A Prototype of D.I.Y. Landslide Alarm

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Abstract: Landslides can be described as a movement of soil, debris or rock down a slope caused by earthquake, rainfall or rapid snow melts. Many years back, it was considered as a potential hazard that can kill dozens of lives when not properly addressed. In the Philippines, many areas around certain regions are located in the possible hazardous places of a landslide. In order to address this problem, the researchers have created a device that can alert people regarding an upcoming landslide event. A wide array of literature has also created this kind of device and many of them are very successful. The researchers used different sensors like Acceleration and Gyroscope Sensor, Water Flow Sensor, and Soil Moisture Sensor to determine certain thresholds which can foretell an upcoming landslide. Each sensor has been tested in a variety of methods to establish the accuracy and functionality which is crucial for this kind of device. The researchers have found out the correct configuration of sensors so that they can be effective and useful. Just like any other mechanisms, a false alarm can always be expected. That is why the researchers are continuing to improve the prototype's functionality. The researchers recommend determining the quality of the sensors that are going to be used so that false alarms and other malfunctions can be prevented.

Key Words: low-cost; landslide alarm; do-it-yourself; sensors; modules; microcontroller

1. INTRODUCTION

Background of the Study

Landslides are one of the most dangerous geohazards world-wide and constitute a serious menace for public safety leading to human and economic losses (Park, 2011, cited by Formetta et al., 2016). Every year, thousands of lives are taken away by this unexpected slope failure while also destroying economical and infrastructural assets. It is impossible to stop a slope from failing but there are ways to mitigate or reduce the risk of slope failure (Akbar & Chen, 2017). The production and creation of different landslide alarms is evolving every day to perfectly suit the phenomenon itself (Ismail et al., 2017). In conceptualizing an early warning device, the possible threats like slope failure and heavy rainfall must be considered and taken into account. Possible ground movements require mechanisms that can detect slight changes in a slope's altitude and shall therefore be also present in the prototype's start up (Arbanas et al., 2011).

The phenomenon leads to the development of different types of early warning systems specifically designed to take the attention of the local community living in a landslide prone area. Early Warning Systems (EWSs) are defined as monitoring devices that can be applied to reduce the risk of natural hazards. They can warn a certain area for an incoming phenomenon that may otherwise be lethal if not acted upon immediately (Medina-Cetina & Nadim, 2008 cited by Intrieri et al., 2013).

Many scientific groups have already created certain landslide alarms that use different methods of gathering data. An example of this is the utilization of ALOS / PALSAR imagery based on geomorphological satellite data interpretation to monitor landslide events (Schlögel et al., 2015). Certain research used a Geocube system with GPS sensors that span at a distance of at least 5 km which is capable of observing and monitoring the behavior of avalanches (Benoit et al., 2015).

Central Problem

As the future progresses, the locals need a more precise and accurate way of predicting landslides. A landslide alarm system that is cost-effective and easily understood without that need of increasingly complex mechanisms too advanced for those who are living near a landslide prone area, will significantly affect their living. This study aims to explore the possibility of creating a practical and simple landslide alarm system that can warn locals regarding a possible landslide incident in their area.

