Slope, Humidity and Vibration Sensors Performance for Landslide Monitoring System

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***Abstract*— A design of landslide disaster monitoring system, that embedded with Internet of Things (IoT) are presented. Several monitoring studies on landslide detection were carried out onto soil displacement caused by artificial rainfall and earthquake, in online and real time mode. Three sensors performance for soil movement monitoring that investigated were slope, humidity and vibration. Data measurement on sensors shows that all parameter has potential presentation for landslide monitoring. The system was built using sensors detection, and data was processed to be completed on the web server through cloud services.**

Keywords—slope, humidity, vibration, landslide, monitoring

I. Introduction

Landslides, events of land or rock when moving down or out of the slope, caused by disruption of soil stability or slope constituent rocks [1], is one of the natural disaster that often occurred in Indonesia, especially during rainy season, or it also can be triggered by earthquake. According to Badan Nasional Penanggulangan Bencana (BNPB) data, there have been landslides occurred for 3,753 times, since 2010 until February 2018, and resulted 1,661 number of peoples death [2]. Since 2014, landslide disaster was designated as the most deadly disaster in Indonesia. Factors contributing to the increase in casualties, include the density of the population in disaster prone locations (at highland), so that resulting in a large number of fatalities [3]. It was also caused by the tendency of residents to build settlements under slopes prone to landslides.

Until now, there are not less than 40.9 million Indonesian people living in the region prone, from medium to high scale landslides. Meanwhile, some monitoring research with certain methods has been carried out by experts from geophysical geology field, by carrying out data retrieval directly in the field periodically, such as per quarter or per 6 months in certain areas. This is probably sufficient enough to observe the topography and conditions of land shifting, so that recommendation of land situation dealing with landslide potential has been provided, as a reference for initial mitigation information to the community and local government. However, because the system cannot provide information continuously, sometimes the evacuation process when landslide disaster occurs cannot be performed quickly. This background therefore driven us to complement the ground shifting, by recording the ground data using sensor detection in real-time mode.

There are many sensing techniques and sensors for landslide monitoring, which has capabilities for detecting the soil movement and it is crucial in developing landslide monitoring systems. Some examples of these sensors are rain gauge, moisture sensor, piezometer, tiltmeter, geophone and strain gauge [4].

Each sensor has typical function to monitor, predict and analyze potential landslide. For example, to collect any rainfall levels in periodic data sampling, rain gauge sensor was set to measure for advance purposes such as modeling, monitoring and predicting landslide potentials because prior to landslide was occurred, this is used when rainfall was a main factor of the landslide disaster. Moisture sensor was feasible to be considered to overview humidity of soil or dry and wet conditions. Dielectric moisture sensor is one of moisture sensor that can be used by embedding the sensor in soil vertically to measure soil wetness, therefore the information of water penetrating can be obtained. Piezoelectric sensor was usually used to measure any land vibration sources that appeared since it can create slope instability. The instability can be measured by tiltmeter that capturing the angle change of slope and strain gauge for measuring the strain of land during slope instability. Vibration caused by slope instability can be detected by geophone.

Generally speaking, landslide monitoring and mitigation system were carried out by geophysics and geology researchers. The researchers usually used geophysical methods to study the landslide disaster, the often used one was geoelectric [5], [6] and other methods such as smorph-slope [7] and geology information system [8]. Landslide movements itself usually occurs on the hills not only caused by their rainfall level [9], but in other case, earthquake is also possible, even vibration in area with train traffic railway area can trigger the landslide when it is crossing [10]. Some efforts to develop accuracy improvement in landslide system detection can be found in [11]. They investigated fields slip using differential methods for subsurface data and hydrologycal modeling on 1-kilometer slope [12].

In this paper, we concerned on sensor performance used in landslide monitoring and mitigation system. Three sensors for supporting the soil movement: slope sensor, moisture sensor and vibration sensor using piezo sensor that attached to land slope, as shown in Figure 1. Node 1 and Node 2 represent different set up locations of networked sensors for future purposes, since distributed and networked sensors especially Wireless Sensor Network (WSN) until right now is recommended as one of the best methods and technology for landslide monitoring systems [13, 14]. By using these sensors, developing a soil monitoring mitigation system landslides in real time and online based on Internet of Things (IoT) is expected useful in the future.

