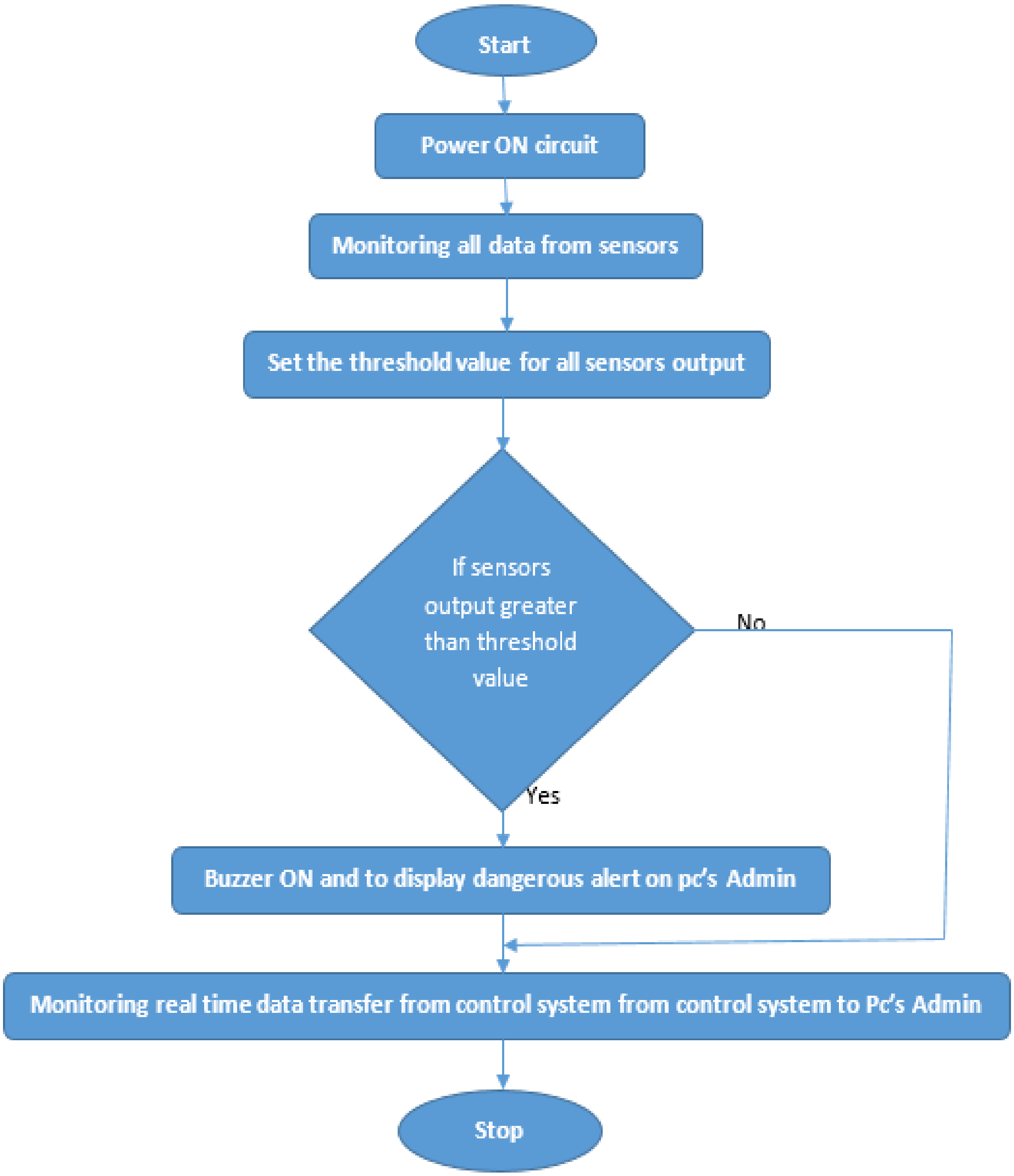


Figure 6:Flow chart design

4.3.3 Circuit Design

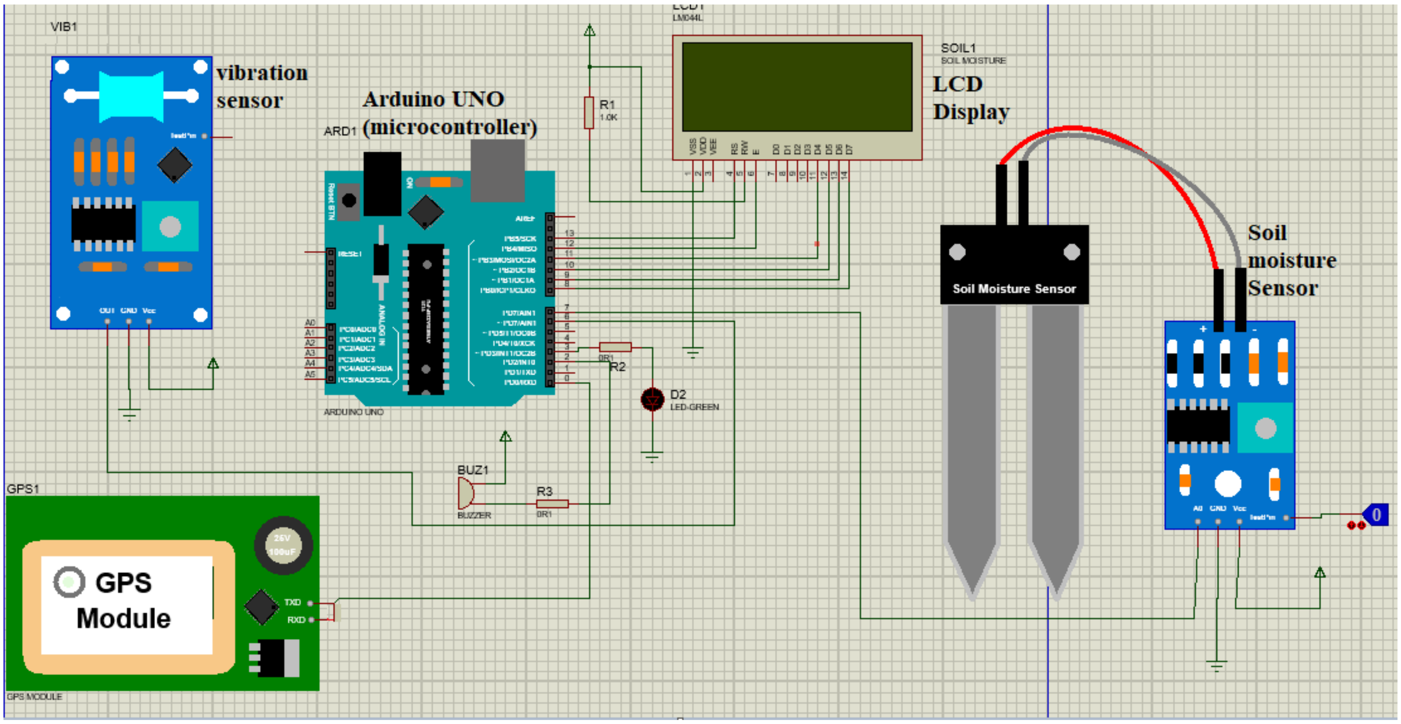


Figure 7: Circuit Diagram

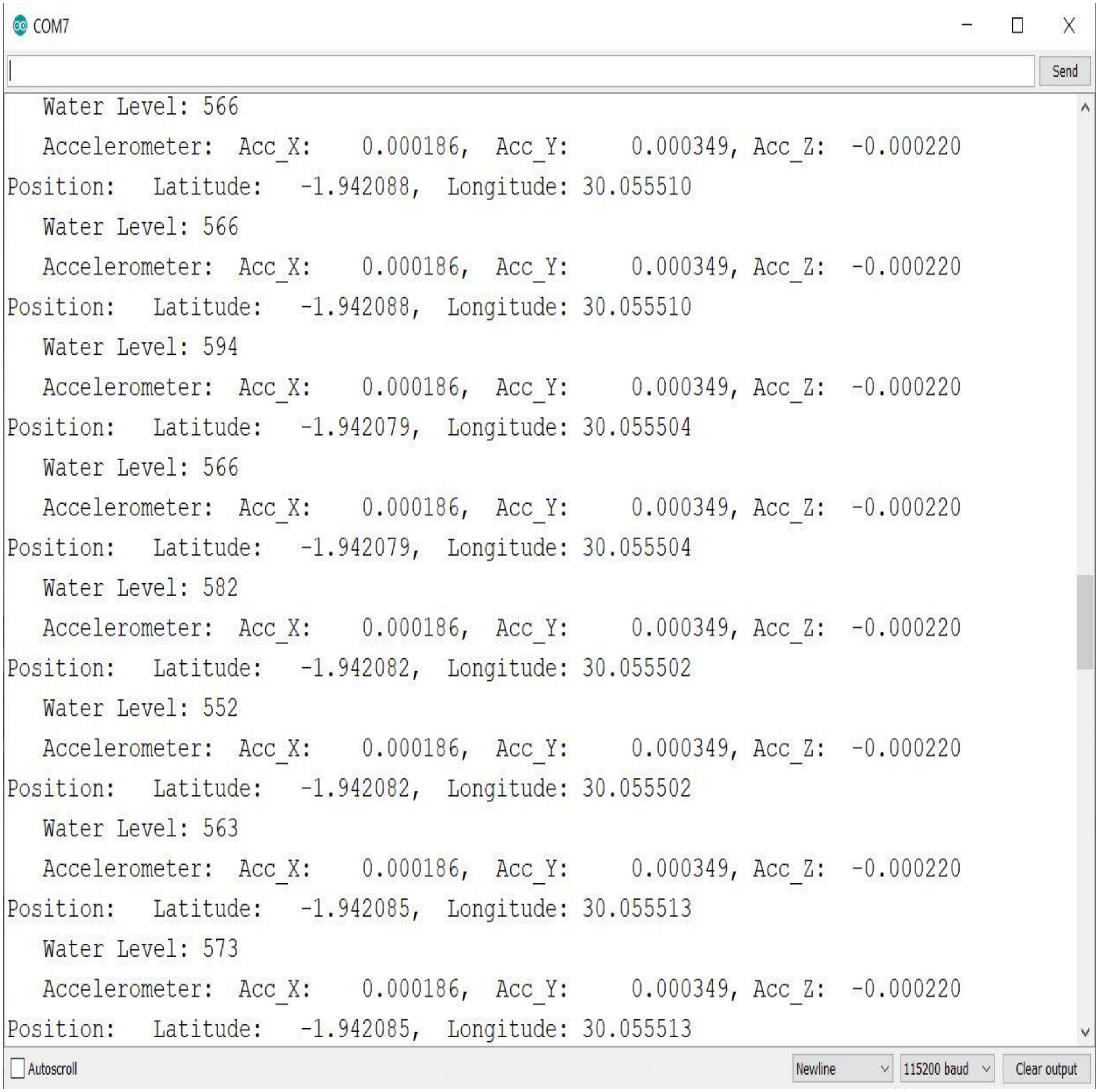
CHAPTER 5: RESULTS AND ANALYSIS

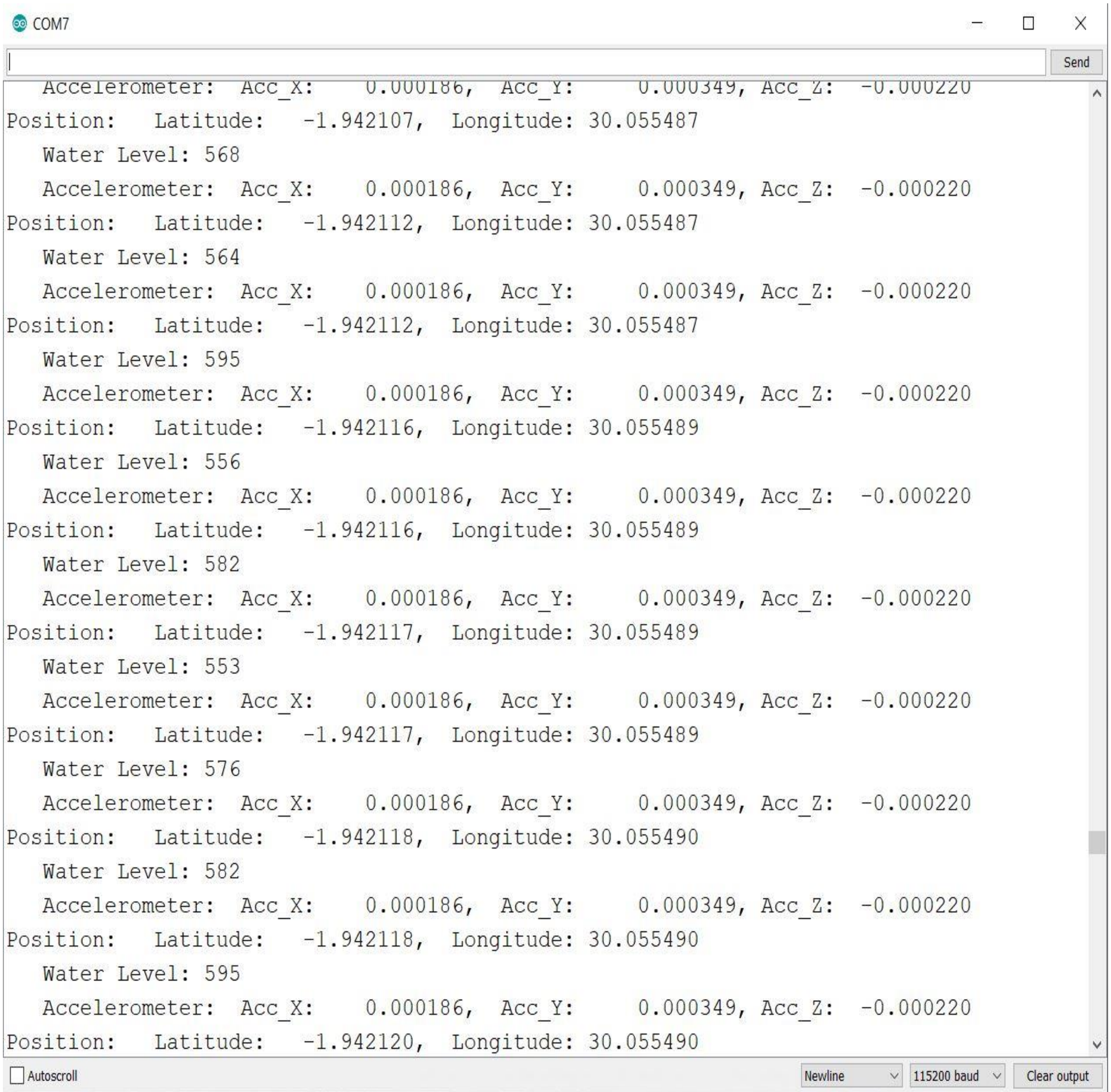
5.1 INTRODUCTION

The landslide Early Notification Based on the Internet of Things system is successfully implemented as a prototype. All the sensors and other components work as per the expectations. The sensors effectively sense the surrounding conditions like water in the soil and displacement of the soil in other to detect the landslides and give the readings. Based on the readings, the prediction of a landslide is achieved successfully therefore, verifying the research hypothesis. The system senses data and transmits it continuously. The system takes only less time to collect data from the sensor and transmit it to MQTT over the Wi-Fi module and also to upload data from MQTT to the IoT cloud where the administration can access them.

5.2 EVALUATION OF DATA ON THE FIELD (Serial Monitor)

Field information is the information that is provided by sensors immediately via Arduino that information via MQTT reaches the cloud where an end-user or administrator can access them and logically and easily anywhere at any time.