Theories

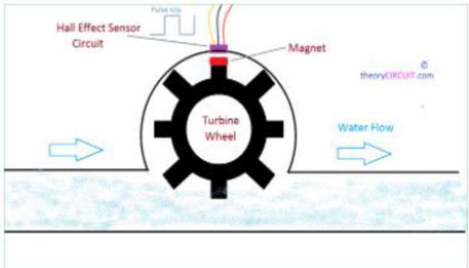

Figure 1. *Hall Effect Theory*

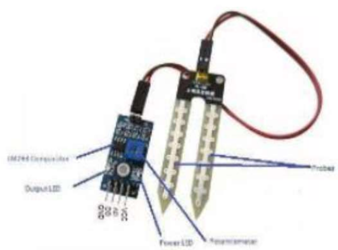

Figure 2. *Soil Moisture Sensor Mechanism*

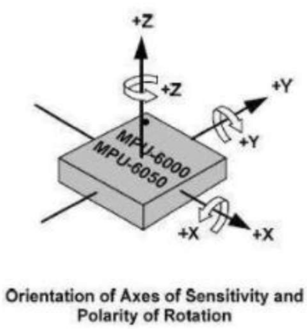

Figure 3. *MPU-6050 Sensitivity*

Theoretical Framework

As shown in the first theory, the Hall Effect is utilized by a sensor called, Water Flow Sensor. The Hall Effect is the production of a voltage difference across an electrical conductor, transverse to an electric current in the conductor and a magnetic field perpendicular to the current Hall Effect sensors are used for proximity switching, positioning, speed detection, and current sensing applications (Suresh et al., 2014). The sensor can measure the flow rate of the fluid within the range of 1-30 liters per minute and can withstand water pressure less than or equal to 2.0 MPa. This sensor can be used to determine the volume of water that has passed through it. Therefore, it can be applicable as a rain gauge that will measure the volume of the rain that has already penetrated it.

The second theory pertains to the mechanism of a sensor called Soil Moisture Sensor. The soil moisture sensor is provided as a pair of cylindrical rods each coated with a thin layer of dielectric material, which is buried in the soil or other medium and is connected to a conversion circuit in which the electrodes act as a variable capacitance (Gluck et al., 1994). The soil moisture content of land masses affects the capability of soil to be stable. The higher soil moisture content the soil has, the more possible a landslide incident will occur.

The third theory talks about the sensor called MPU 6050. The MPU-6500 sensor is a 3-axis accelerometer and 3-axis gyroscope that can detect changes in a system's movement. It has a power consumption of 3-5 volts and can detect even the slightest concussions. This kind of sensor is also used for fall detection for senior citizens (Jefiza et al., 2017). Landslide systems shall have this kind of sensor to monitor the movement of the soil. The sensor, integrated to the prototype, can increase the functionality of the system.

Research Questions
Below are the proposed research questions that will be discussed in this study:
Proposed research questions:
What is the functionality level of the sensors?
soil moisture sensor b. water flow sensor
What is the difference between the functionality levels of the Prototype in terms of types of soil?
Is there a significant difference between the functionality levels of the Prototype in terms of types of soil?

Ho: There is no significant difference between the functionality level of the Prototype in terms of types of soil.

2. METHODOLOGY

2.1 Product Design

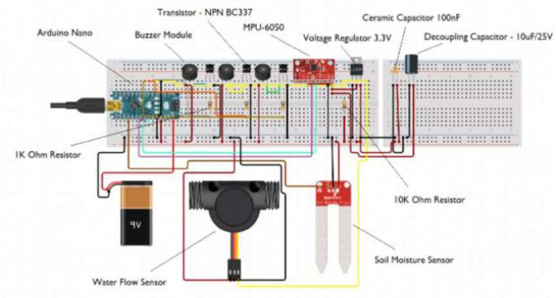

Figure 4. *Pictorial representation of the Prototype*

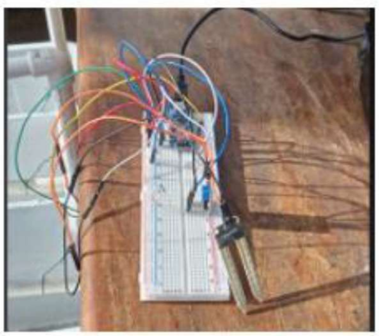

Figure 5. *Actual design of the Prototype*

2.2 Research Method

To ensure the functionality and efficacy of the prototype, the researchers have created several testing simulations for each of the sensors. The water flow sensor, soil moisture sensor, and the MPU-6050 were tested accordingly with different procedures to obtain necessary data that will then be used in further processing. The researchers were guided by a professional when the sensors were tested.

