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Soil Movement Monitoring System Based on IoT using Fuzzy Logic

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Abstract: Landslide is one of the disasters that often occurs in several areas in Indonesia, especially in hilly areas, valleys, and volcanoes. Soil conditions in some parts of Indonesia are classified as prone to landslides. The latest data from the Central Statistics Agency related to landslides in 2018 occurred as many as 10,246 events with the highest incidence on the island of Java IoT-based ground motion monitoring using fuzzy logic is a tool that is able to detect ground movements that can trigger landslides. The manufacture of this tool is based on the ig-norance of the community in predicting the occurrence of landslides. To avoid this, an early warning tool is needed in the delivery of information that is easily understood by anyone, especially the public. This tool consists of a Microcontroller, Weather Sensor, Rain Sensor, Ground Movement Sensor, and GSM Shield as well as programs to make it hap-pen. This system was created to provide information to the public directly in land-slide-prone areas. With this early warning system, it is hoped that people who are in landslide-prone loca-tions will know more quickly and can monitor the condition of landslide-prone areas so that they will be more alert to possible dangers that come suddenly, especially fatalities, can be minimized. Through this tool can also be known when the weather is cloudy, raining as well as movement or signs of ground movement, can be monitored and monitored automatically. directly by everyone from mobile phones through "SIPEGERTA" Land Movement System in Wonosalam District, Jombang Regency

Keywords: IoT, soil, fuzzy logic, telegram bot

1. Introduction

Landslide is one of the disasters that often occurs in several areas in Indonesia, especially in hilly areas, valleys, and volcanoes. Soil conditions in some parts of Indonesia are classified as prone to landslides. The latest data from the Central Statistics Agency related to landslides in 2018 occurred as many as 10,246 events with the highest incidence on the island of Java [1]. The landslide disaster caused direct damage such as damage to public facilities, agricultural land, or hampered community activities [2]. The magnitude of the losses caused by landslides due to the loss of property and even lives due to the lack or even the absence of early detection of ground movement that can be used to detect the early occurrence of landslides[3][4]. Soil displacement and excess water content are the main causes of landslides. Landslides are also triggered by the driving force on the ground. In principle, landslides occur because the driving force is greater than the resisting force [5].

In 2019, the landslide that occurred in the Wonosalam sub-district, Jombang Regency resulted in many victims and left deep wounds. This disaster happened suddenly and unpredictable. Around the location there are many residential areas and government facilities. Landslides are difficult to detect. To be able to monitor landslides, a tool is needed that can help provide early warning [6]. The device must be a remote-control system. The internet can be used as a medium of communication and control equipment remotely. Its advantages are its ability to connect countries and continents with low cost and relatively easy. The internet is no longer only for connecting between humans but also connecting between any objects that can be connected (Internet of Things) [7]. In previous studies, a landslide early warning system has been designed using a weight sensing method with a sensor system consisting of a spring with an LED attached to one end of the spring and a photodiode at the other end, so that it can activate the LED indicator [8].

Another study designed electronic devices in the form of a combination of vibration sensors and groundwater content. The landslide model is made on a box made of mica and soil materials. The results obtained based on the slope of the soil [9]. However, this system has a weakness in terms of notification, because it only uses a buzzer as an indicator of a danger sign on the system and uses an LCD as a system interface.

Based on previous research, an early warning for landslides is needed that can be accessed directly and in real time through a mobile application, so that people can be more alert and quickly anticipate victims due to the landslide [10]. The author in this study will make a prototype of an IoT-based landslide detection tool. This tool uses sensors placed in earthquake-prone areas that will send sensor reading data and will provide reports directly through a mobile application. Because landslides are not only caused by shifting soil, but also other factors such as weather conditions. So this tool is not only accompanied by a ground movement sensor but also equipped with rain, cloudy and vibration sensors. Thus, predictions of landslides will be known earlier and the impact of landslides can be anticipated to a minimum.