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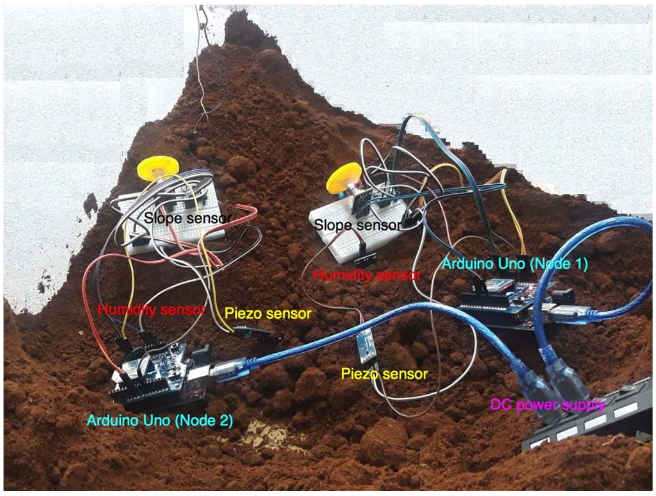

Fig. 1. Sensors placement on land slope model

Roadmap of this research work follows these steps:

The method of detecting soil motion and vibrations used several sensors (humidity, vibration and accelerometer), then the data is processed on the server. This paper concern on data sensor collecting in this step. Data collecting was also including cloud server Firebase.

Next step is the provision of landslide monitoring information. It was designed in real time and online with IoT communication data. At present, this kind of system is not implemented yet, particularly in Indonesia, therefore the system will be a forerunner the formation of the first Landslide Information and Monitoring Center in Indonesia.

II. Model and System Design

The designed system to investigate the sensors performance, included microcontroller Arduino Uno, slope sensor using Inertial Measurement Unit (IMU) 6050, humidity sensor for soil wetness detection, and piezoelectric SW420 for vibration detection. Piezoelectric SW420 provided threshold data, where it only recorded whether vibration was occurred or not (1 or 0). To increase the sensitivity of vibration data measurement, geophone sensor was also implemented. Figure 1 shows the sensors wiring diagram that used in this research work.

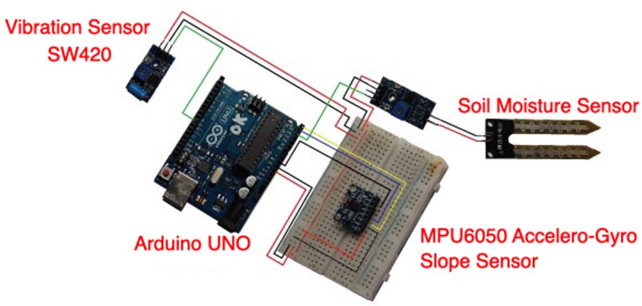

Fig. 2. Wiring of sensors controlled by Arduino Uno microcontroller

All sensors were placed on an artificial highland with 60x60 cm size as soil model, to test their performance. The photograph of landslide system prototype used in this research work is shown in Figure 1.

Because measurement of vibration sensor SW 420 was a little bit conservative in signal output, represented the occurred vibration or not, then we used other alternative sensor, which is geophone 45 Hz, embedded with instrumentation amplifier AD620 for signal conditioning, as shown in Figure 3. The output result was varied and less conservative, especially for analysis and modelling prediction. However, geophone sensor only detect vibration in vertical direction. To detect horizontal vibration, its position to the ground had to be adjusted with the designed system.

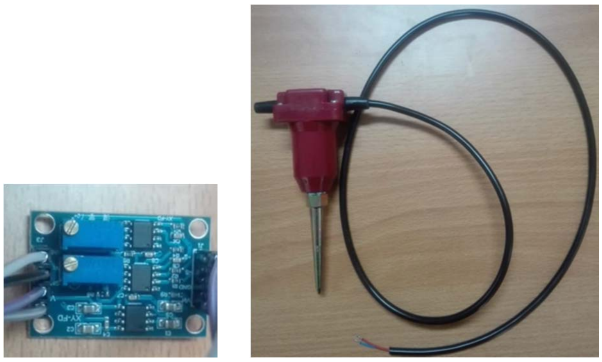

Fig. 3. Instrumentation amplifier AD620 and Geophone 45 Hz for detecting vertical vibration

III. Sensor Measurements and AnalYsIs

Landslide study in this research work was investigated by triggering the soil movement by continuous rainfall and earthquake (vibration), related to the slope changed, humidity and vibration measurements. For wetness effect, the study was performed by supplying artificial rainfall to the soil using water spray with constant rate.