COM7
Send
Water Level: 566
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942088, Longitude: 30.055510
Water Level: 566
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942088, Longitude: 30.055510
Water Level: 594
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942079, Longitude: 30.055504
Water Level: 566
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942079, Longitude: 30.055504
Water Level: 582
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942082, Longitude: 30.055502
Water Level: 552
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942082, Longitude: 30.055502
Water Level: 563
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942085, Longitude: 30.055513
Water Level: 573
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942085, Longitude: 30.055513
Autoscroll
Newline
115200 baud
Clear output


COM7
Send
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942107, Longitude: 30.055487
Water Level: 568
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942112, Longitude: 30.055487
Water Level: 564
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942112, Longitude: 30.055487
Water Level: 595
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942116, Longitude: 30.055489
Water Level: 556
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942116, Longitude: 30.055489
Water Level: 582
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942117, Longitude: 30.055489
Water Level: 553
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942117, Longitude: 30.055489
Water Level: 576
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942118, Longitude: 30.055490
Water Level: 582
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942118, Longitude: 30.055490
Water Level: 595
Accelerometer: Acc_X: 0.000186, Acc_Y: 0.000349, Acc_Z: -0.000220
Position: Latitude: -1.942120, Longitude: 30.055490
Autoscroll
Newline
115200 baud
Clear output

5.3 EVALUATION OF MQTT DATA

5.3.1 EVALUATION OF MQTT DATA 1 (GPS Coordination with Soil wetness)

The information from the ground sensors first goes through the MQTT before it reaches the beneficiary. This information is in different ways depending on the sensor that provided them. The following figure shows the amount of water in the soil and the direction of the tube that holds the system so that the combination of this information we can determine if it is biased or in good standing.

