Smart Monitoring and Warning Landslide System using Internet of Things

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Abstract
A landslide is a natural disaster that will damage social life. Currently, the established monitoring system for the landslide is not very efficient as no system uses a component that can detect rainfall, seeing that Malaysia is a tropical country with high rainfall intensity. This research aims to design a smart monitoring and warning system to detect the occurrence of landslides in real-time. The system will be proposed at Bukit Bauk Dungun, which is the only place for hiking trails, so the rainfall sensor is a suitable sensor that can alert and give an early sign to people because most people are coming from a different place. Three sensors, rainfall, vibration and soil moisture sensor, are connected to NodeMCU (ESP8266). When the data is collected, it will send an alert to the end-user using cloud Blynk via mobile phone. The result obtained based on the sand and soil shows that the soil sample is highly triggered to landslide because the reading of sensor at the soil for rain sensor is quickly high with 71% and reading sensor of soil moisture is 90% so that there will have a movement of the land. Therefore, this proposed system will get a more accurate value that will be easier to user monitor the condition of land triggered by a landslide.
Keywords: Landslide, Internet of Things (IOT), NodeMCU, Sensors, Blynk

Introduction

Based on the resolution of the National Disaster Management Agency by the Law, landslides call for one type of landmass movement, or mixed acceleration, down or out of the slope due to disturbance in the stability of the soil or rocks up the slope. In regions susceptible to the failures of the slope, the landslide risk assessment must consider available economic resources, environmental impact, and safety [5]. Landslides occur when gravitational and other types of shear stresses within a slope exceed the shear strength of the materials that form the slope. The landslide is also caused by rain, earthquakes, volcanoes, or artificial activities. The landslide movement can happen in many ways, such as fall, topple, slide, flow or spread [1].

Landslides are a serious geologic hazard common in most countries of the world because it is one of the unpredictable catastrophes that could cause death and property loss. Landslide disasters often occur in some regions of the world. Besides, the sorts of the landslides.

Vary concerns the rate of movement, nature of movement and type of the material. Several agencies, such as Jabatan Kerja Ray (JKR) and National Disaster Management Agency (NADMA), supervise the landslide disaster. All of these regencies have their ways of managing landslides [10]. The development in monitoring, warning and early detection of environmental disasters such as landslides can reduce fatalities, especially for the countries [3].

Internet of Things (IOT) is one of the top technological concepts where the users and objects are interconnected using wired and wireless technology. Many wireless technologies include Wireless Sensor Network (WSN), Long Range Wide Area Network (LoRaWAN), Zigbee, RFID, GPRS and Bluetooth. [13]. The innovation of devices based on the Internet of things (IoT) can collect and analyze the data and rapidly send the information to the collector section in territories about the landslide. It is also a low-cost device because the cabling is not needed. The IOT device can continuously process and transfer the required data.

Recent years shows that landslide can affect every aspect of human life [6] [15]. However, because of the many deaths and injury due to landslide, every country prone to landslide need to take it as necessary to establish a system that can early detect and inform the concerned people about the occurrence of landslide [5]. There is a need for regional landslide monitoring techniques considering the various local live data. People nowadays expose to the era of technology where any information can get at the end of their fingertips.

Based on the previous research, past researchers have used many methods to create landslide monitoring. Table 1 shows the comparison between the component from past researchers. However, through the literature review, no previous researcher used soil moisture sensor with vibration and rain sensors. The proposed system has been adapted from previous research [12]. There is a difference between the proposed project and the previous project. In this paper, the development of an early.

A warning system for landslide occurrence based on the Internet of Things (IOT) has been proposed. Therefore, the system can provide an early warning to communities in any region susceptible to the landslide. Moreover, the data on the presence of rain, condition of soil and ground movement can be analyzed by the system that can be monitored by governmental agencies and can take any action plan to reduce public risk and minimize the loss of economic activities.