2.3 Data Collection Tool

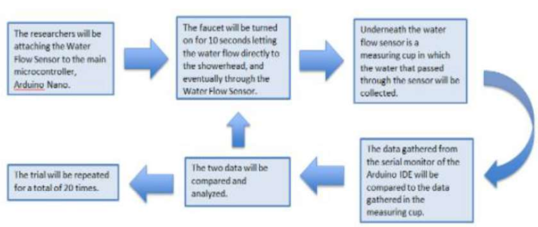

Figure 6. *Water Flow Sensor Trial*

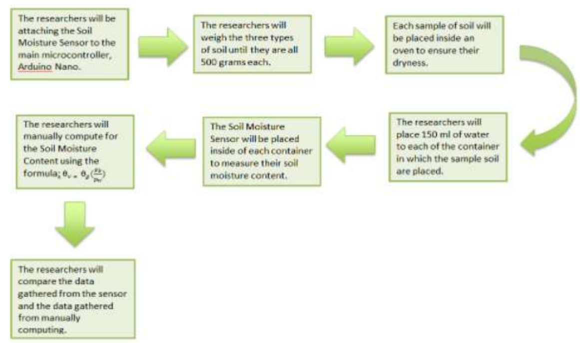

Figure 7. *Soil Moisture Sensor Trial*

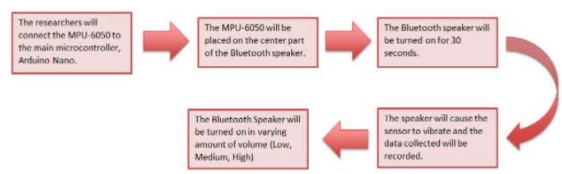

Figure 8. *MPU-6050 Sensor*

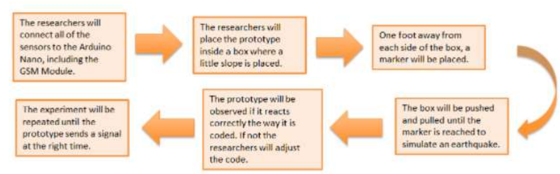

Figure 9. *Movement Trials*

2.4 Data Analysis

The statistical tool used by the researchers was One-way Analysis of Variance.This method is defined by the comparison of means from two or more samples. The statistical tool Percent Error was also used to determine the Accuracy and Reliability.

3. RESULTS AND DISCUSSION

Presentation of Data

The data gathered was based on the inquiry and presented by the research questions as follows:
What is the functionality level of the sensors?
(Accuracy Rate)
Soil Moisture Sensor
Water Flow Sensor

Table 1. *Soil Moisture Sensor Trials*

	Wet Weight	Dry Weight	Soil Moisture Data (Experimental)	Computed Data (Expected)
Sand	655 g	500 g	42%	45.6%
Loam	694 g	500 g	55%	40%
Clay	641 g	500 g	42%	42%

Table 2. *Water Flow Sensor Trials*

Experimental (ml)	Expected (ml)
66	120
171	140
207	160
117	250
184	145
232	165
173	155
128	140
63	115
150	150
47	105
458	260
74	80
52	80
94	125
88	120
74	120
60	130
35	100
211	155
192	130
175	170

Based on the gathered data from the trials conducted, the percentage error of the soil moisture sensor on sand, loam, and clay is approximately equal to 37.5%, 7.9%, and 0% respectively. To calculate these values, the researchers have used the formula stated on the methodology that relates the bulk density of each type of the soil to the volumetric soil moisture content.

After the Volumetric Soil Moisture Content is calculated, the percentage error can now be computed using the Percentage Error formula. This gives rise to the percentage error presented above.

The computation for the Percentage Error of the Water Flow Sensor comes from the mean value of both the experimental value and the expected values, which are 152.55ml and 155.75 ml, respectively. The formula for the Percentage Error, that is used for both the Soil Moisture Sensor and the Water Flow Sensor, is as follows:

$$Percentage\ Error = \frac{experimental - expected}{expected} * 100 \quad (1.1)$$

The water flow sensor gave off a percentage error of 2.07%, significantly lower, thus, can be concluded, more accurate. The researchers have conducted the same experiment 22 times to gather enough data for this value to be derived. This percentage error value can signal that the water flow sensor can be fully integrated to the prototype to increase its overall functionality.

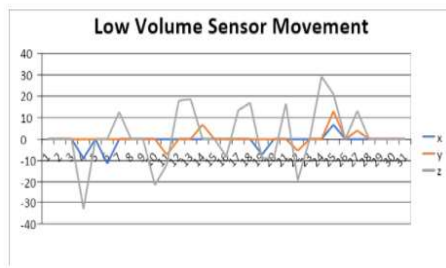

Figure 10. *Low Volume Gyroscope Trials*

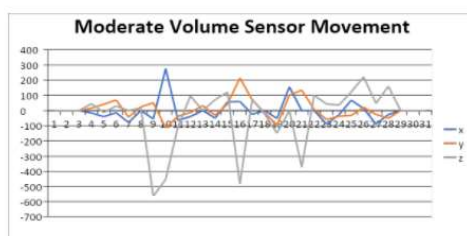

Figure 11. *Moderate Volume Gyroscope Trials*

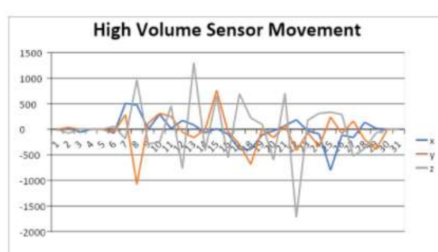

Figure 12. *High Volume Gyroscope Trials*

The MPU-6050 / Gyroscope's trials gave the result that the researchers expected. The ups and downs of the graph are proportional to the volume of the speaker which causes the vibration. The movements caused by this commotion reflect the expected outcome thus, proving its nonparametric functionality.

