MONITORING SYSTEM FOR LANDSLIDE EARLY DETECTION BASED ON INTERNET OF THINGS

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ABSTRACT

The purpose of this research was to provide information on monitoring and early warning to officers of the City Disaster Management Agency (BPBD) City of Tasikmalaya regarding soil conditions in areas with landslide potential and to help reduce the risk of landslides. The system created can provide an early warning with 4 warning levels which are, normal, Level 1, level 2, and alert. The purpose of this research is to help reduce the risk of landslides. The research method used in this study is the approach to the prototyping method. wherein this study several parameters will be measured to determine soil conditions, these parameters are, parameters of soil moisture, air humidity, rain information, and vibration. Then the monitoring data is sent periodically to the web server after the data is sent then the data will be displayed on the web interface, which will display all information regarding soil conditions. From the results of tests conducted the system can send information about soil conditions in landslide-prone areas and provide a warning sent by reading the value of changes in each soil measurement parameter.
Keywords: Landslide, Internet of Things, webserver, Disasters, Monitoring

1. PRELIMINARY

Indonesia is one of the countries with contour areas in the form of mountains and cliffs, due to the contour of the region, landslides occur frequently in Indonesia, based on observations, West Java Province is an area that has high landslide potential, based on data. from the National Disaster Management Agency (BNPB) over the past 10 years there were around 516 landslide events, with 793 fatalities and 248 physical losses [1], one of the areas that are landslide-prone areas in West Java is the southern region of Tasikmalaya. Cliffs and hills which are indicated to have a high potential for landslides, based on data from the past 10 years, there have been 101 landslides with 783 fatalities, and 832 physical losses. [1],

The method used in this research is to use the prototyping approach

1.1 Landslide

Based on the resolution of the National Disaster Management Agency by the Law, landslides are 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 making up the slope [1]. Soil movement or better known as landslides. It is a product of the balancing process that causes the mass movement of soil and soil towards a lower place [2].

1.2 Cause of Landslide

1. Rainfall

   Rainfall intensity will increase the chance of landslides. Two types of rain trigger the landslides, those are heavy rain which reaching 70 mm to 100 mm per day [3] and light rain but lasted continuously for several hours to several days then followed by heavy rain. All landslides that occur generally occur after rain rains for 1-2 hours and followed by heavy rain [2].

2. Slope

   The slope becomes a very important factor in the occurrence of landslides. Zoning of vulnerability is related to the condition of the slope. The condition of the slope over 15 degrees needs attention to the possibility of landslides and of course taking into account other factors that support [3].

Tabel 1. Slope Specifications Table

Class	Slope (%)	Classification
I	< 3	Flat
II	3 – 15	Low Slope
III	16 – 25	Medium Slope
IV	26 – 40	High Slope
V	> 40	Steep

3. Vibration

Other causes of landslides are vibrations, that can be sourced from earthquakes, machines, traffic,

etc. the effect of that is landslides, cracked roads, and others. [2].

4. Conditions and Types of Soil

4. Conditions and Types of Soil

Conditions and types of soil in a landslide area was very influential on the occurrence of landslides in an area, this factor is the main trigger for landslides, soil permeability values will affect the soil susceptibility to water and precipitation which affect the stability of the compiler land at landslide-prone locations

Tabel 2. Conditions and Types of Soil Table

Soil Texture	Effective Porosity	Permeability (mm/h)	Permeability (mm)
Sand	0.471	235.6	96.2
Clay Sand	0.401	59.8	119.6
Clay Sand & Sand	0.412	21.8	215.3
Clay	0.434	13.2	175.0
Clay	0.390	2.0	408.9
Clay & Sand	0.321	1.2	466.5
Clay& Loam	0.423	1.0	577.7
loam	0.385	0.6	622.5

1.3 Internet Of Things

Internet of Things, or also known as IoT, is a concept that aims to expand the benefits of internet connectivity that has expanded [4]. The method used by the Internet of Things is wireless or without cable, so it can be controlled automatically without limit. The implementation of the Internet of Things usually follows what the developer wants in developing an application that will be made, if the application is made to help monitor a room then, the implementation of the Internet of Things itself must follow the flow of programming diagrams about sensors in a home, how far distance so that the room can be controlled, and the speed of the internet network used [4].

