

LANDSLIDES EARLY WARNING SYSTEM WITH GSM MODEM BASED ON MICROCONTROLLER USING RAIN, SOIL SHIFT AND ACCELEROMETER SENSORS

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ABSTRACT: Landslide is triggered by several things, including rainfall that moves soil easily. Padang, West Sumatera is an area in Indonesia that has dangerous hills and slopes. This research aims to build landslide early warning system with parameters as follows: rainfall, soil-shifting, and vibration. In order to detect those three parameters, rain, soil-shifting and accelerometer sensors were used. In the data process, microcontroller ATmega 2560 was utilized. There are several warnings identified. First, "Alert" warning is happened when the slope is 40° and the rain sensor reaches 70%, or 50° slope with 68% rain sensor, and when the slope is 60°, the rain sensor moves to 58%. Secondly, "dangerous" warning occurs when the soil-shifting sensor has moved 3 cm from its initial position. The output used in this research is a text-message, bell in audio form, and LCD to read the sensor values. The test result of this tool was successfully sent to observers when the soil changes.

Keywords: *Landslide, Early warning system, Sensor.3 sensor*

1. INTRODUCTION

Hilly areas where rain occurs frequently like in West Sumatera, Indonesia, are areas prone to landslides. As a dynamic volcanic archipelago, more than 60% of Indonesia's territory is covered by mountainous areas and hills encompassing volcanic rocks, composed of rock joints. This geological condition causes high landslides susceptibility in Padang, West Sumatera [1]. Furthermore, high rainfall – exceeding 2000mm and now reaches 3000mm per year –, frequent earthquake, extensive land use, and deforestation are catalysts of landslides and recently known to escalate. Landslides, also known as landslip, is a geological phenomenon comprising of various soil movements [2] and its characteristic also have geotechnical properties and geologic ages [3]. Landslide is a disaster triggered by some occurrences, including rainfall [4]. It will lose the soil consistency so that the soil is easy to move [5], [6], [7]; if this happens around hilly areas, landslides is likely to occur [8] and could hit the houses under the foothills. In the worst scenario, peoples could die because of landslides [9]. Mostly, it is caused by failure related to natural phenomenon and human activities; in addition, the debris of slopes are channeled and have fallen on the slopes of hills and destroyed some footing structures; many people were dead and some were hurts due to this sort of incident [10].

The early warning system is believed to be capable of protecting people's life and the surroundings [11] [12]. There are some early warning systems for example occupying electronic

and sensor technology advancement are believed to be able to resolve the issue, particularly the natural disaster such as landslides frequently taking place in India, Vietnam, China, and Thailand [13], [14], [15], [16] etc. The previous studies have also used the same sensors with the exception of landslide sensor and used humidity sensor instead [17]. Mainly the designs commonly focus on tilt sensor, accelerometer sensor that detects acceleration object which is managed by the controller [18]. The microcontroller as well as microelectromechanical system (MEMS) which has many applications in various fields of live [19].

In this study, the authors tried to design a prototype early warning system for landslides as well as the delivery of information with the Global Mobile System (GSM) modem based Microcontroller using 3 different sensors i.e the rain sensor, soil shifting sensor and accelerometer. These sensors are different from the tools that have been created by previous researchers, namely using rain sensor, accelerometer sensor, humidity sensor, which according to experimental data where the land movement factor is more dominant to the occurrence of landslides compared with the soil moisture factor. The landslides early warning system is rarely used. Only bell and text-message sent to officials are available for landslides information and evacuation [20]. This landslides' early warning system could detect 3 cm shift from soil mass [21], followed by responses from other sensors like rain sensor and accelerometer [22]. The research significance is designing a prototype early warning system for landslides as well as the delivery of information with the Global Mobile

System (GSM) modem based Microcontroller using 3 different sensors i.e the rain sensor, soil shifting sensor and accelerometer where the previous work only based on one or two different sensors.

2. METHODOLOGY

There are some steps in designing the prototype of landslides early warning system using rain sensor, soil-shifting sensor, accelerometer with microcontroller-based GSM modem as the followings:

- Designing a landslides simulation prototype design mechanism.
- Forming soil construction close to the structure of termite land.
- Creating a landslides detection system hardware.
- Creating a landslides detection system software using GSM modem.
- Combining both hardware and software with wireless General Packet Radio Service (GPRS) communication.