Table 1 Comparison of components, past researchers

Research	**Accelerometer**	**Soil Moisture Sensor**	**Vibration Sensor**	**Temperature Sensor**	**Humidity Sensor**	**Rainfall Sensor**	**Slope Sensor**	**Shift Soil Sensor**
Landslide and Rockslide Detections System with Landslide Early Warning System for Railways/ 2018 [8]			✓					
Slope, Humidity and Vibration Sensors Performance for Landslide Monitoring System/ 2019 [14]			✓		✓		✓	
IoT based Landslide Detection and Monitoring/ 2019 [7]	✓	✓						
Landslide Early Warning System with GSM Modem based on Microcontroller using Rain, Soil Shift and Accelerometer Sensor/ 2020 [15]	✓					✓		✓
Landslide Detection System: Based on IoT/ 2021 [12]		✓	✓					
Smart Monitoring and Warning Landslide System using IoT/ 2022		✓	✓			✓		

Methodology

This section can be separated into two main parts: the hardware and software parts of the system.

Hardware Part

Figure 1 below shows the block diagram of the system. Two parts show the input and output of the system. All components used for the construction are in the hardware part. There are three sensors used as the inputs for the system. Those sensors are rainfall sensors, vibration sensors and soil moisture sensors. The system uses NodeMCU as the microcontroller. Besides, the smartphone is used as the output of the system. The system starts when each sensor detects the threshold value to obtain the data. Then, NodeMCU transmits the data and sends it to the smartphone. People can monitor through the Blynk application on their smartphones.

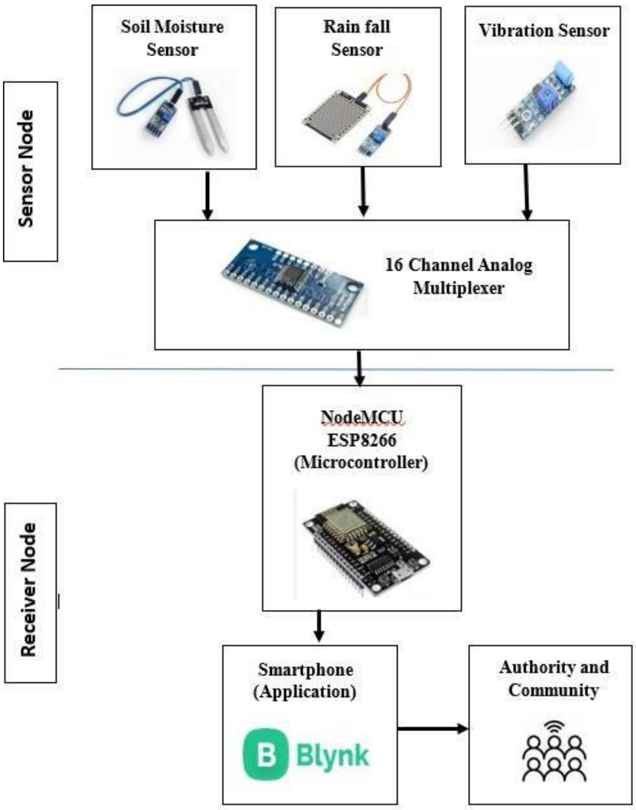

Figure 1 Block diagram of system

Referring Figure 2, it shows the prototype of the research. The prototype is placed at the soil, which enables the sensors to acquire the data. In order to obtain the soil moisture value and vibration voltage value, soil moisture sensor and vibration sensor are immersed in the soil meanwhile, the rainfall sensor is hanging on top of the soil, which is to measure the presence of rain.