1.4 Arduino

Arduino is an electronic kit or open-source electronic circuit board in which there are main components, namely a microcontroller chip with AVR type from Atmel company [5]. The microcontroller itself is a chip or IC (Integrated Circuit) that can be programmed using a computer. The aim is to embed the program on the microcontroller that can read the electronic circuit input, process the input and then generate the desired output. The microcontroller serves as the brain that controls the input, process and outputs an electronic circuit [6].

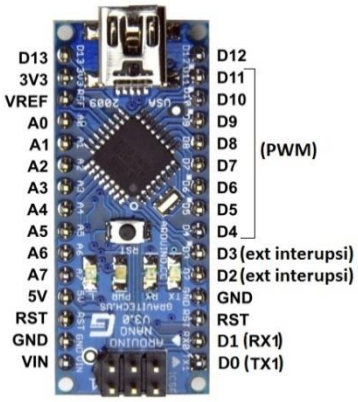

Figure 1. *Arduino Nano*

1.5 Raspberry Pi 3

Raspberry is a platform to create a prototype in many application strung together by a multitude of sensors, In the world of IoT, Raspberry much important role in aspects of life that is digital today, a variety of systems for monitoring and controlling many uses raspberry as a selection of development platforms constructed systems [7] . Raspberry Pi 3 is the third generation of Raspberry Pi, replacing Raspberry Pi 2 Mode B in February 2016. Raspberry Pi 3 has an identical shape to the previous Raspberry Pi 2 (and Pi 1 Model B +) and has 5 complete compatibilities with Raspberry Pi 1 and 2 . in this new device Raspberry adds built-in wireless and a more powerful processor that has never been held in previous versions [8].

Figure 2. *Raspberry Pi 3*

1.6 Prototyping

Software development methods in this study using prototyping methods, Because developers and users have a major involvement, so that the results of the system according to user needs [9,10].

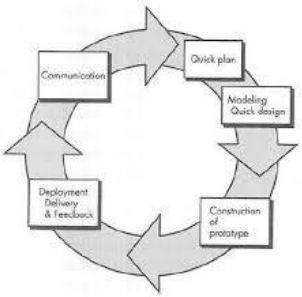

Figure 3. Prototyping Methods

The following is an explanation of the prototyping method:

1. *Communication*
   At this stage communication research is carried out with the user explaining the overall objectives of the system and identifying and analyzing needs, in this study communication is carried out with authorized personnel regarding landslide disasters.
2. *Quick plan*
   Quick plan is a continuation of the communication phase, at this stage the data needed to build and analyze is in accordance with the system requirements, which is a system that can provide results of monitoring and detecting landslides.
3. *Design*
   At this stage, modeling is carried out quickly in accordance with the needs by designing the data structure, software architecture, and the Unified Modeling Language (UML) of the application design quickly to create an overview of the systems and tools that will be built in this study.
4. *Construction of Prototype*
   At this stage the website development begins, and the construction of tools according to user needs, encoding for the arduino microcontroller to be connected to the rainfall sensor, soil moisture sensor, vibration sensor, air humidity sensor and connecting with Raspberry Pi as data communication media then send the measurement data from the sensor then save the data into a database which is then processed and displayed in a website display. After the coding is complete then testing is done on the system built with the aim to find errors that can then be corrected.
5. *Deployment Delivery and Feedback*
   This stage is the final stage of the system development process, after a series of stages is carried out, the system has been completed created and used by the user, after which an evaluation by the user is carried out as feedback from the system development.