Block diagram of the project can be seen in Fig. 1 which illustrate how the whole system works.

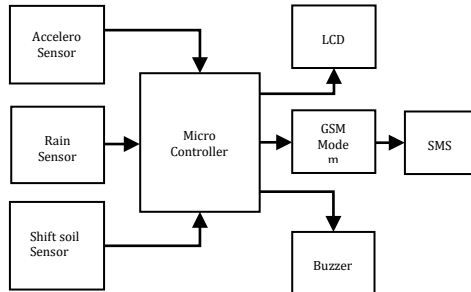


Fig. 1 Block diagram of the system

There are three sensors (accelerometer, rain sensor, soil-shifting sensor) used. Prototype mechanics is a device used to produce movements or vibrations that copies the movement of landslides when the rain comes – either it is artificial rain or not –; this is triggered by firstly providing several types of soil placed in such a way. Prototype design landslides simulation can be seen in Fig. 2, accelerometer, rain sensor, and soil-shifting as the input; whereas LCD, bell, and GSM modem – to send text-messages – as the output devices.

2.1 Work Principle

Figure 1 depicts how landslides early warning system prototype detects landslides through

vibration, rainfall, and soil-shifting, which then send messages to cellphone through GSM modem or GSM SIM900L as the server. This early warning system uses ATMEGA2560 micro controller with C programming language as the controlling system to regulate time system and phone number, and it will send news in the form of short messages.

Based on the block diagram in Fig. 1 above, the landslides early warning system is divided into three parts: input, controller, and output. Input is a sensor used to detect vibration, rainfall, and soil-shifting. Microcontroller ATMEGA2560 is an element where input of the sensor is processed based on the program used which then forwarded to the output. Output is data from the sensor processed by microcontroller that results in text-messages and siren that produces sound.

2.2 Creating Mechanical Designs from Proto Types

Mechanical prototype is a device used to produce vibrations or movements that could mimic landslide movement while raining. Either it is artificial rain or not, certain types of soil must be firstly added. The landslide simulation prototype design can be seen in Fig. 2.

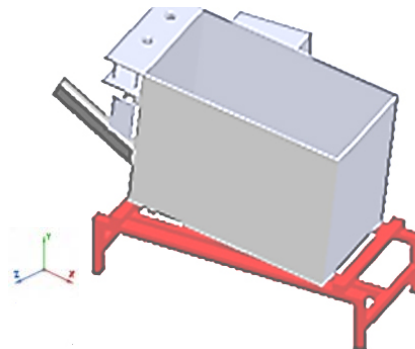


Fig. 2 The design prototype

2.2.1 System main components

Creating a landslide detecting system involves several components as follows:

a) Input of landslide detecting system

Input is a scale read by the system which then becomes materials to be processed. Figure 2 illustrates the scheme of GY-61 accelerometer sensor of a 3-axis series used to detect movements caused by soil shifted from a landslide location. Figure 3 depicts the scheme of rainfall sensor used to detect precipitation in units of time. The rain sensor is used to authenticate the precipitation intensity. The microcontroller PIN of ATMEGA2560 that can be used to link the rain sensor and microcontroller ATMEGA2560 are :

Data Pin connected to A5 Analog pin.
Vcc (+) pin connected to 5V resource pin.
Gnd pin (-) connected to ground resource pin.

Figure 4 portrays the soil shifting series scheme that detect the shift of soil, and inform if the shift is more than 3 cm.