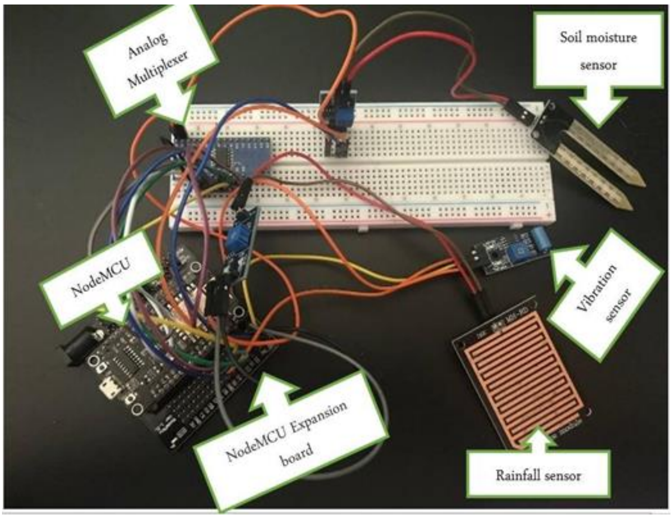

Figure 2 The connection of the system

Component Description

Usually, there are several sensors needed to cover a certain area. This research used three sensors to collect the landslide monitoring parameters such as soil moisture, rainfall and vibration. The proposed system used the soil moisture sensor that operates on 3.3V to 5V [11]. This sensor has two plates to measure the water in the soil. The electric current through plates is proportional to the volume of water content. When the moisture is high, the current will also increase, which means less output resistance and the output voltage is low.

In addition, less moisture around the sensor draws less current, resulting in high output resistance and high corresponding output voltage. However, the soil moisture sensor output can be analogue and digital. But this research uses analogue output, which is preferred for the analogue input channel of the multiplexer.

The vibration sensor, SW-420, is the sensor that can sense vibration. It is embedded with an LM393 comparator and 10k potentiometer to adjust the sensor's sensitivity. It also operates at 3.3V to 5V. However, this sensor cannot provide the value that determines the strength of the vibration as it is non-directional [4]. When there is no vibration, the sensor provides a logic low, and when the vibration is detected, the sensor provides a logic high.

Next is the rainfall sensor. A rainfall sensor is a low-cost electronic sensor which can detect rainfall or water drops. It works as a switch which is in open condition. The switch will close when rainfall or water drops fall, such as in the soil. There have the sensing pad surface and sensor module. The water will fall on the sensing pad surface, and the sensor mule will read and process data to convert digital or analogue output.

The multiplexer gives all the collected data from the sensors to the controller (NodeMCU ESP8266). The multiplexer is used because the NodeMCU ESP8266 only has one analogue input pin and in-build the Wi-Fi module required to transmit the data. Multiplexer blocks also can be eliminated if the other controller has more analogue input pins and is suitable for the interface of the Wi-Fi module.

The controller will accept the receiver nodes. If all the sensors cross the threshold value, it will notify the cloud. The sensed data communicate using NodeMCU ESP8266 via the Blynk application on the smartphone.

Maintaining Software Part Blynk

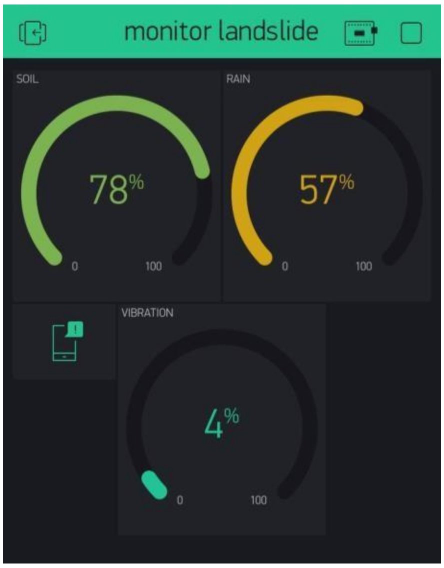

Figure 2 The Blynk application on the smartphone

The system utilizes by Blynk as the IoT platform. Blynk is a platform for Android and IOS apps to control microcontrollers like Arduino over the internet. It is allowed with a quickly built interface that controls and monitors the project using IOS and Android devices. It is also easy to use and have perfect for interfacing the project. Figure 3 shows the data from sensors that transmit by the microcontroller. There are three widgets for each sensor. The notification will appear on the smartphone when the condition exceeds the threshold value.