2. Related Works

A slope will experience a landslide if there is a disturbance in the balance of the forces acting on the slope, where the driving force is greater than the resisting force. The driving force can be caused by external factors, such as the influence of water (rain water, fish ponds, bathtubs or leaking water hoses/pipes), large slopes, and stripping. slopes by humans (land use change). While the retaining force will greatly affect the landslide depending on the type of soil. In principle, avalanches occur when the resisting force is less than the driving force. Simple general formula used in slope stability

Diana With the title Design of an SMS-Based Early Detection System for Landslides. The method used is a weight sensing method with a sensor system consisting of a distance sensor VL53L00X (reflecting object in the form of a mirror) and a spring (with a length of 9 cm, a diameter of 2 cm). and spring constant 62.39 N/m). When the ground shifts in the direction of the slip plane, the upper end of the spring will be compressed by the gravity of the shifting ground plane so that the distance of the reflected object with the sensor is getting closer. As a result, the distance detected by the sensor is getting bigger. The test results show that the prototype is able to detect surface soil shifts in the range of 1 to 7 cm. In addition, this system is also capable of sending SMS for alert status II (2.39 cm ground shift), standby III (3.17 cm), and danger (4.11 cm; alarm-sound)[11]

Zetri R. N with the title Design of an Early Warning System for Flood Disasters Via SMS Based on a Pic16f877a Microcontroller. The purpose of this research is to create a flood warning tool that is provided through SMS and siren services. The results of the design of a disaster warning system are given in the form of a short flood warning message to the community in flood prone areas and a buzzer as another warning medium that serves to provide direct warnings if the disaster warning message is not sent to the destination number.[12]

Novi Herawadi Sudibyo and Muhammad Ridho with the title Landslide Detector Using Light Sensors with the aim of being a tool that can help provide early warnings of sudden landslides. The results of system testing in phase 1 ground shift 1 cm to 1.5 cm where the tool will turn on the green LED as a sign that the ground shift is still relatively safe, in phase 2 ground shift 2 cm to 2.5 cm the tool will turn on the yellow LED as a sign that the surrounding community must start to be alert, while in phase 3 the ground shift is more than 3 cm the tool will turn on a red LED indicating that the land has the potential for landslides, Simultaneously the red LED will activate the buzzer, at the same time the tool will send an SMS to the village head so that he can instruct to its citizens the danger of landslides. [13]

2. Experiment and Analysis

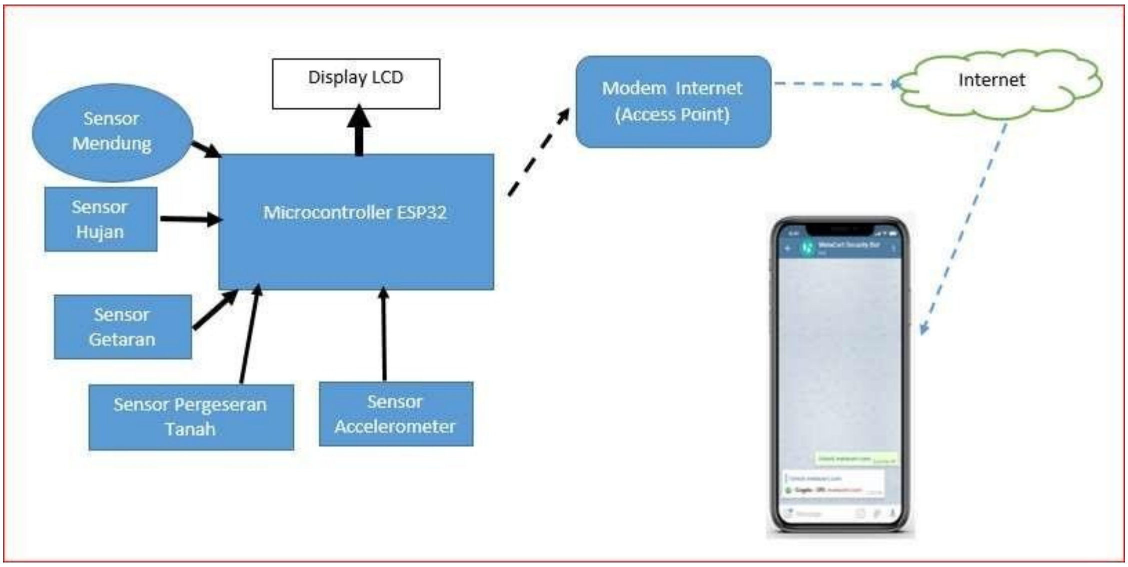

Figure 1. The System Workflow

Figure 1 shows Functional requirements needed for a disaster early warning system:

a) The system can read data from each sensor
b) The system can receive data from sensors that will be sent to the SIPEGERTA Ground Movement System.
c) The system can provide warnings and information about possible landslides through a mobile application. The non-functional requirements so that the system can run properly is a stable network condition.

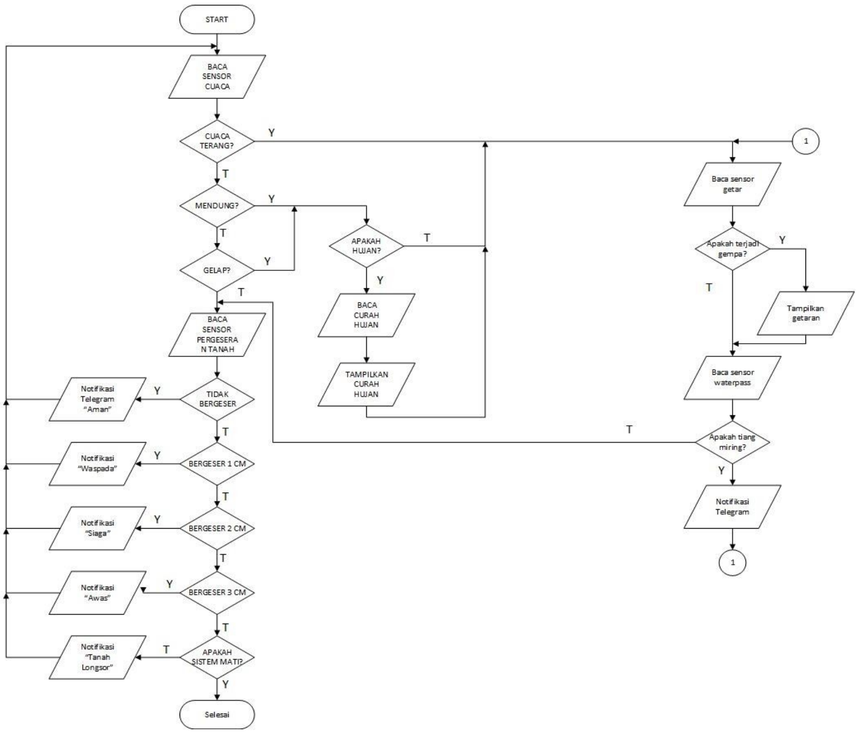

Figure 2. Flowchart Landslide Detection System

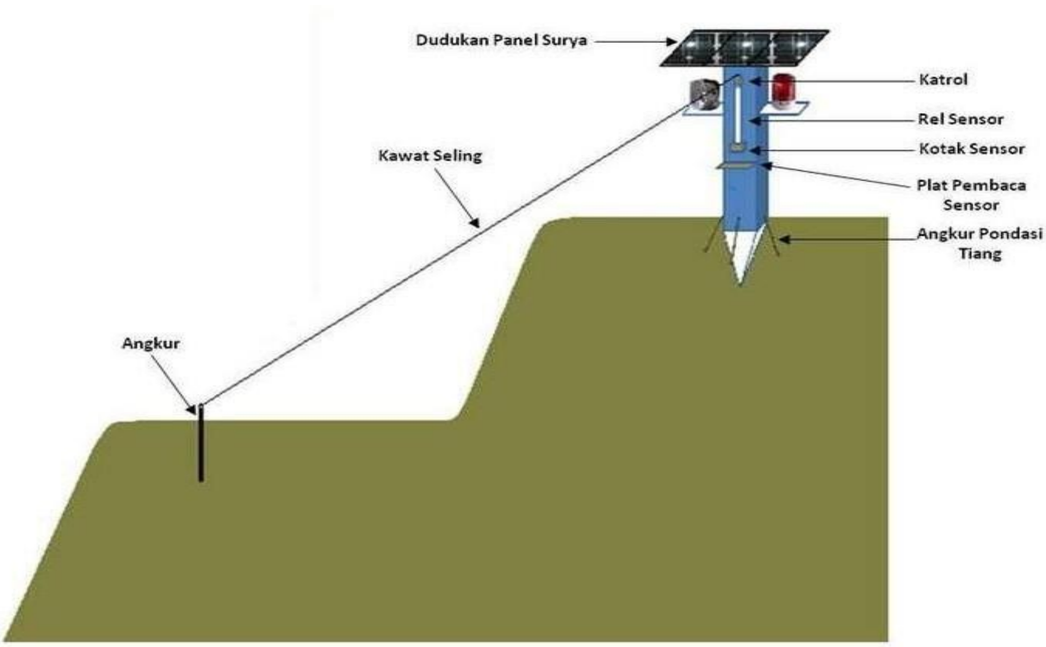

Figure 3. Block Diagram of Landslide Detection Control System

Figure 2 Show ESP32 microcontroller functions as the controlling brain of the landslide detection equipment. The sensors installed will provide information to the microcontroller then the microcontroller will process the data and send it to the internet. First, the cloudy sensor will be read whether the weather is sunny or cloudy around the device, the data will be stored in a variable to determine the weather around. If the conditions around the equipment are cloudy then the tool will

provide information whether it is raining in the vicinity, if it rains the microcontroller will provide a notification to the smartphone (Telegram application) so that officers are more alert because it is raining around the location. Besides, if there are vibrations with a certain scale, it will provide a notification on the smartphone.
If it rains or there are vibrations at the location and there is ground movement which is marked by a shift in the ground, the ground shift sensor will detect the shift and provide notification as an early warning for landslides around the location where the landslide detection equipment is installed. Then there is one more sensor, namely the accelerometer which functions as a water pass from the pole supporting the equipment which is equipped with a solar cell as a power generator. The accelero sensor is set to the normal position at the zero point of the pole, if the pole is also tilted the microcontroller will also provide information If the pole of the equipment has a slope, it can also