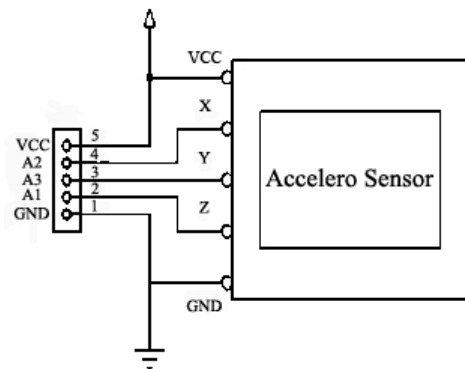


Fig. 3 Accelerometer sensor

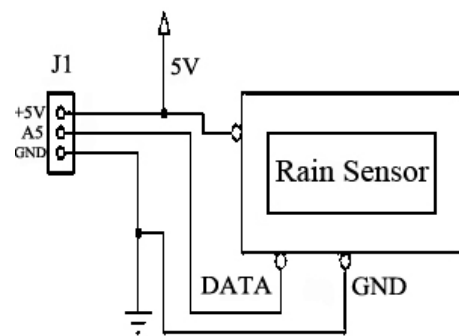


Fig. 4 Rain sensor circuit

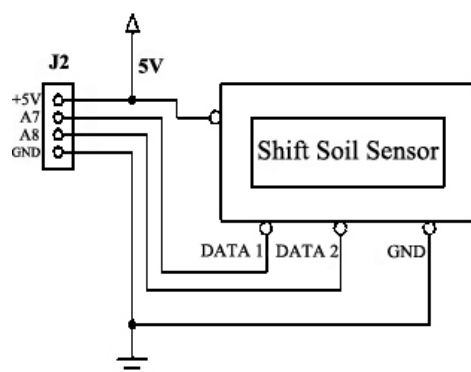


Fig. 5 Soil shift sensor circuit

Solid potentiometer is employed to detect the soil shifting as shown in Fig. 5. The

microcontroller ATMEGA2560 PIN which is used to connect the solid potentiometer are:

Data1 pin connected to A7 Analog pin.
Data2 pin connected to A8 Analog pin.
Vcc (+) pin connected to 5V resource pin.
Gnd (-) pin connected to ground resource pin.

b) Process of landslide detecting system

In this part, input is changed to valuable and useful output and all data from the output are processed to get the results.



Fig. 6 Microcontroller

In order to process the data, microcontroller is necessary. Microcontroller in this research is used to process the signal of the input as seen in Fig. 6. The microcontroller pins of ATMEGA2560 which is used to link the GY-61 accelerometer sensor and micro controller ATMEGA2560 are:

X Pin connected to A2 Analog pin .
Y Pin connected to A3 Analog pin.
Z Pin connected to A4 Analog pin.
Vcc (+) pin connected to 5V resource pin.
Gnd pin (-) connected to ground resource pin.

c) Output of landslide detecting system

Output is the result of data processing in the form of LCD and Buzzer.

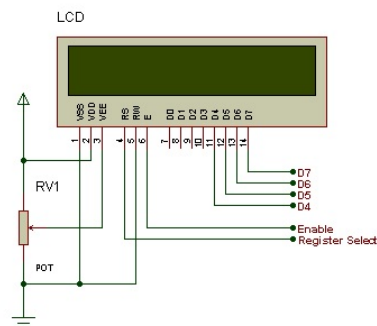


Fig. 7 LCD circuit

- LCD Circuit

Fig. 7. illustrates the Liquid Crystall Display (LCD) circuit scheme utilised to show the result of the process carried out by microcontroller. The microcontroller Pins of MEGA2560 which is used to link the LCD and microcontroller are :

D4 Pin connected to 31 Digital pin .
D5 Pin connected to 33 Digital pin .
D6 Pin connected to 35 Digital pin.
D7 Pin connected to 37 Digital pin.
RS pin connected to 39 Digital pin.
E Pin connected to 41 Digital pin.
Vcc Pin connected to 5V resource pin.
Gnd (-) Pin connected to ground resource pin.

- Buzzer

Buzzer circuit is an audio signal device that will be activated when the landslide occurs. As portrayed in Fig. 8, buzzer is worked as a warning signal which will be activated when the landslide happens. The sensor gauges which will act as the output of 6 PIN for activating the bell are:

Data Buzzer Pin to A14 ATMEGA2560 micro controller Pin.
GND Buzzer Pin to GND ATMEGA2560 micro controller Pin.