2. RESEARCH CONTENT

2.1 Analysis of Current Procedures

Analysis of ongoing procedures is the stage for analyzing the sequence of activities carried out in the stages of monitoring landslide-prone lands, the process carried out, as well as the people who carry out the monitoring process, the following is the sequence of monitoring procedures on landslides:Petugas melakukan survey lapangan menuju lokasi yang rawan longsor

1. Officers conduct field surveys to landslide prone locations
2. Officers conduct soil moisture testing using a special hygrometer for measurement in the soil
3. Officers take measurements of the slope of the land.
4. The official records the results then submitted to the BPBD headquarters for inventory.
5.

Table 3. Evaluasi Prosedur yang Berjalan

No	Problem	Solution
1	The process of checking the soil moisture do not at any time.	check the soil moisture using a soil moisture sensor so that checking can be done at any time and give a warning when the soil moisture level becomes high.
2	Monitoring is carried out with limited parameters.	By using multi sensors that can measure landslide prone conditions.
3	Ineffective monitoring of rainfall is a major factor causing landslides, rainfall used to detect not based on territory landslides	Using the rainfall sensor at the monitoring point, the rainfall sensor can provide information about the rain that occurs and can help determine the danger signs when rainfall is high.

2.2 Systems Architecture Analysis

System architecture analysis is an analysis of a landslide monitoring and early detection system to be built, a landslide monitoring and detection system using internet of things uses Arduino as a data processor from the server then the data is sent to the Raspberry Pi which then communicates with the webservice and exchanges data with JSON, here is a picture of the architectural analysis of the design of the monitoring and detection of landslides.

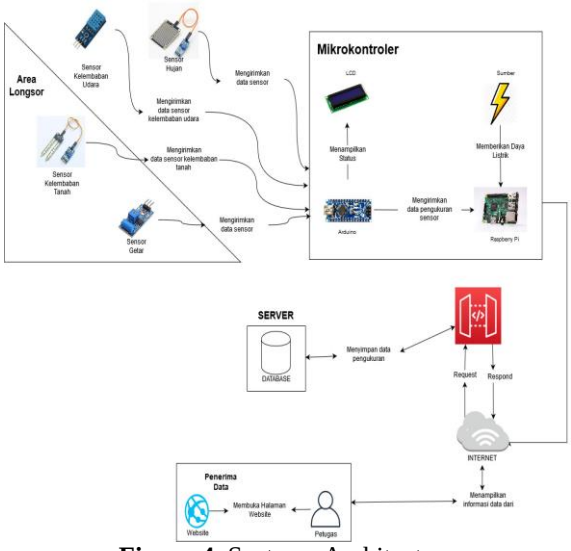

Figure 4. Systems Architecture

The explanation of the architecture of an Internet-based landslide monitoring system of Thing

1. The rainfall sensor is used as a rain detector, data from this rainfall sensor will provide information about the intensity of the rain that occurred in the landslide area.
2. Soil moisture sensor using Soil moisture Sensor, this sensor data is used to measure the level of soil moisture.
3. The air humidity sensor uses DHT 11, data from this sensor is used as a gauge of air humidity in areas prone to landslides.
4. Vibration sensor uses SW420, this sensor is used to detect vibrations when landslides occur.
5. 16x2 LCD is used as a media to display sensor measurement data directly.
6. Webservice is used as a medium for sending data between sensors and web page.
7. Web application is used as a media to display data from measurements of soil moisture sensors, rainfall, air humidity, and vibration sensors.

2.3 Data Communications Analysis

Data communication is a matter that is needed in the design of tools that are built, in this case data communication plays an important role as conveying information to interested parties regarding the detection and monitoring of landslides. The data is an electronic signal created by the data source which is then captured and sent to the recipient.