Flowchart of the system

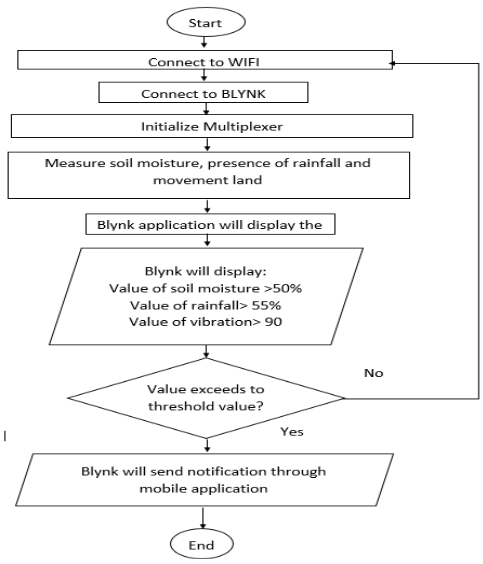

Figure 3 Flowchart of a system

Figure 4 shows the flowchart of the system. First, when the system is powered up, NodeMCU configures itself to WIFI and Blynk applications. The connection successfully initializes the multiplexer. Then, it will accept the readings from all the sensors: soil moisture sensor, vibration sensor and rainfall sensor. The soil moisture reads and compares with the programmed threshold value. Next, after reading the presence of rain, the microcontroller sends it to Blynk. After publishing rainfall and soil moisture sensors, microcontrollers receive vibration sensor readings. All the values from sensors are mapped in percentage (%) level. The notification (DANGER) will notify when all the maximum threshold values, such as the soil moisture sensor exceed >50%, vibration sensor >90 and rainfall sensor >55%.

Result And Discussion

Landslide Monitoring System

The three tables below show the threshold value for each sensor: soil moisture sensor, vibration sensor and rainfall sensor. In this experiment, different soil types, such as soil and sand, were used to determine the effect of the sensor reading.

Table 2 The threshold value and status of the soil moisture sensor [2]

Threshold Values	**Status**
0%	Dry
>0 -25%	Rather Moist
26-50%	Moist
51-75%	Very Moist
76-99%	Wet

These threshold value has been adapted from the previous research [2]. The sensor reading has their condition levels: dry, rather moist, moist, very moist and wet. Each level has a range of soil moisture. The range is indicated by the amount of water content in the soil. When there is water content, the Blynk application will show the value in percentage in the smartphone.

Table 3 The threshold value and status of the vibration sensor [1]

Threshold Value	**Status**
1	Vibration detected
0	No vibration detected

The vibration sensor has two remark conditions: there is vibration, or no vibration detected. The vibration sensor only shows the digital output, but when the Blynk application exceeds the threshold value, it will show the voltage in percentage. If there is a vibration, the voltage will increase.

Table 4 the threshold value and status of the rainfall sensor [1]

Threshold Value	Status
0%	No Rain
>0-31%	Light Rain
32-60%	Normal Rain
61-71%	Heavy Rain
72% and above	Storm Rain

Table 4 shows the threshold value indicated by the past researcher. [1] The sensor detects the presence of rain and shows in percentage value as in Table 4.

Soil Moisture Sensor Testing

Soil moisture sensor has been done in different types of soil; soil and sand. There is a comparison between the amount of moisture soil in the soil and sand.