function to detect the detection device is still standing or collapsing. All information is displayed in a display at once sent to the internet to provide notifications to the officer's smartphone that has the Telegram application installed. The delivery process is via an internet access point or modem from one of the providers with the best signal at the location.

To test the landslide detection tool, it is necessary to prepare software with several libraries needed to support the hardware used. Some of the required libraries are as follows:

```
#include <SPI.h>
#include
<Wire.h>
#include
<ezTime.h>
#include
<WiFi.h>
#include <Adafruit_GFX.h>
#include
<Adafruit_SSD1306.h>
#include
<WiFiClientSecure.h>
#include
<UniversalTelegramBot.h>
#include <ArduinoJson.h>
#include
"I2Cdev.h"
#include
"MPU6050.h"
```

SPI Function: The SPI.h library is a library specifically tasked with handling SPI (Serial Peripheral Interface) synchronous serial communication on Arduino. Synchronous serial is a data communication protocol that works in serial but requires a clock line to be synchronized between the transmitter and receiver. However, specifically the term 'SPI synchronous serial' is used, which is intended for the type of synchronous serial communication protocol that has three cable lines, namely MISO (Master In Slave Out), MOSI (Master Out Slave In) and SCLK (Serial Clock). MOSI is the channel for sending data from master to slave, while MISO is the opposite. There is one additional pin used to enable or disable the SPI slave device called CS (Chip Select) or SS (Slave Select). The CS or SS pins are specific to each slave device that uses SPI communication

Wire function: The wire.h library is used to generate pins used for I2C serial communications that require data pins and clock pins. The serial data pin on I2C is called SDA and the clock pin is called SCK/SCL. In the ESP32 there are already hardware I2C pins, namely pin 22 is SCK and pin 21 is SDA. If you feel you want to create shadow pins for I2C communication, you can use the wire.h library.