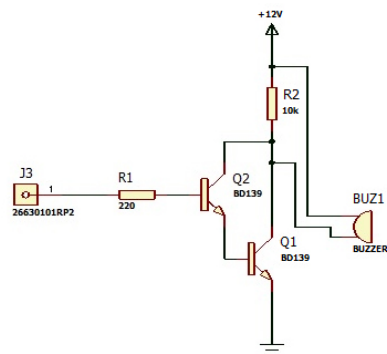


Fig. 8 Buzzer circuit

2.3 Creation of Landslide Detection System Software

Landslides detection system consists of landslide main program, subroutines and initialization are shown in Fig. 9.a, 9.b, and 9.c respectively.

The initialization encompasses initialization of microcontroller AT MEGA2560, serial initialization, LCD and timer initialization. Regarding the subroutines, it involves a connection to cellphone, sub-system for soil shifting sensor and subroutine landslides warning. The flowchart of this process is pictured as follow.

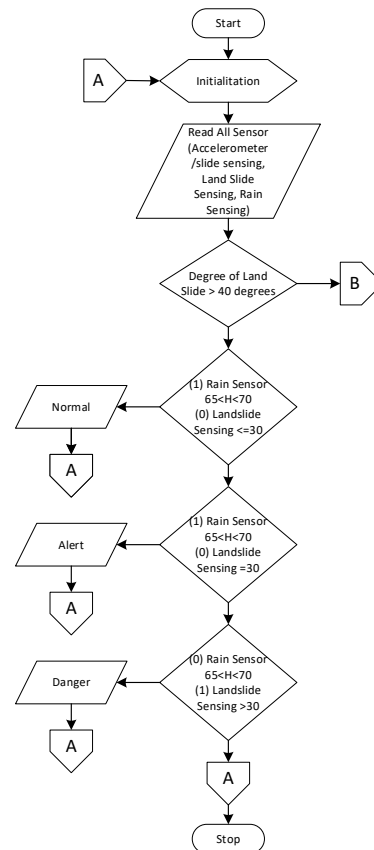


Fig. 9.a Main program flowchart of system

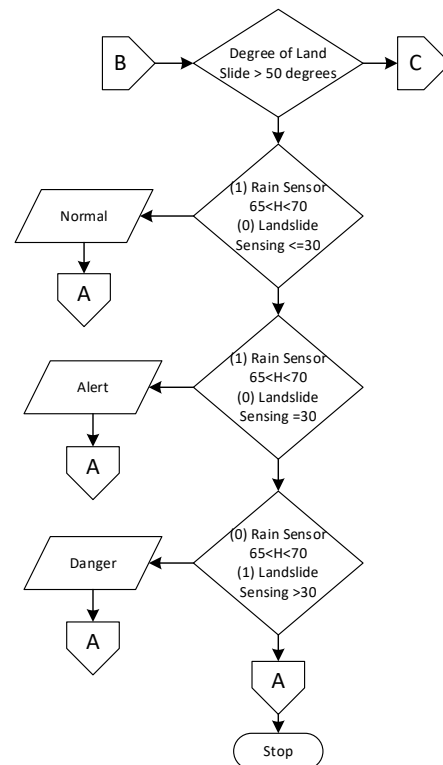


Fig. 9.b Sub program flowchart of system

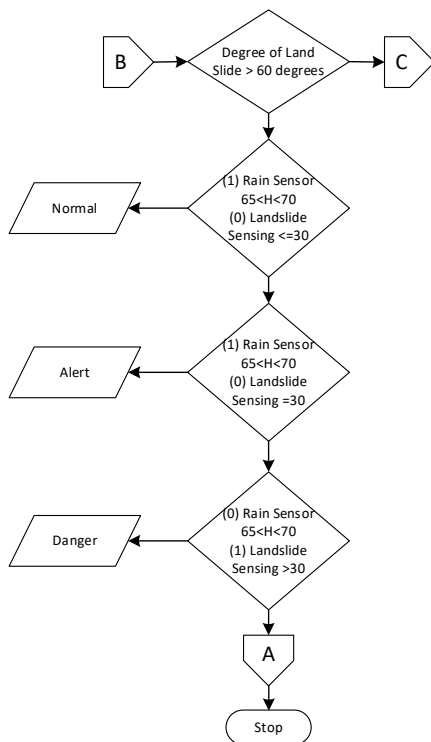


Fig. 9.c Sub program flowchart of system

2.4 Combining hardware and software with wireless GPRS



Fig. 10 GSM SIM800L

The wireless GPRS communication in this system is benefitted to send information to cellphone with GSM SIM800L module as indicated in Fig. 10. GSM SIM800L has used to send short text messages for user. The circuit of GSM Modem as shown in Fig.11.

