Instrumentation system design and laboratory scale simulation of landslide disaster mitigation

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Abstract. Research on landslide has been developed recently because it may endanger human life. Landslide is the movement of rock, detritus, or soils caused by the action of gravity. Landslides are influenced by several factors such as ground slope, degree of rainfall, land cover (ground layers), and the vibration around the slopes. From these factors, tilt detection sensors and soil moisture sensor have been developed to detect landslide failure. These sensors mounted so that it can detect the occurrence of landslides. The study was conducted on a container which contains the sloping ground. Landslide, slope processes, and soil humidity were investigated in this container. MMA8451Q accelerometer was used as a tilt sensor to detect the acceleration assembled in MEMS (Micro Mechanical System) technology since it is easily available, mass-produced, inexpensive, and high-precision output data. Landslide simulator has been developed hence the process leading to landslide event can be directly analyzed without the need of real life occurrence of landslides. The simulator was made from glass with size 80 cm × 20 cm × 40 cm that was filled by soil. Based on the simulation results, there were changes on accelerometer and soil moisture data during the landslide occurrence.

1. Introduction

Research on landslide has been an intriguing topic in disaster mitigation. There are many methods that have been utilized in this research, such as retaining walls and ground anchors to anticipate landslides. Nevertheless, these methods have obstacles for several reasons, such as its operating cost and ineffectiveness in wider slopes [1,2].

An alternative solution to the aforementioned problems is designing an early warning system that incorporates low cost sensors which are installed in slopes. The designed system is comprised of an accelerometer to identify the change in slope gradient and a moisture sensor to detect soil water content. This system was arranged in a laboratory scale to observe the parameters that lead to landslides.

Recently, a laboratory scale landslide simulator was developed by de Dios et al. [3]. This system consisted of a box with a size of 2.43 m × 1.21 m × 1.21 m with soil inserted to the box. A module of sensors that is made up of a tilt sensor LIS3LV02DL with a range of (+/- 2 g) and sensitivity of 1024 lsb/g, moisture sensor, and pressure sensor planted in the soil [3,4]. However, the box used took an

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extensive space, so a more space-effective equipment would be needed. Therefore, in this research a smaller box with a size of 80 cm × 40 cm × 20 cm was made, and a sensor of greater sensitivity (4096 lsb/g) and range (2g, 4g, and 8g) equipped the box. Furthermore, the instrumentation system for landslide detection and monitoring was developed and thoroughly discussed.

2. Design and calibration
The instrumentation hardware is divided into three main parts. The first part is detectors which consist of the MMA8451Q GY-45 triaxial accelerometer and FC-28-C soil humidity sensor. This part serves as data collector from measured physical quantities. The triaxial accelerometer serves as a slope detector of the land while the moisture sensor identifies the level of water content in the soil. The forms of data are digital for the triaxial accelerometer and analog for the moisture sensor. Both sensors are integrated to detect the states of the ground movement during the occurrence of landslides. The second part of the hardware is a controller. It uses the ATMEGA328 microcontroller to control the sensors and communicate between interface and hardware which will be displayed in a computer [5]. The triaxial accelerometer communicates with the microcontroller using the I2C (Inter-Integrated Circuit) interface, while the moisture sensor uses the SPI (Serial Peripheral Interface) due to their forms of data [6,7]. The third part is outputs which consist of a computer that displays the data from the microcontroller using the serial communication. The schematic diagram of the system is shown in Fig. 1.

![Schematic of designed system](image)

Figure 1. Schematic of designed system

3. Landslide simulator system design

For simulating the landslide occurrence, a chamber as landslide simulator has been made in laboratory scale. This chamber was made of a glass with size 80 cm × 40 cm × 20 cm [8]. The inner part of the chamber was filled by soil in which its slope can be arranged to identify landslides. The sensor module containing three triaxial accelerometers was installed inside the chamber to detect the tilted state of landslide and a moisture sensor. The sensor module was made of a PVC (Polivynil Chloride) pipe with
a diameter of 2 cm with a height of 60 cm. The pipe was made into 3 segments that can change shape according to the state of the ground. Each segment has an accelerometer sensor to identify the simulated ground movement while the moisture sensor was placed in the bottom one. The schematics of landslide simulation chamber and sensors module are given in Fig. 2. Figure 3 demonstrates the landslide simulation chamber with soil inside it.

![Image](image.jpg)

**Figure 3.** The developed landslide simulator

### 4. Result and Discussion

Simulator was conducted by pouring the chamber in figure 3 with water as artificial rain in area about 6 cm with water flow of 50 mL/sec. The water flow was given periodically until the soil surface changes or shifts. Land deformation occurred significantly after the fifth water was discharged or after 2.5 liters of water infiltrated into the soil as shown in Table 1. Moreover, the landslide occurred between 15:15:38-15:16:40. This event was relatively rapid considering the sensor module moved and fell quickly. This is consistent with the changes shown in the graphic of accelerometer movement and the variation of soil moisture in Figure 4.

| Time       | Notes                        |
|------------|------------------------------|
| 15:14:40   | First water pouring (500 mL) |
| 15:15:07   | Second water pouring (500 mL)|
| 15:15:35   | Third water pouring (500 mL) |
| 15:16:02   | Fourth water pouring (500 mL)|
| 15:16:30   | Fifth water pouring (500 mL) |
| 15:16:38   | Start of landslide event      |
| 15:16:40   | End of landslide event        |

The landslide simulation result is shown in figure 4. Figure 4a shows change in x-axis, figure 4b shows change axis, and 4 c in z-axis. It is evident that in 15:14:40, 15:15:07, 15:15:35, 15:16:02, 15:16:30 a change of data is observed. This deviation occurred because of vibration induced by poured water. The vibration caused the accelerometer to respond by giving unstable output. The largest accelerometer value occurred at 15:16:33 that indicated a deformation had appeared.

The landslides occurrence in this simulation was indicated by the ground shifting around the sensor or the position change of the sensor. In this state, the sensor position changed quickly between 1-2 second and the sensor then felt. It was caused by the push of surface soil on the measurement system. The graph shown in figure 4 is the position of x, y, and z axis as the simulation progressed. The moisture data change during the simulation is displayed in figure 5.
Figure 4. (a) X-, (b) Y-, and (c) Z-axis acceleration vs. time during the simulation. A significant change occurred during the fifth pouring.

Figure 5. The change of soil moisture during the simulation.

Significant changes occurred when the amount of water given on the simulation were about 2 liters. Figure 5 show clearly changed when water was given in stepped pouring. In the fifth pouring, at 15:16:38 there was immense change of soil moisture (0.2 V – 0.8 V) which caused by the falling of module sensor due to landslides. The landslide event is indicated to occur when the 0.2 V of output voltage is reached.
5. Conclusion
The instrumentation system and lab scale simulator for landslide disaster mitigation has been developed. The output data of the slope was obtained from the sensor module before and after the landslide along with the time progression. A change in soil moisture chart was also obtained before and after the occurrence of landslides in accordance with the time (real time). The slope failure occurred in simulation when the moisture of the soil was measured around 0.2 V.

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