Table 5 The reading of moisture sensor for the soil and sand

Time	Sensor Reading (Soil)	Sensor Reading (Sand)	Condition
14:10	0%	1%	Dry
14:20	32%	16%	Dry
14:30	51%	21%	Moist
14:40	77%	34%	Wet
14:50	95%	50%	Very Wet

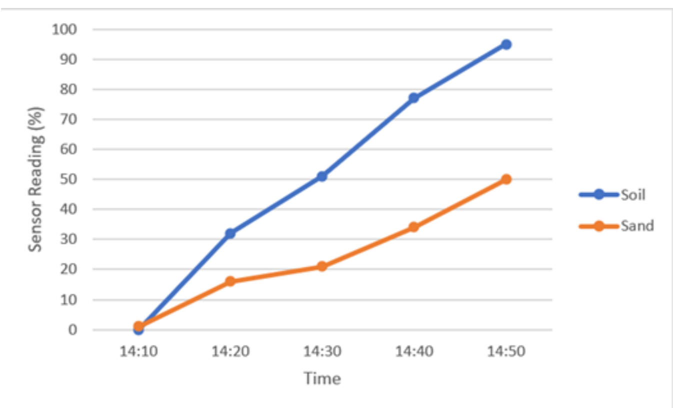

Figure 5 Graph of the comparison of soil and sand between the soil moisture sensor

Based on Figure 5, both samples are to see the effect of groundwater content on the stability of the slope performed by the soil and sand samples. Sand responds to water more quickly than soil. As the water content increases, the soil and rock strength will decrease, leading to landslides. In between 10 minutes, there is more water which causes the reading sensor in the soil to be high at 95% in wet conditions. However, the soil is higher to get landslide because the water content is faster absorbed in the soil.

Vibration Sensor Testing

The vibration sensor shows reading from the SW420 vibration sensor, which has two conditions: vibration detected and no vibration. It also has been done by soil and sand samples as in Table 6.

Table 6 The reading of the vibration sensor for the soil and soil

Time	Sensor Reading (Soil)	Sensor Reading (Sand)	Condition
16:00	0	0	No Vibration
16:10	0	0	No Vibration
16:20	1	0	Vibration and No Vibration
16:30	1	1	Vibration
16:40	1	1	Vibration

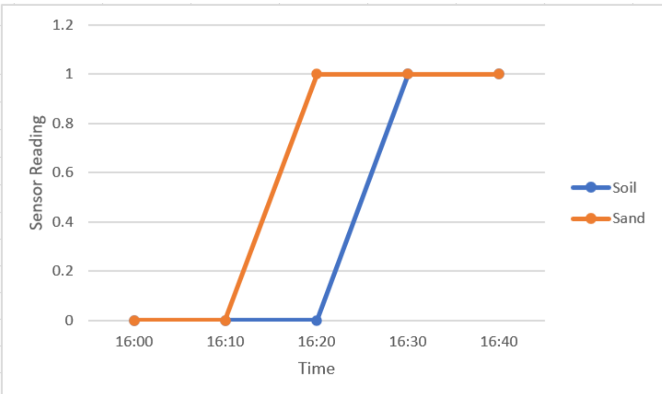

Figure 4 The graph of the comparison of soil and sand between the vibration sensor

The graph in Figure 6 shows the vibration sensor reading in soil and sand. There is a show in digital output. There is vibration when there is a movement of the soil because of the moist soil. It has been done after dropping a quantity of water inside the soil. Soil is at higher risk of vibration because of water content. The graph at soil shows at the time 16:20, there is a vibration compared to sand, where still no. The vibration frequency is caused by high water pressure, which can trigger slope movement and debris flow.

Rainfall Sensor Testing

Table 7 shows the reading of the rainfall sensor for the sand and soil. The rainfall sensor reading was tested by simulation using the water droplets on the sensor surface, from dripping in small amounts to dripping water in sufficient quantity. The data was observed from 5:00 pm until 5:40 pm. The result shows more waterfalls on the sensor surface, and the reading sensor will increase. In this case, the parameters were performed five times from volume 50 ml up to 250 ml with the addition of 40 ml in each experiment. It was done by doing the same step for both samples: soil and sand.