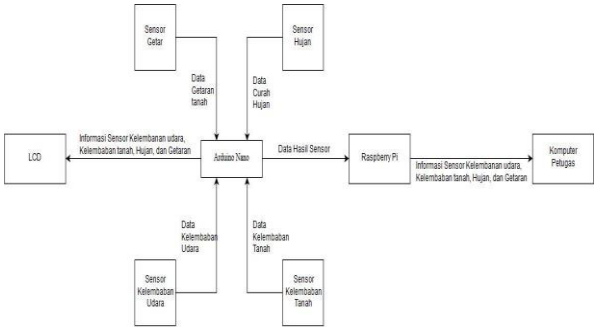

Figure 5. Data Communications Analysis

Following is an explanation of the main elements in data communication systems as follows:

1. All sensors transmit data to Arduino. Then the data from Arduino is sent to Raspberry Pi3 to be transmitted.
2. Raspeberry Pi 3 in the design of landslide detection and monitoring devices is used as a medium for sending data from the measurement results processed by Arduino.
3. Data exchange is carried out by Raspberry pi with the website using JSON, sending data from the measurement of the sensor is done at intervals of 5 minutes at regular intervals.
4. Arduino will give a trigger if one of the sensors changes to the measurement, and continued by giving status to the computer officer.
5. 16x2 LCD is used as a media to provide information directly on the location of landslide detection and monitoring equipment.
6. Vibration Sensor Vibration sensor is used as a vibration detector in the event of a landslide, or as an earthquake detector that can cause landslides.

2.4 *Use Case Diagram*

Use case or use case diagram is a modeling to find out information system behavior that will be made. Use case diagrams are the highest part of the system's functionality that will describe how a person or actor will use and utilize the system.

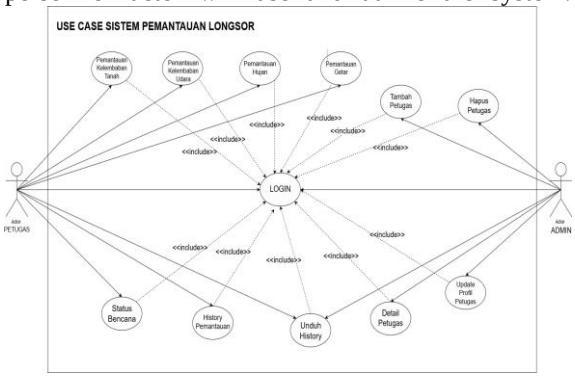

Figure 6. Use Case Diagram

2.5 Class Diagram

Class Diagram is a specification of functionality that produces objects and is the core of the development of this application. The Class diagram of the Early Landslide Disaster Monitoring and Detection system can be seen in the following figure*:*

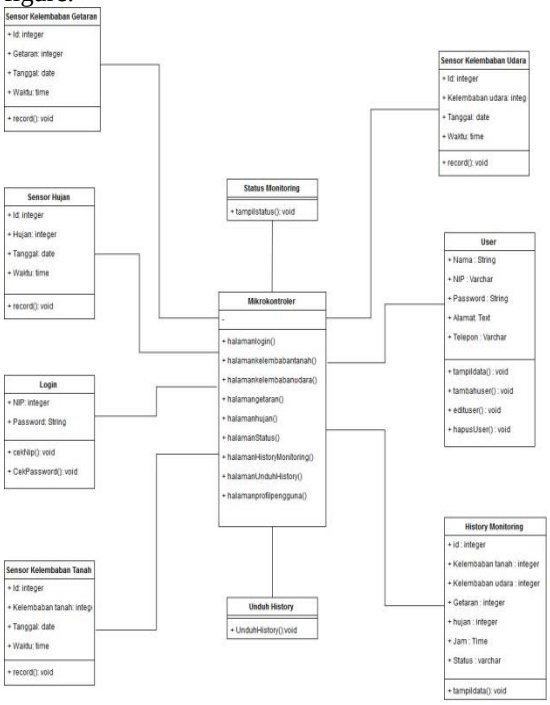

Figure 7. Class Diagram

2.6 System Testing

After the design phase is done, then the next stage is the implementation and design stages. At this stage the system testing is based on the results of the analysis, both in the form of software and hardware.

2.6.1 Blackbox Testing

Black box testing focuses on whether the software built meets the requirements mentioned in the specifications. Tests carried out by running or executing units, then observed whether the results of the units tested are in accordance with what is expected or not.