The ezTime function: The ezTime.h library is used to retrieve clocks on the internet, because the system already utilizes IoT (Internet of Things) technology, so to generate time, there is no need for an RTC (Real Time Clock) component because the internet has provided time according to international rules. . By using the Timezone object function to read the time in the Asia zone with the myTZ variable, so that the event() command then sets the location to "Asia/Jakarta" the system will automatically read the time according to the location, which must first be synchronized with the waitForSync() function. The date and time will be run in RFC2822 format. Wifi function: To run the ESP32 board connected to the internet, the library used is wifi.h. This function will define the wifi mode followed by the SSID and password parameters of the access point used for network access.

Functions for OLED Display : Adafruit_GFX.h and Adafruit_SSD1306.h libraries work for set up the OLED display, so that it can display the information data needed by the system. The 0.96” OLED display with 128X64 pixel size uses I2C communication to access it at address 0x3C.

Function for Client: Because the landslide detection tool functions as a client that takes data from sensors then processes and sends results in the form of notifications to the Telegram server, the system requires the WiFiClientSecure.h library which will handle the client to be able to send information data to the server.

TelegramBot function: To be able to access the Telegram server and communicate with the Telegram Bot, the system must use the UniversalTelegramBot.h library. By using the library, ESP32 can access the Telegram server using the Token from the Telegram Bot that we created and the Chat ID belonging to the officer whose smartphone is used to receive notification of conditions reported by the landslide detection tool.

Arduino Json function: To accommodate information data from Telegram, the ArduinoJson library is used so that the received data can be in Arduino Json format and recognized by ESP32. The Arduino Json version used should be version 5.13.5 which supports the TelegramBot library. I2C Development Function: This function is used to generate the I2C address used by the waterpass sensor (MPU6050), namely the gyroaxcelero.

MPU6050 function: to measure the perpendicularity of the support poles of the landslide detection device with its installation, a detection device such as a waterpass is needed, so that the support poles are in a perpendicular position on the X axis and Y axis. This sensor will later be used also to detect the slope of the support pole, if there is a slope, immediately provide a notification to the officer's Telegram application so that immediate action is taken to correct the landslide detection tool.

2.1 Weather Sensor

This LDR sensor reads the weather around and will divide it into three conditions, namely light, cloudy and dark. In this design, the LDR is installed in series with a 1kΩ resistor and the output is a voltage divider between the LDR and the resistor and is inserted into the analog pin of the ESP32 (pin34) which is then converted into digital data.

Figure 4. Weather sensor

```
void setup() {
 // put your setup code here, to
 run once: Serial.begin(9600);
}
void loop() {
 // put your main code here, to
 run repeatedly:
 Serial.println(analogRead(34));
 delay(200);
}
```

2.2 Rain Sensor

To find out at the location of the landslide detection device it is raining or not, the rain sensor is installed on the detection tool. Here is the installation of the rain sensor.

Figure 5. Sensor Rain

To test the rain sensor used a program as follows. #define rainAnalog 27

```
#define
rainDigital 26
void setup() {
Serial.begin(960
0);
 pinMode(rainDigital,INPUT);
}
void loop() {
 int rainAnalogVal =
 analogRead(rainAnalog); int
 rainDigitalVal =
 digitalRead(rainDigital);
 Serial.print(rainAnalogVal);
 Serial.print("\t");
 Serial.println(rainD
 igitalVal);
 delay(200);
}
```

The results of the test program above produce the following graph:

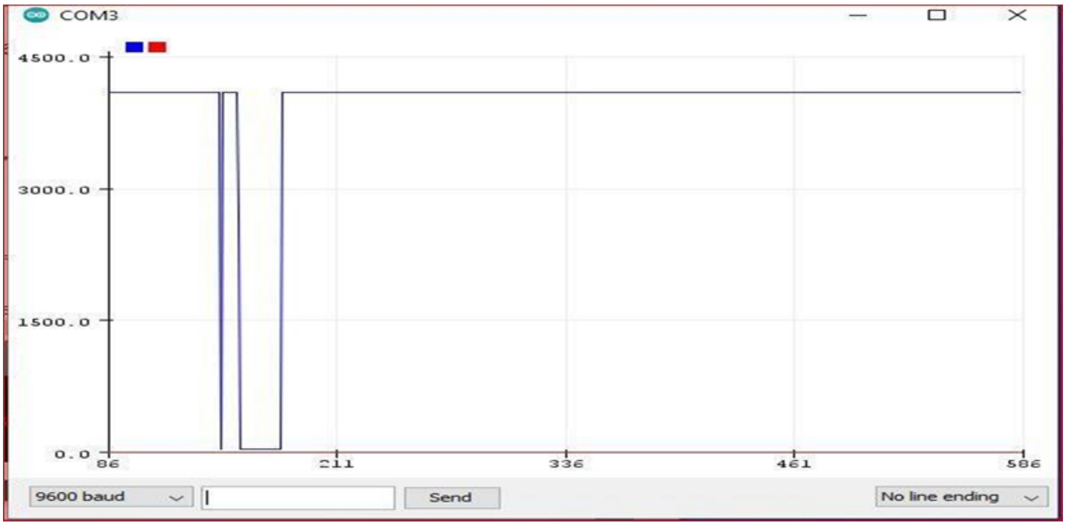

Figure 6. Grafik Rain Sensor

Meanwhile, to test the rain sensor in the system that provides notifications to the Telegram server, it is as follows.

```
void baca_sensor_hujan(){
 rainAnalogVal =
 analogRead(rainAnalog); int
```

```
rainDigitalVal =
digitalRead(rainDigital);
Serial.print(rainAnalogVal);
Serial.print("\t");
Serial.println(rainDigitalVal);
if
 (rainDigitalVa
 l == 0) cuaca
 = "Hujan";
 if (rainAnalogVal <
  250){ cuaca =
  "Hujan Deras";
}
```

2.3 Vibration Sensor

In the landslide detection system there is a sensor that detects ground vibrations around the location where the tool is placed. Of course, a landslide process will be initiated by a process of ground vibration around the site. The vibration is monitored by the SW-420 vibration sensor which is able to sense any vibrations that occur. Vibration sensor photos are as follows
To test the vibrations that occur and display a graph of the vibrations that occur around the detection device and are sensed by the sensor, it is as follows.

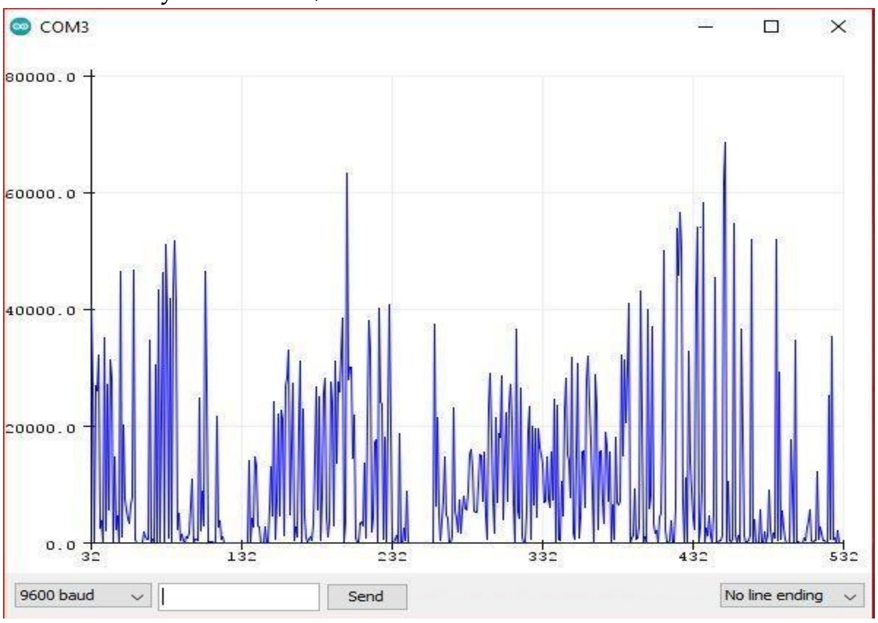

Figure 7. Graph of Sensor Vibration

In the detection system, it only displays numerical functions without displaying graphics, because the Telegram application cannot display graphics but only in the form of text notifications so that the sensor reading results in the form of numeric are displayed on the display and sent to Telegram in the form of number notifications.