Table 7 the reading of the rainfall sensor for the soil and sand

Type of Land	**Time**	**Sensor Reading**	**Condition**
	17:00	0%	No Rain
	17:10	12%	Light Rain
	17:20	44%	Normal Rain
Soil Sand	17:30	71%	Heavy Rain
	17:40	90%	Storm Rain

Overall Testing System on Soil and Sand sample

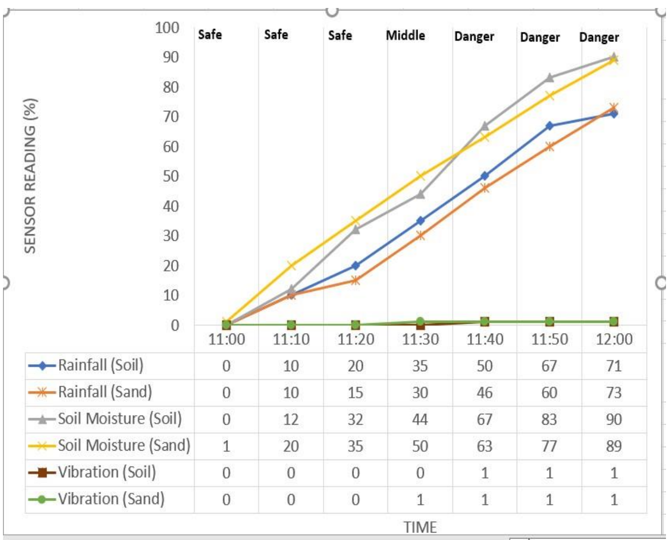

Figure 7 The overall comparison system of soil and sand

Figure 7 shows the experiment result on soil and sand samples. The experiment was done by testing all the sensors. At first, the main component of this research is the rainfall sensor because it can detect rain, which can trigger land movement. In addition, a rainfall sensor is an early sign for measuring the soil's water content. However, a soil moisture sensor measures the soil's water content volume. At type soil condition, people should be alert when the reading by rainfall sensor is between 50%-70% because there will be movement of land because of increasing water content in the soil, which is between 67% and above.

Besides, the simulation done in the sand sample shows an extremely high landslide. The rainfall reading in normal rain is between 30%-48%; the landslide happened because the water absorbed in the sand increased. The reading shown by the soil moisture sensor is 50%, which is very wet. Then, increasing water content causes a landslide that the vibration sensor detects.

Generally, every soil type has characteristics, such as material composition, porosity, and bulk density. Those characteristics are related to soil strength, pore pressure, and matrix suction of soil. As the flow of water and air in the soil is influenced by pores, bulk density will affect the matter's capability through the soil. Based on the result, it can conclude the soil has strong cohesion between each particle, but when a higher amount of water does not directly lead to the landslide, the sand has a smaller attractive force between particles, so that when more water content can cause the landside. This is because the higher volume of water increases the water absorbed. However, the sand particle's size is large, and it has high permeability and low surface area. Due to the high permeability, water will make easier runs down through the sand, and the low surface area only allows the small number of water molecules to sand particles and get absorbed. In conclusion, the value of threshold water for each type of soil are different measurements of water content.

Conclusion

This research has proposed to design a monitoring and warning system for landslides using IoT. Based on the result obtained, it achieved the objective of developing a monitoring and warning system that can monitor the soil's movement, presence of rain, and moisture in real-time using IoT technology. Besides, the system also can get notify people immediately. Furthermore, in the research area, which is more to type soil conditions, people can get alert when all the sensors have stated the value that will cause the landslide. On soil, it will be an occurrence of a landslide when the soil moisture sensor is at 60% above, and it comes from the reading of the rainfall sensor by 50% above. It also will have a movement of soil that cause sliding and danger to people.

Future Work

The system can be improved by using wireless communication implemented by Long Range Wide Area Network (LoRaWAN), which data can be delivered at a very far distance around 15km and 10km for urban and rural areas. It also can be monitored by the user instead of government agencies, so it will be easier to get an alert immediately.

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