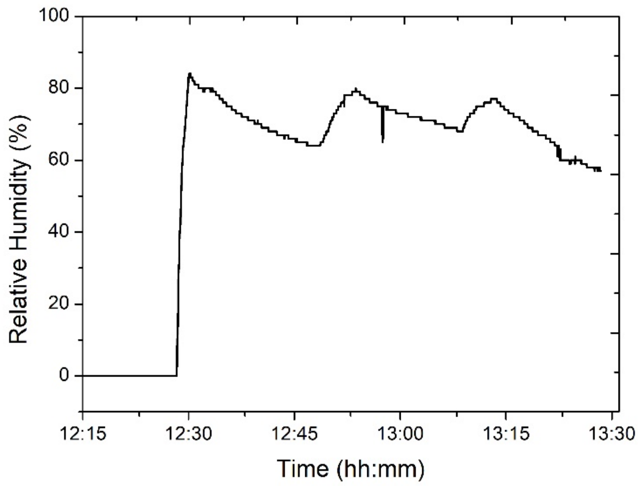

Fig. 4. Relative humidity measurements for dry and wet conditions with water spray treatment

At the beginning, measurements of soil slope and vibration were treated in dry condition for duration around 15 min, as seen in the Figure 4 at 12:15-12:30. By supplying water spray as artificial rainfall effect (can be seen at 12.30-13.30 time), RH start gradually increases and saturated around 80%. Decreasing graph after the RH reached 80% (during 12.35-12.45), probably it is caused by the adsorption of water on soil. The increasing graph again at 12.50, owing to continuous rainfall is still applied to the system. Along with wetness effect, soil slope and vibration were measured as shown in Figure 5 and Figure 6.

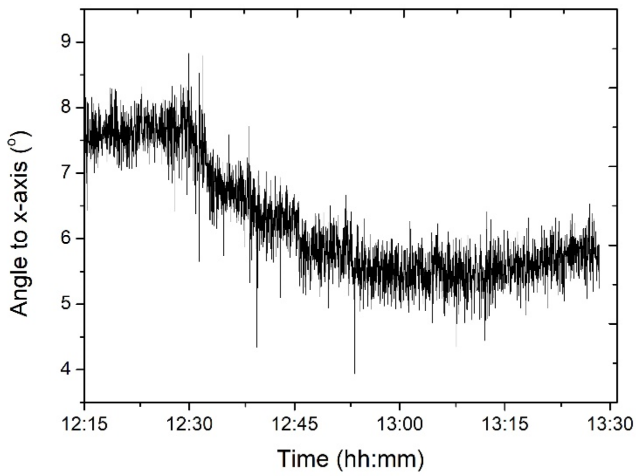

Fig. 5. Soil slope changing for x axis in degree (^{0})

Figure 5 shows the soil slope changing, indicated by the difference of angle to x-axis during dry and wet conditions. At dry condition, the soil position is consistent at 7.5^o. Just after water spraying was applied, the slope gradually decreases and reaching 5^o after several minutes. At the same time, the soil slope to y-axis is also changed, as seen in Figure 6. The angle to y-axis is changed from 30^o to 33^o during water spraying. According to Figure 5 and Figure 6, it can be summarized that soil wetness influenced the soil slope both in x-axis and y-axis. The change of wetness and soil moisture were, it would influenced the soil slope, because the water is impregnated by the soil.