2. What is the difference between the functionality levels of the Prototype in terms of types of soil?

Table 3. *Prototype Trials*

Sand	Loam	Clay
5.23s	3.22s	4.46s
2.17s	4.26s	3.51s
4.5s	3.39s	4.07s

*Note.*The amount of time the prototype took to send an output signal (seconds)

The researchers have found out that the type of soil on which the soil moisture sensor is inserted affects the output data it can collect. As presented in Figure 15, the type of soil with the highest percentage error is loam. The researchers hypothesized that this phenomenon happens because of the impurities found in loam soil that affects the conductivity of the sensor itself. The variety of sawdust, rice straw and other organic materials are insulators that prevent the sensor from giving the right output, thus having a higher percentage error.

Trials conducted in sand gave off a significantly lower percentage error compared with loam. The fact that sand has more spaces in between each particle means that water can easily sink at the bottom of the container. This means that the data collected from the sensor can be off, the researchers hypothesized, for a certain margin because of this phenomenon.

The clay seems to be the best type of soil on which the sensor could work on. With a percentage error of 0%, the researchers believed that this is because of the fact that clay naturally sips water and distributes it equally in all parts. That is why the sensor readings are far more reliable since there are no impurities nor does water easily sink. This data however, is still inconclusive. Further trials must be conducted to truly identify the sensor's functionality.

3. Is there a significant difference between the functionality levels of the Prototype in terms of types of soil?

Table 4. *ANOVA: Single Factor for the three type types of Soil*

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.2721556	2	0.136078	0.131965	0.878847	5.143253
Within Groups	6.187	6	1.031167			
Total	6.4591556	8				

The researchers have also found out that the variety of soil did not affect the efficiency of the prototype's signal efficiency as shown in Figure 16. Also, in Figure it showed that the p-value is greater than the level of significance, hence, the null hypothesis is accepted.

Based on the works of Purnomo (2019), who had used a very similar methodology to this research, an instantaneous distance shift within the smallest scale of 0.4 mm can indicate a landslide event. They have created a system on which the significant data input came from the soil; whereas this research mostly relies on the data given by the atmosphere for it may also indicate a landslide event. The difference in this data structure can be varying at different times for there is a more suitable environment for the prototype to be tested.

4. CONCLUSIONS

The very purpose of this study is to create a landslide alarm system that could warn locals regarding a possible landslide incident in their area. The data gathered by the researchers using various trials have proven that the soil moisture sensor, water flow sensor, and the MPU-6050 are capable of such requirements. The soil moisture sensor was tested on different types of soil and based on the results, it can work best on clay soil. The water flow sensor has a percentage error of 2.07%. The MPU-6050, although no statistical treatments were applied, was observed to be functional.

As said above, the researchers have found out that the types of soil do not matter to the functionality of the prototype. The time it takes for the prototype to send an output signal (buzzer), is roughly the same whether the type of soil is changed. This means that the prototype can work with the same signal-sending efficiency even though the overall environment is changed. It can also be concluded that the prototype does not pick any particular soil on which it can work the best.

DISCUSSION AND RECOMMENDATION

The data gathered, together with the prototype created, has been found out to be effective and accurate on different aspects. After the trials, the researchers have realized several features that must be done in order to improve the system. The prototype's functionality can definitely fulfill its goals if a little more time and effort is put into it. Even though some problems were experienced along the way, the researchers worked hard in order to put this product into its initial stages. The development will definitely be sure to follow because the researchers will work on it more after this study has been presented.

After the entire study is done, the researchers recommend to

Create a more stable enclosure for the sensors to sit in

Attach a solar panel module to increase the prototype's lifespan

Increase the prototype's functionality by adding another sensor called DHT22 (Temperature and Humidity Sensor)

Create a more rigid experimental design to test the functionality of the sensors.