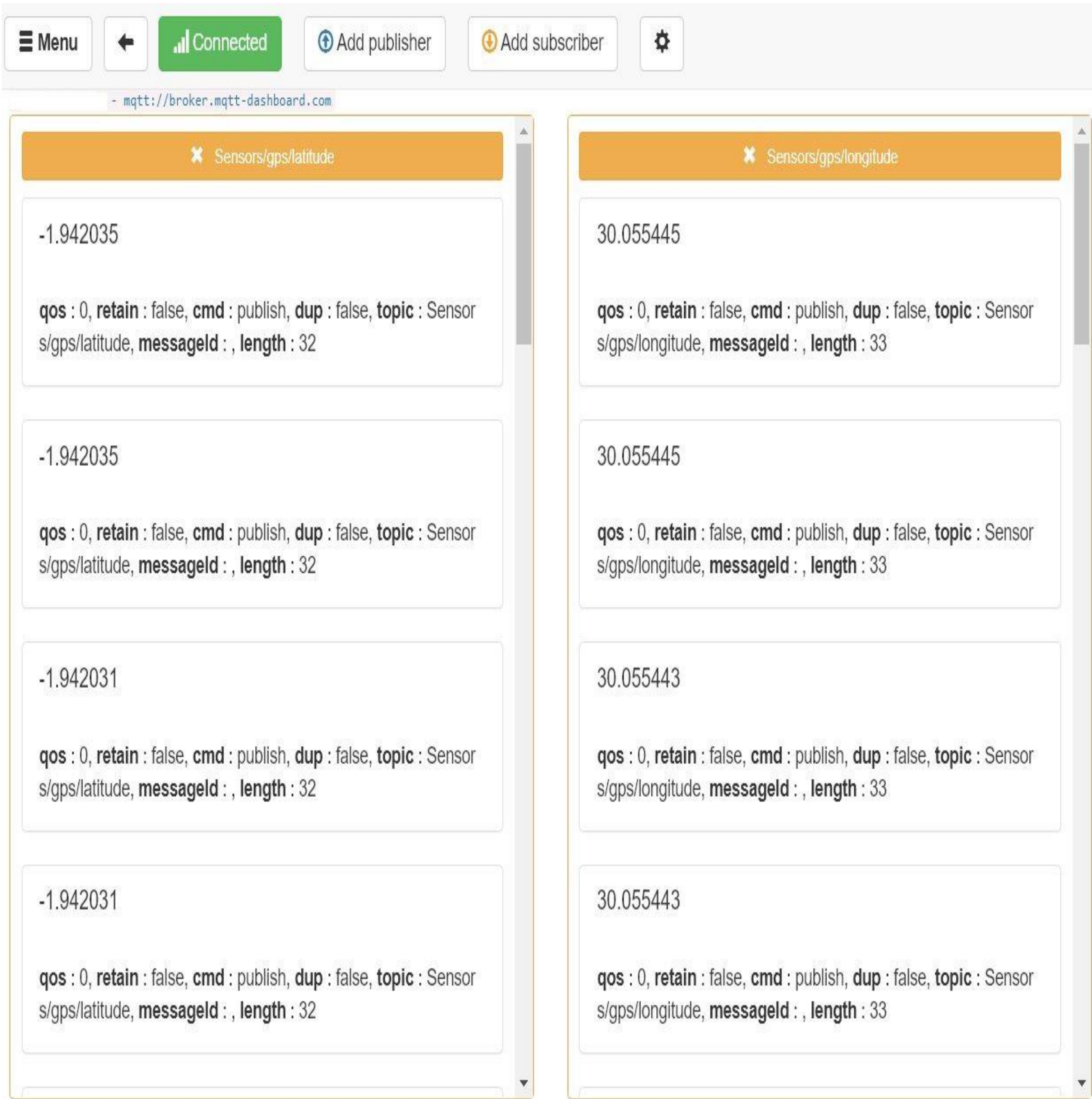


Figure 8 Evaluation of MQTT data 1 (GPS Coordination with Soil wetness) 1

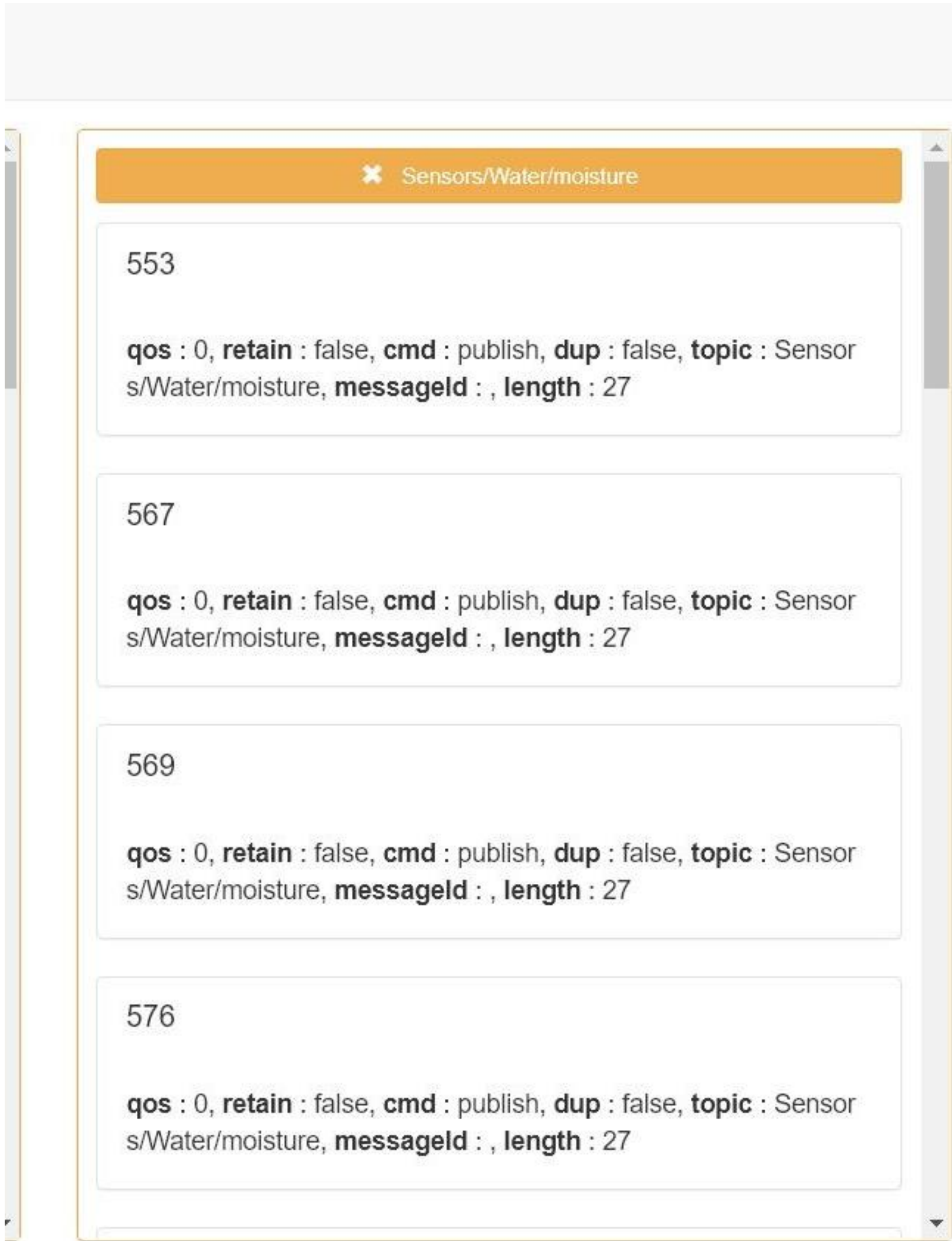


Figure 9 Evaluation of MQTT data 1 (GPS Coordination with Soil wetness) 2

5.3.2 EVALUATION OF MQTT DATA 2 (Accelerometer Sensor)

An accelerometer is a dynamic sensor capable of a vast range of senses. Accelerometers are available in measuring acceleration in one, two, or three axes [20]. in this system, the accelerometer sensor helps to know for sure if the tube holding the system is tilted or in good condition when connecting the information from this sensor and the GPS as well as water in the ground so that it can make a firm decision that the Landslides can occur at any time.