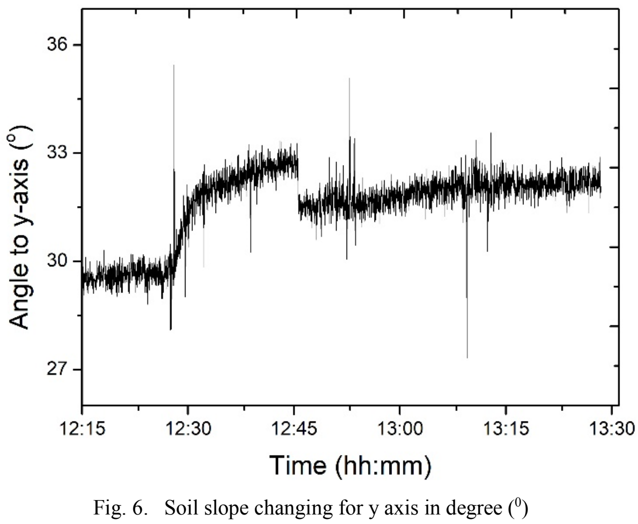

Fig. 6. Soil slope changing for y axis in degree (^{0})

To overcome the landslide triggering caused by earthquake/vibration, reading the vibration signal also can be yielded by using geophone sensor, embedded with instrumentation amplifier AD620, to increase geophone voltage output level. Script for reading of sensor output is written in following code:

```
float voltage_backup;
void setup() {
Serial.begin(9600);}

void loop() {
int sensorvalue=analogRead(A0);
float voltage=sensorvalue*(5.0/1023.0);
if (voltage!=voltage_backup)
Serial.println(voltage);
voltage_backup=voltage;
//delay(1000);
```

Example of vibration detection using geophone sensor is shown in Figure 7. At 0-200 s, there is no vibration is applied to the system, and the magnitude of vibration was recorded approximately 0. As vibration was applied interval time 200-400 s, the vibration is detected and varying over the time. The magnitude of vibration also can be recorded. This setup then expected is useful to be utilized for detection of landslide disaster, triggered by earthquake.

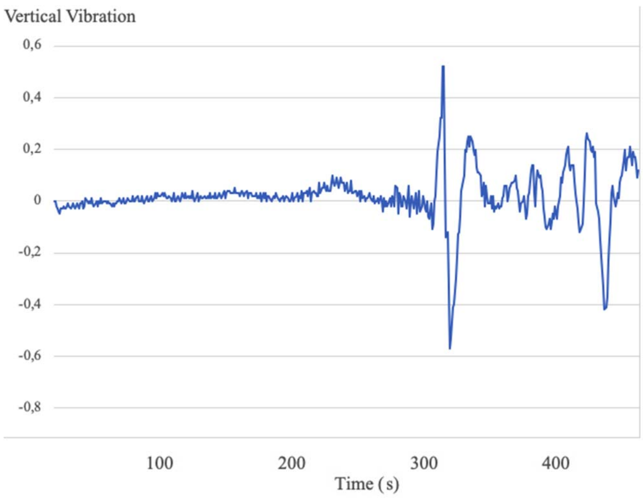

Fig. 7. Vertical vibration detected by geophone

Moreover, all detected data by sensors were sent to Firebase server. The interfacing process itself is shown in Figure 8, therefore the obtained data can be displayed interactively in a website, as shown in Figure 9, therefore, any changed in soil condition can be remotely monited in real-time condition and it is expected is useful for mitigation system of landslide disaster in the future.

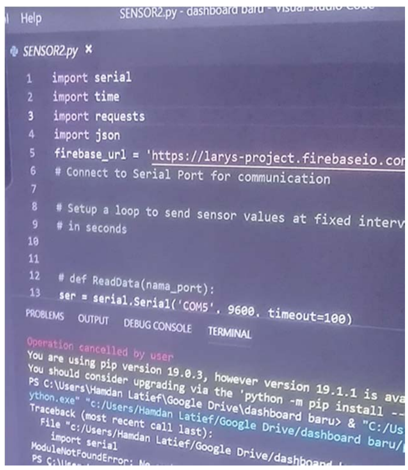

Fig. 8. Interface of collecting data using Firebase server

Fig. 9. Interface of on line and real time area monitoring

IV. CONCLUSIONS

This paper presented the performance of three networked sensors: slope, humidity and vibration for monitoring potential landslide. The results yield correlation between water spray effect (humidity) and soil slope. This shows the potential landslide that can be monitored real time by Internet of Things technology interactively in the future.

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