SIM800L GSM modem is used to send short text messages. The Mega2560 microcontroller pins which is used to connect the GSM modems Sim 800L and micro controller are:

Rx pin connected to 7 digital pin.
Tx pin connected to 8 digital pin.
Vcc pin connected to 5V resource pin.
Gnd (-) pin connected to ground resource pin.

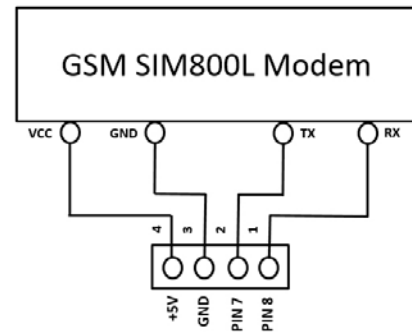


Fig. 11 GSM SIM800L with Microcontroller

3. RESULT AND DISCUSSION

This trial simulation uses three variables; rainfall, soil-shifting, and vibration with the soil slope angle 40, 50, and 60. The result of this experiment can be perceived in Table 1. For land slope with angle of 40, the rain will be >70% and the soil condition is >9%; if the land slope angle is 50, rain <60% with soil condition >9%, and with angle of 60, rain will be less than 58%, with soil condition >9%.

3.1 The Shift of Soil Sensor Tested in Each Slope

Rain sensor testing is accomplished to understand the rain precipitation where output was gained from the sensor in the form of data analog and is transformed into percentage value of 0-100% from the ACD data 0 – 1023 using the Eq.1.

$$SV = \frac{1023 - SRV \times 100\%}{1023} \quad (1)$$

where:

SV = Sensor value

SRV = Sensor reading value

On grounds of the above equation, the percentage of the Analog to Digital Converter (ADC) of rain sensor could be obtained. Hereafter, some trials of landslide prototype are conducted to gain the limit of rain percentage that could cause soil-shifting and landslide. This is shown in Table 1 below:

Table 1 Test the rain sensor on the prototype

Rain 40° & 50°	ADC	Rain on 60°	ADC
72% - 75%	250 - 279	68% - 75%	235 - 279

3.2 Rain Sensor Testing of Every Slope.

In order to test the tilt and vibration using one sensor on accelerometer, it needs output data on X axis for vibration and Y axis for tilt. Therefore the ADC data are displayed on serial monitor at angle of 40°. If there are no vibrations identified, then the ADC data on X axis is constant at 87. Meanwhile the Y axis used to read the tilt of ADC data for angle of 40° is 97. At an angle of 60° of ADC data observation that is different with that of angle of 40° appears on Y axis; this determines the value of soil slope.

3.3 Accelerometer Sensor Testing of Every Slope

At a slope angle of the ground of 40° with 70% precipitation, this logic is represented by logic 1; if the rain is $\geq 70\%$ and logic 0 if the rain is $< 70\%$. Meanwhile, shift soil uses logic 1 if the shift ≥ 3 cm and logic 0 if the shift soil < 3 cm, presented in Table 2. If the shift soil logic is 1 and rain logic 0 or 1, there will be a warning alarm from the EWS system. The other warning is “alert”; that is when the rain has logic 1 and shift soil logic is 0. As for “normal” warning, all sensors (shift soil and rain sensor) have logic 0. At the soil slope angle of 50°, a dangerous situation will take place only when the landslide condition is logic 1 and rain is logic 1 or 0. A “normal” warning is active when the shift soil and rain logic is 0 and “alert” when the rain logic is 1. Further, for soil slope angle of 60°, a “danger” warning happens when the landslide logic is 1, rain logic is 1 or 0. A “normal” warning appears if all condition of sensor shift soil and rain sensor logic are 0. No warning at soil slope angle of 60°.