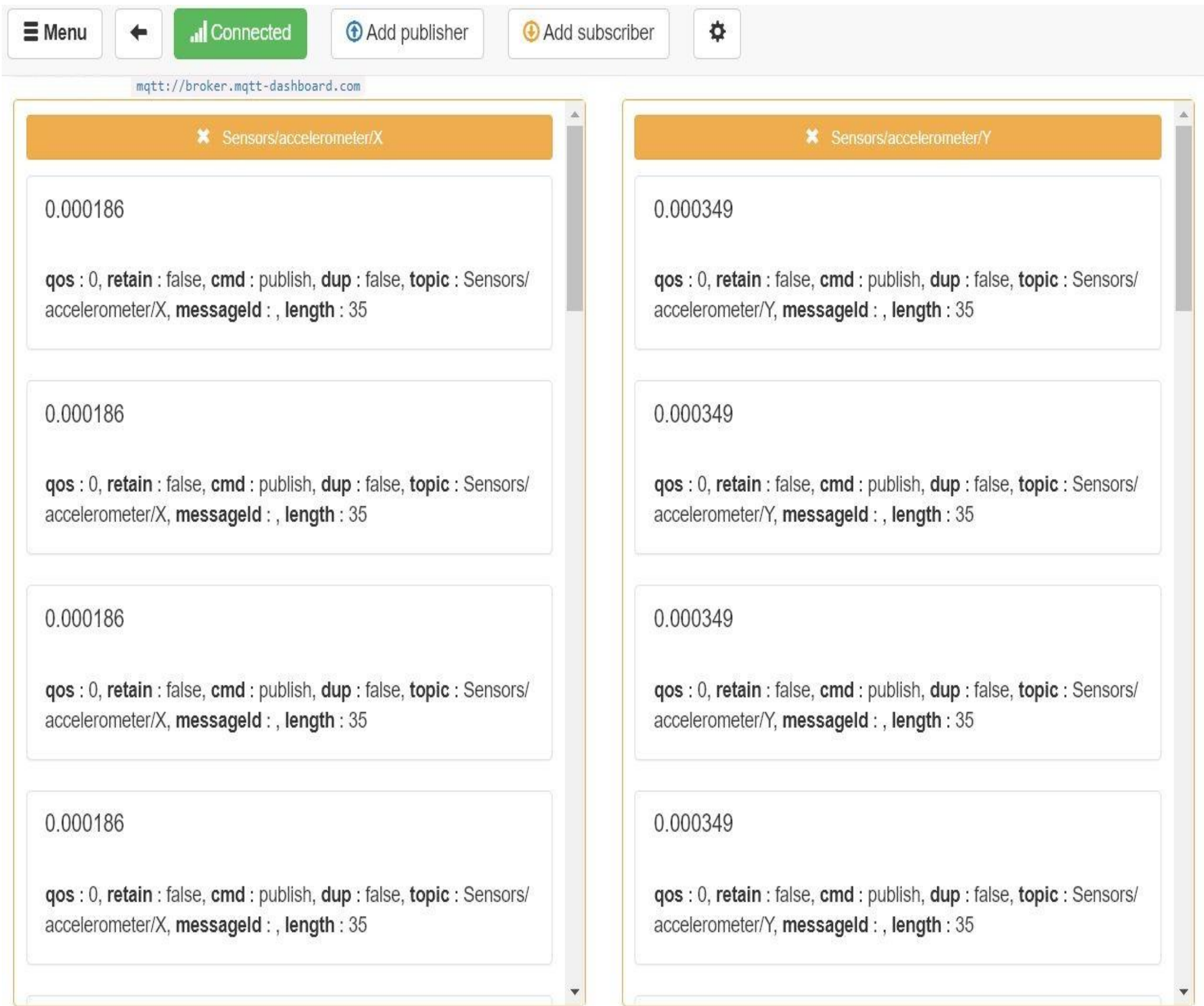


Figure 10: Evaluation of MQTT data 2 (Accelerometer Sensor) 1

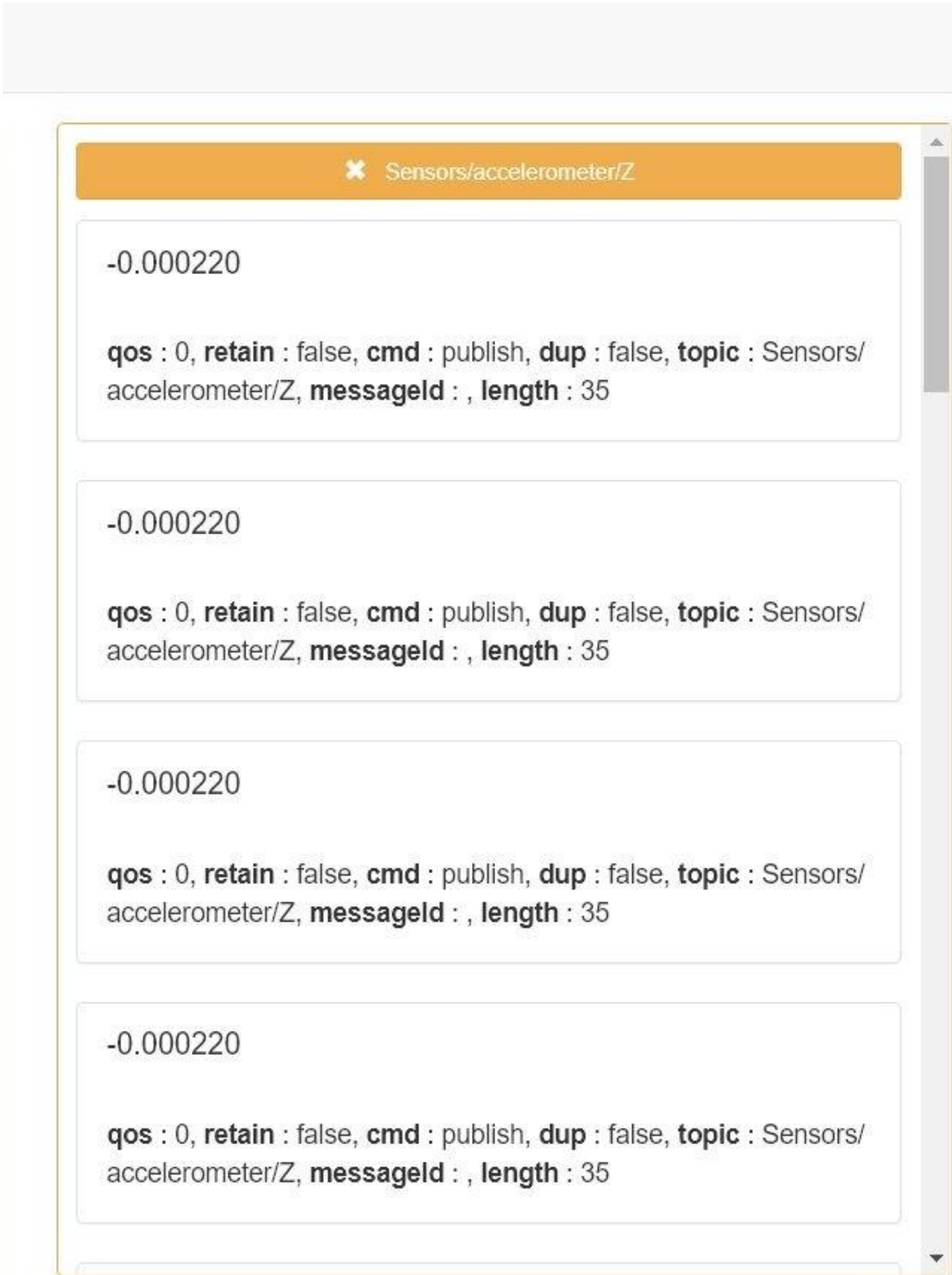


Figure 11 Figure 9: Evaluation of MQTT data 2 (Accelerometer Sensor) 2

5.4 EVALUATION OF LANDSLIDES EARLY NOTIFICATION BASED ON IoT

5.4.1 DASHBOARD WITH NO DANGER

A dashboard is a type of graphical user interface that often provides at-a-glance views of key performance indicators relevant to a particular objective and is considered a form of data visualization. The following dashboard shows the direction of the system tube's position, the amount of water in the ground, and when combined with the information from the accelerometer sensor data it indicates that the suspected mountain is not in danger, if danger is found then the system is supposed to warn the population of an imminent danger.

Figure 12 Dashboard with no danger 1

Figure 12 shows location data of the sensor placed on the mountain displaying default latitude and longitude, when there is a change in longitude and latitude it shows displacement of the mountain.