Based on a research journal article, it was found that the conversion of the SW-420 vibration sensor reading to the Richter scale of a vibration. If the value of the vibration sensor is below 2677, the system is analogous to below 1 SR (Ritcher scale), whereas if the value is between 2677 and 8433 in the range of 1-2 SR, for values between 8433 to 16322 it has a value of 3-4 SR. between 16322 to 22889 has an equivalent value of 5-6 SR, then the vibration value between 22889 to 38662 has an equivalent value of 7-8 SR, and if the value exceeds 38662 then the vibration equivalent is on a scale of 9-10 SR.

The results that can be obtained from the vibration and temperature sensors can be reported via the telegram boot which will notify the Telegram server and be received in the official Telegram Bot chat. If the "Safe" notification will be sent to Telegram every 8 am, if the "alert" notification will be sent twice a day, namely at 8 am and 8 pm. While the "Alert" condition this notification will be sent every hour, the more critical the condition, the more frequent the notification to the officer's Telegram. If the "Beware" condition, a notification will be sent every ten minutes, the more intense so that the officer can be more alert and immediately provide information to the public to avoid the location where landslides will occur. And finally, if the landslide condition occurs, a continuous notification will be given to the officer's cellphone that a landslide has occurred at the location, so that it can be detected earlier so that there are no casualties.

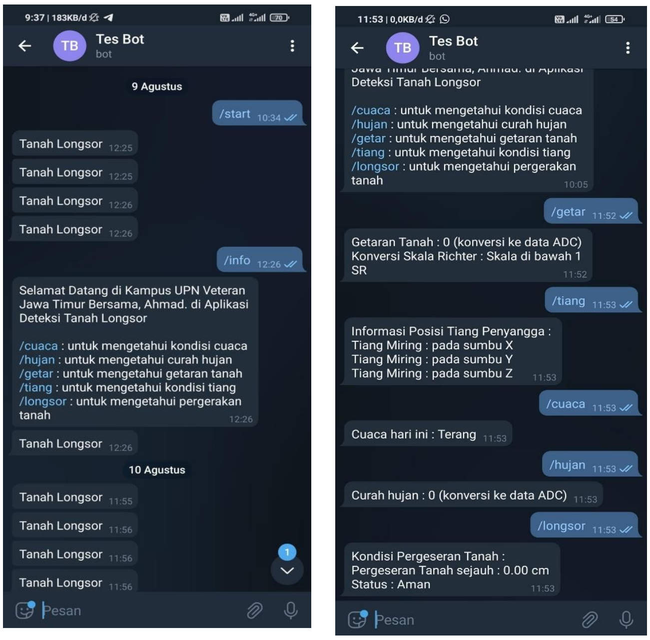

Figure 8. Notification display to telegram

4. Conclusions

Based on the results of the framework analysis can be concluded the following.

1. IoT-based ground motion monitoring using fuzzy logic is a tool that is able to detect ground movements that can trigger landslides. The manufacture of this tool is based on the ignorance of the community in predicting the occurrence of landslides. To avoid this, an early warning tool is needed in the delivery of information that is easily understood by anyone, especially the public. This tool consists of a Microcontroller, Weather Sensor, Rain Sensor, Ground Movement Sensor, and GSM Shield as well as programs to make it happen. This system was created to provide information to the public directly in landslide-prone areas.

2. With this early warning system, it is hoped that people who are in landslide-prone locations will know more quickly and can monitor the condition of landslide-prone areas so that they will be more alert to possible dangers that come suddenly, especially fatalities, can be minimized.
3. Through this tool can also be known when the weather is cloudy, raining as well as movement or signs of ground movement, can be monitored and monitored automatically. directly by everyone from mobile phones through "SIPEGERTA" Land Movement System in Wonosalam District, Jombang Regency

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