Further, parametric statistical treatment is suggested to get the empirical data to determine the functionality of the MPU-6050.

5. ACKNOWLEDGMENTS

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Also, the researchers would like to acknowledge themselves for the passion and determination they have given off. The hard work and effort will certainly pay off in the end.

The researchers also acknowledge the readers who have read, who are reading and those who will read their study. The researchers are doing it for them and for the sake of the people's lives this study is trying to save.

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6. REFERENCES

Akbar, A. Q., & Chen, G. (2018). Comparison of major statistical methods and their combination using matrix validation for landslide susceptibility mapping. Lowland Technology International, 20(3, Dec), 401-412

Arbanas, Ž., Vivoda, M., Jagodnik, V., Dugonjić Jovančević, S., & Ljutić, K. (2011, December). Consideration of early warning system on the Grohovo Landslide. In Proceedings of the 2nd workshop of the project's risk identification and land-use planning for disaster mitigation of landslides and floods in Croatia', Rijeka (pp. 51-54)

Arduino and Soil Moisture Sensor -Interfacing Tutorial. (n.d.). CircuitsToday. https://www.circuitstoday.com/arduino-soil-moisture-sensor

Basics: Project 020a MPU 6050 GY 521 (GY-521) module 3 Axis Gyroscope and Accelerometer. (n.d.).Acoptex.https://acoptex.com/project/118/basics-project-020a-mpu-6050-gy-521-gy-521-module-3-axis-gyroscope-and-accelerometer-at-acoptexcom/

Beltran Jr, A., Dizon, K. J., Nones, K., Salanguit, R. L., Santos, J. B., & Santos, J. R. (2021). Arduino-based Disaster Management System. Journal of Robotics and Control (JRC), 2(1), 24-28.

Formetta, G., Capparelli, G., & Versace, P. (2016). Evaluating performance of simplified based models for shallow landslide susceptibility. Hydrology and Earth System Sciences, 20(11), 4585-4603.

Gluck, I., Friedman, A., & Feniger, N. (1995). U.S. Patent No. 5,424,649. Washington, DC: U.S. Patent and Trademark Office.

Intrieri, E., Gigli, G., Casagli, N., & Nadim, F. (2013). Brief communication" Landslide Early Warning System: toolbox and general concepts".

Ismail, E. S. B., Habaebi, M. H., Ibrahimy, M., & Islam, M. R. (2018). Low-Cost Vibration Chamber for Landslide Sensory and Alarm System. Indonesian Journal of Electrical Engineering and Computer Science, 10(1), 110-119.

Jefiza, A., Pramunanto, E., Boedinoegroho, H., & Purnomo, M. H. (2017, September). Fall detection based on accelerometer and gyroscope using back propagation. In 2017 4th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI) (pp. 1-6). IEEE.

Nano, A. (2018). Arduino Nano.

Pecoraro, G., Calvello, M., & Piciullo, L. (2019). Monitoring strategies for local landslide early warning systems. Landslides, 16(2), 213-231.

Piciullo, L., Siano, I., & Calvello, M. (2016, June). Calibration of rainfall thresholds for landslide early warning purposes: applying the EDuMaP method to the system deployed in Campania region (Italy). In Proceedings of the International Symposium on Landslides (pp. 1621-1629).

Purnomo, F. A., Yoeseph, N. M., & Abisatya, G. W. (2019, February). Landslide early warning system based on arduino with soil movement and humidity sensors. In Journal of Physics: Conference Series (Vol. 1153, No. 1, p. 012034). IOP Publishing.

Schlögel, R., Doubre, C., Malet, J. P., & Masson, F. (2015). Landslide deformation monitoring with ALOS/PALSAR imagery: A D-InSAR geomorphological interpretation method. Geomorphology, 231, 314-330.

Srivastava, D., Kesarwani, A., & Dubey, S. (2018). Measurement of Temperature and Humidity by using Arduino Tool and DHT11. International Research Journal of Engineering and Technology (IRJET), 5(12), 876-878.

Suresh, N., Balaji, E., Anto, K. J., & Jenith, J. (2014). Raspberry PI based liquid flow monitoring and control. International Journal of Research in Engineering and Technology, 3(07), 122-125.

Water Flow Sensor YF-S201 Arduino Interface. (n.d.). TheoryCircuit. https://theorycircuit.com/water-flow-sensor-yf-s201-arduino-interface/