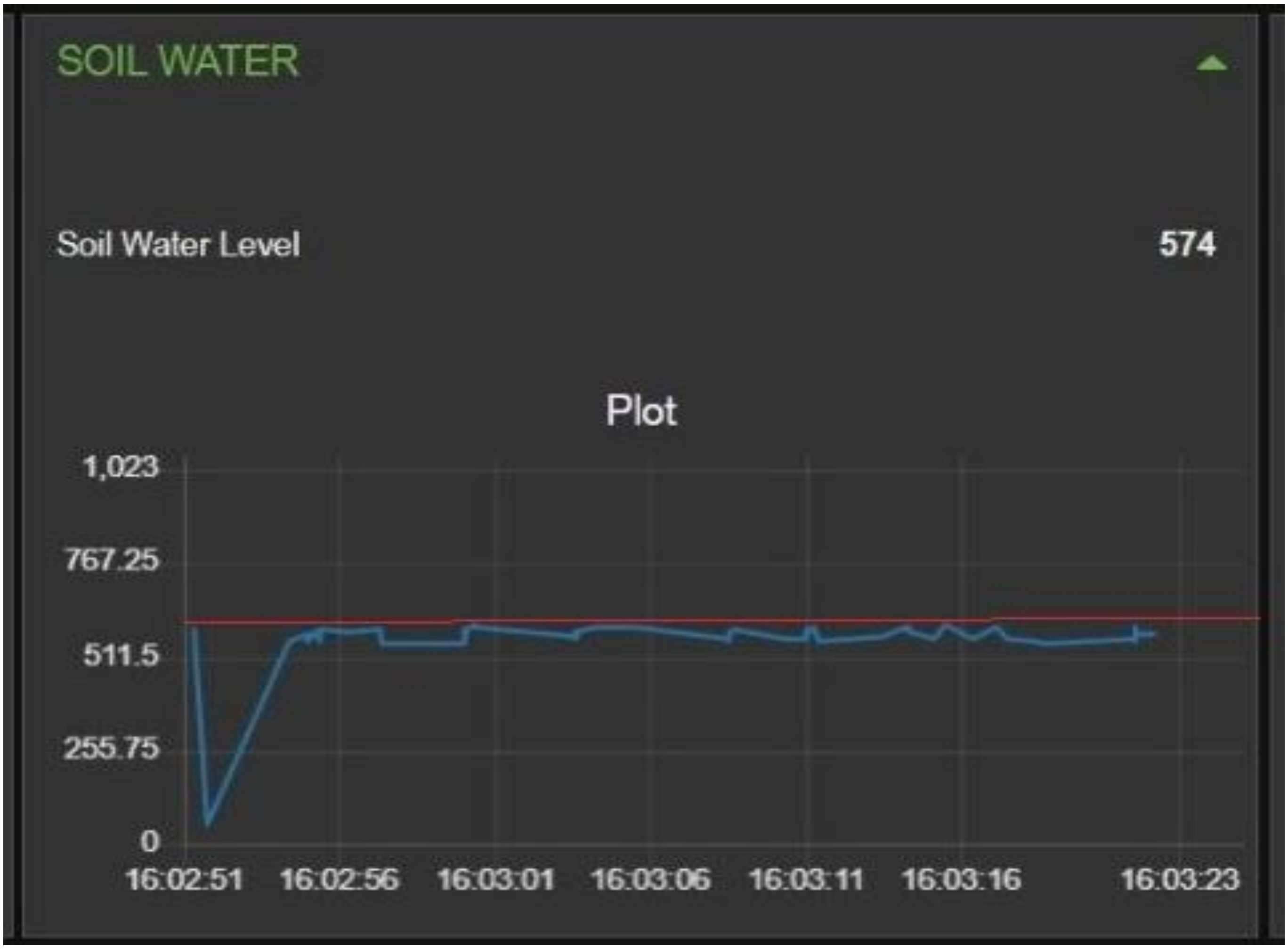


Figure 13 Dashboard with no danger 2

Figure 13 shows when the threshold was not reached which means there was no danger, the threshold is shown in the system displaying data collected by a red line, everything above that line is considered to generate a danger alert.

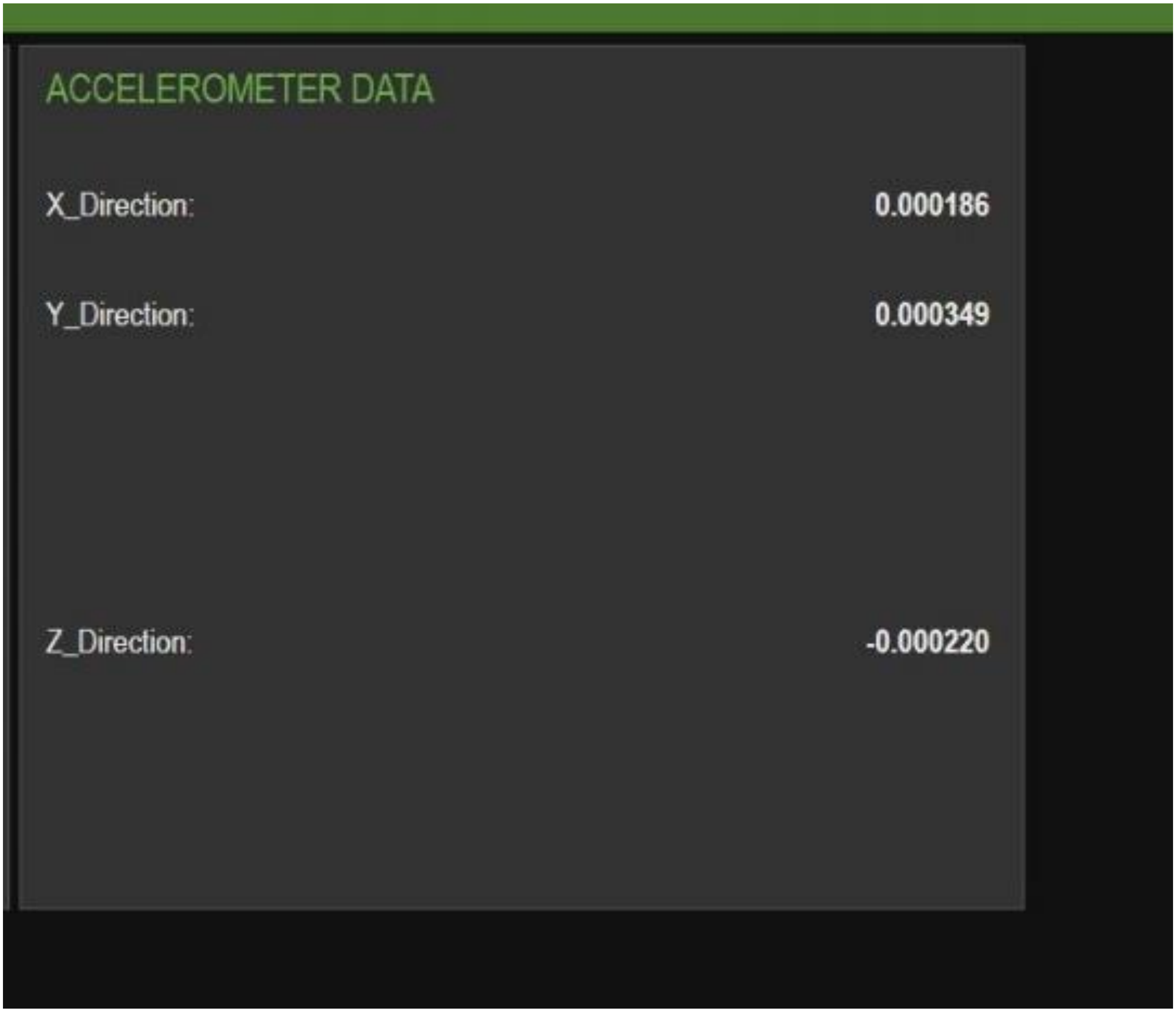


Figure 14 Dashboard with no danger 3

Figure 14 shows x, y and z axis data generated by the accelerometer sensor, by using data generated by the accelerometer and the GPS, those data are used for the purpose of knowing if there was displacement due to landslide.