Table 2 Rain sensor value on landslides prototype at angles of 40°, 50° and 60°

Value of events	40<angle< 50	50<angle< 60	angle > 60
Shift Soil (S)	S>9%	S>9%	S>9%
Rainfall (R)	R<70 %	R>68%	R>58%
Vibration (V)	V > 83	V > 83	V > 83

The “danger” and “alert” warning above are influenced by soil slope and massive rain on the surface of grounds. Consequently, the ground's load is increased because of the rainwater density and it can release the soil bond, this then triggers the landslides [23][24].

Table 3 Slope angle and data ADC test results

Angle	ADC Data	
	X (%)	Y
40	83	380 – 390
50	83	391 - 396
60	83	397-405

Table 4 Value of logic events

Events	0	1
Vibration	83	V > 83
Rain	H< 65 %	H > 65 %
Shift Soil	P < 9 %	P > 9 %

Table 5 Result of combining rain sensor and soil shift sensor test at 40°

Angel	S S	R	V	Result
40°	0	0	0	Norm
40°	0	0	0	Norm
40°	0	0	1	Norm
40°	0	0	1	Norm
40°	0	1	0	Crack/Alert
40°	0	1	0	Crack/Alert
40°	0	1	1	Crack/Alert
40°	0	1	1	Crack/Alert
40°	1	0	0	Shift/Danger
40°	1	0	0	Shift/Danger
40°	1	0	1	Shift/Danger
40°	1	0	1	Shift/Danger
40°	1	1	0	Shift/Danger
40°	1	1	0	Shift/Danger
40°	1	1	1	Shift/Danger

Table 6 Result of combining rain sensor and soil shift sensor test at 50°

Angel	S S	R	V	Result
50°	0	0	0	Norm
50°	0	0	0	Norm
50°	0	0	1	Norm
50°	0	0	1	Norm
50°	0	1	0	Crack/Alert
50°	0	1	0	Crack/Alert
50°	0	1	1	Crack/Alert
50°	0	1	1	Shift/Danger
50°	1	0	0	Shift/Danger
50°	1	0	0	Shift/Danger
50°	1	0	1	Shift/Danger
50°	1	0	1	Shift/Danger
50°	1	1	0	Shift/Danger
50°	1	1	0	Shift/Danger
50°	1	1	1	Shift/Danger

Table 7 Result of combining rain sensor and soil shift sensor test at 60°

Angel	S S	R	V	Result
60°	0	0	0	Norm
60°	0	0	0	Crack/Alert
60°	0	0	1	Crack/Alert
60°	0	0	1	Crack/Alert
60°	0	1	0	Crack/Alert
60°	0	1	0	Crack/Alert
60°	0	1	1	Crack/Alert
60°	0	1	1	Crack/Alert
60°	1	0	0	Shift/Danger
60°	1	0	0	Shift/Danger
60°	1	0	1	Shift/Danger
60°	1	0	1	Shift/Danger
60°	1	1	0	Shift/Danger
60°	1	1	0	Shift/Danger
60°	1	1	1	Shift/Danger

3.4 Data SIM800L Testing of Every Slope

The test done towards GSM SIM800L modem aims to understand whether the GSM modem could function well with the microcontroller as a connection to the GSM network of the microcontroller used as a controller of when and where the text-messages will be sent and the message content as well. Messages will be sent only in danger and alert situation and it needs two seconds for the message to arrive. Regarding the time, though, actually depends on users' needs and it can be arranged by the users. For a danger and alert warning, text messages will be sent every minute repeatedly before the landslide occurs so that people are aware and have the time to evacuate themselves.

3.5 Data Buzzer Testing of Every Slope

Buzzer functions as a warning siren of soil condition that are read by several sensors. Buzzer will ring for a minute after the messages have been sent and will be off after the second message is sent. Henceforth, the buzzer will ring once again and be off until the grounds back to normal.

4 CONCLUSION

According to the landslide early warning system prototype, the landslides occur when the ground slope is 40° and rain sensor reaches 70%, or when the slope moves to 50° – 60° and the rain sensor reaches 68%; meanwhile, if the rain sensor is above 60°, the sensor reaches 58%. The prototype also shows that if the landslide position is more than 3 cm, then the slope is in a dangerous condition. The warning alert messages will be sent

every minute repeatedly before the landslide occurs.

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