Table 4. Blackbox Testing scenario

Test Case	Detail Test	Test Type
Login	Login Petugas	Black Box
Soil moisture monitoring	See Soil Moisture Status	Black Box
Rainfall monitoring	See Rainfall status	Black Box
Vibration monitoring	See Vibration Status	Black Box
Humidity monitoring	See humidity status	Black Box
Disaster Status	See Disaster status	Black Box
Download File History	Downloading a history file	Black Box
Viewing a PDF File history monitoring	See The history file	Black Box

2.6.1 Result of Blackbox Testing

Tests conducted by the possibility of wrong data, following blackbox testing results in the following table

Table 5. Result of Blackbox Testing

Cases and Test Results (Correct Data)			
Action / Data Input	To be expected	observation	Conclusion
input fields that correspond to the database	Displays to the main page	Displaying the main page	[√] Accepted [ ] Rejected
Cases and Test Results (Incorrect Data)			
Action / Data Input	To be expected	observation	Conclusion
input fields that do not match the database	Displays the words 'wrong nip or password' below the password field	The words 'wrong nip or password' appear under the password field	[√] Accepted [ ] Rejected
Leave the input field blank	Displays an error information icon that says atau Username or Password is required '	An error information icon appears in each field with the words 'Username or Password is required'	[√] Diterima [ ] Ditolak

2.6.2 Black Box Testing Conclusions

Based on the results of BlackBox testing that has been done. then it can be concluded that functionally all processes in the system have been running as expected.

2.7 Hardware Testing

2.7.1 Soil Moisture Sensor Testing

Testing of soil moisture sensor is done by testing the sensors on dry soil conditions, then testing in wet soil conditions. Here are the results of testing of soil moisture sensor in the following table:

Table 6. Soil Moisture Testing Table

Time	Soil Moisture	Soil Conditions
06:10	0%	Dry
06:20	21%	Dry
06:30	33%	Dry
06:40	39%	Dry
06:50	53%	Moist
07:00	57%	Wet
07:10	61%	Wet
07:20	73%	Wet
07:30	82%	Very Wet
07:40	89%	Very Wet

2.7.2 Testing the Humidity Sensor

Testing is done by testing the air humidity sensors with various levels of air humidity, starting with dry air humidity levels up to high levels of air humidity, following the results of testing the humidity sensor in the table:

Table 7. Air Humidity Testing Table

Time	Air Humidity	Air Conditions
08:00	55%	Normal
08:10	67%	Moist
08:20	43%	Normal
08:30	73%	Very Moist
08:40	41%	Normal
08:50	44%	Normal
09:00	77%	Very Moist
09:10	63%	Moist
09:20	66%	Moist
09:30	61%	Moist

2.7.3 Rain Sensor Testing

Rain sensor testing is done by testing the sensor by performing a simulation using water droplets on the sensor surface, starting with dripping water in small amounts to dripping water in sufficient quantities, the following results of rain sensor testing in the following table:

Table 8. Rain Test Table

Time	Rain Sensor	Condition
16:00	0%	No rain
16:10	18%	Light Rain
16:20	32%	Normal Rain
16:30	33%	Normal Rain
16:40	54%	Normal Rain
16:50	61%	Heavy rain
16:00	67%	Heavy rain
16:10	72%	Storm Rain
16:20	81%	Storm Rain
16:30	87%	Storm Rain

2.7.4 Vibration Sensor Testing

Vibration sensor testing is done by moving the sensor and see the value of the sensor changes, the following results of vibration sensor testing in the following table:

Table 9. Vibration Sensor Testing

Time	Vibration Sensor	Condition
09:00	0	No Vibration
09:10	0	No Vibration
09:20	1	Vibration
09:30	0	No Vibration
09:40	1	Vibration
09:50	1	Vibration
10:00	0	No Vibration
10:10	1	Vibration
10:20	1	Vibration
10:30	1	Vibration

2.7.5 System Response Testing

Tests conducted to determine the response of tool sensor response time and the average delay of each tool used, following the results of testing the response tools as follows:

Table 10. Sensor Delay Testing Table

Time	Soil Moisture	Air Humidity	Rain	Vibration
	Time in second			
11:00	2	1,7	3,9	2,7
11:10	2	1,4	3,6	2,4
11:20	2,5	1,6	3,6	2,4
11:30	2,3	1,6	3,5	2,4
11:40	2,1	1,5	3,7	2,7
11:50	2,3	1,4	3,6	2,6
12:00	2,3	2	3,6	2,8
12:10	2	1,8	3,8	2,2
12:20	2,4	1,7	3,5	2,5
12:30	2,2	1,6	3,3	2,5
Average	2,21	1,63	3,61	2,52

2.7.6 Hardware Testing Conclusions

Based on the results of testing of hardware components, it can be concluded that the functional components that are used to run as expected sensors can send alerts in the form of disaster status.

2.8 Testing at a Landslide Location

Tool testing at the landslide location was carried out to determine the work of the tool directly at the landslide location, testing was carried out at the landslide-prone location, namely in the connecting road area of Kutawaringin Village, Salawu District, Tasikmalaya Regency.

Table 11. Spesifikasi Lokasi Pengujian

Specification	Information
Type of soil	Clay
Slope Area	38°
Slope Rate	High
Potential Landslides	High
Composer of Land Geology	Alluvial

Here is a table of testing at the landslide site, testing is done by monitoring the condition of the soil as much as 20 to see how the tool works at the landslide site:

Table 12. Tabel Pengujian Pada Lokasi Longsor

Date	Time	Soil Moisture	Air Humidity	Rain	Vibration	Status
10-7-2019	13:33	51 %	58%	3%	0	Normal
10-7-2019	13:43	51 %	58%	3%	0	Normal
10-7-2019	13:53	51 %	58%	0%	0	Normal
10-7-2019	14:03	51 %	58%	1%	0	Normal
10-7-2019	14:13	51 %	58%	1%	0	Normal
10-7-2019	14:23	51 %	58%	0%	0	Normal
10-7-2019	14:33	50 %	58%	0%	0	Normal
10-7-2019	14:43	50 %	58%	0%	0	Normal
10-7-2019	14:53	51 %	58%	0%	0	Normal
10-7-2019	15:03	51 %	59%	0%	0	Normal
10-7-2019	15:13	51 %	58%	0%	0	Normal
10-7-2019	15:13	51 %	58%	0%	0	Normal
10-7-2019	15:23	50 %	58%	0%	0	Normal
10-7-2019	15:33	50 %	58%	0%	0	Normal
10-7-2019	15:43	50 %	57%	0%	0	Normal
10-7-2019	15:53	51 %	58%	0%	0	Normal
10-7-2019	16:03	51 %	58%	0%	0	Normal
10-7-2019	16:13	51 %	58%	0%	0	Normal
10-7-2019	16:23	51 %	58%	0%	0	Normal
10-7-2019	16:33	51 %	58%	0%	0	Normal

2.8.1 Conclusion of Landslide Testing

From the results of direct testing at the landslide location, it can be concluded that the tool can provide information in accordance with what is expected, each sensor is functioning as it should, and can provide information about soil conditions at landslide prone locations, this makes it easier for officers to monitor soil conditions, without having to come to the landslide site, so that monitoring can be done more effectively and there is no need to come directly to the landslide site.

3 CLOSING

3.1 Conclusion

Based on the results of the implementation and testing that has been created it can be concluded as follows:

1. This landslide monitoring and detection application can help officers in the monitoring process.
2. Application of the monitoring and detection of this disaster could give a warning about the landslide obtained from the sensor
3. The landslide monitoring and detection application can provide monitoring results in PDF format which can then be used as event data
4. Monitoring and detection tools can help the landslide mitigation process.

3.2 Suggestion

1. Improve the Parameter for determining the landslide and make more accurate.
2. Adding a chart with realtime graphic and use an auto refresh for the web application.
3. The use of alternative energy as a substitute for electricity flow if the electricity goes out.
4. Accelerate sensor and detector readings with minimal delay.

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