5.4.2 DASHBOARD WITH DANGER

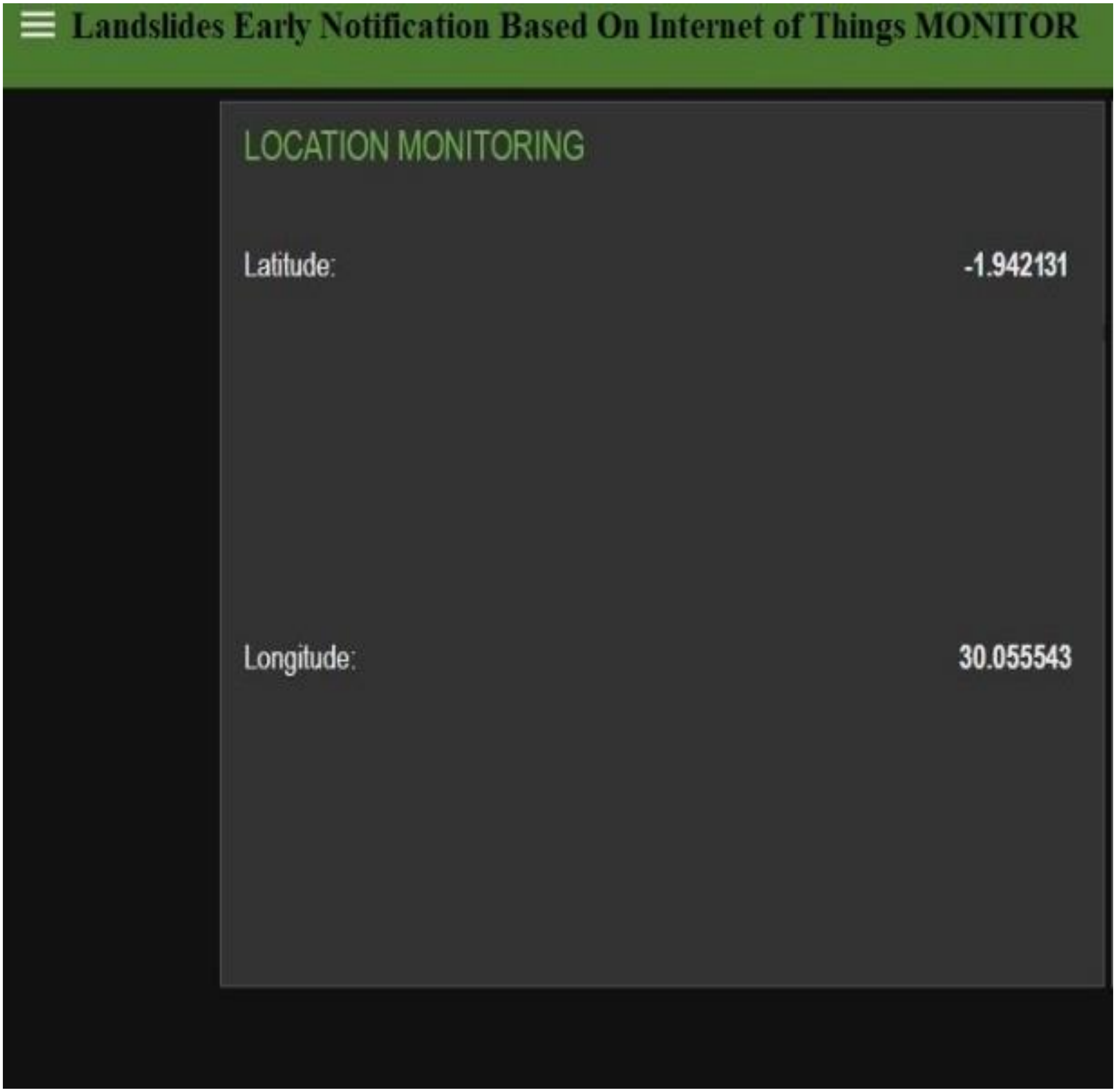


Figure 15 Dashboard with danger 1

Figure 15 shows location data of the sensor placed on the mountain displaying change in latitude and longitude, when there is a change in longitude and latitude it shows displacement of the mountain.

Figure 16 Dashboard with danger 2

Figure 16 shows when the threshold was reached which means there was danger, the threshold is shown in the system displaying data collected by a red line, everything above that line is considered to generate a danger alert. here after seeing that the ground is wet and there has been a change in latitude and longitude no doubt there should be a warning to the people near the mountain.

Figure 17 Dashboard with danger 3

Figure 17 shows x, y and z axis data generated by the accelerometer sensor, by using data generated by the accelerometer and the GPS, those data are used for the purpose of knowing if there was displacement due to landslide, it is not necessary for data from all three sensors to be changed before deciding, that data from two out of three sensors is enough to determine that the mountain is in trouble

CHAP 6 CONCLUSION

Real-time monitoring of landslides is one amongst the challenging research areas available today within the field of geophysical research. The Landslides Early Notification Based on IoT system is to detect those conditions which result in the occurrence of landslide and notify it well before time and ready to save the human loss. The current landslide detection and notification systems are less accurate. This system provides a real-time monitoring system and more accurate. easy and affordable to setup. In conclusion this system will help to cut down the cost of physical and manual monitoring. Even though natural disasters like landslides cannot be stop, however, damages can be substantially reduced through early notification, using IoT based systems can prepare and protect people from disasters accidents in this area.

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