Design of Automatic Rain Gauge Prototype (ARG) As An Early Warning Indicator for Cold Lava Flood Based on The Internet of Things (IoT)

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Abstract. This study aims to design a prototype of automatic rain gauge, characterize the automatic rain gauge, rainfall classification as an indicator of cold lava flood, tested the automatic rain gauge prototype. The design of this tool includes three parts, the first is the reed switch block design. Second, designing an automatic rain gauge block by designing a tipping bucket. The third is designing IoT block and Android applications. The automatic rain gauge prototype was successfully designed with a 0.8 cm reed switch and a tipping bucket with a funnel area of 380 cm$^2$ with a resolution of 0.1 mm and a maximum capacity of 9.4 mm/minute. The classification of rainfall as an indicator of cold lava flood is normal 0-15 mm, advisory 16-20 mm, watch 21-48 mm and warning > 48 mm, so that the early warning system prototype can display rainfall charts and warning alarms on the android application.

1. Introduction
Mount Merapi is a mountain which has an altitude of 2,968 meters above sea level and is in the middle of the island of Java [1]. Based on its shape, Mount Merapi has a strato-volcano type, which is a high, conical composite volcano consisting of hardened lava or volcanic ash [2]. Mount Merapi is listed as the most active volcano in Indonesia with a short cycle that occurs every 2-3 years, while a medium cycle of 5-7 years. With a stable level of activity of Merapi, the possibility of cold lava floods becomes very large, because with the eruption that brings a lot of material out of Merapi, the material can quickly be washed away by rain [3]. The velocity of river water flow with high sediment concentration in rivers with very steep slopes (debris) with coarse sediment has a velocity of between 2-20 m / sec. With such strength and speed, this flow is able to lift large boulders and is able to shift the construction of bridges and settlements in its path [4]. Cold lava flood known in volcanic rivers is a flow of mixed water and sediment of various sizes. The conditions for lava formation are influenced by several factors, including adequate water from the source, abundant deposits of loose debris, steep slopes and the existence of a lahar trigger mechanism. Sources of water that form lava can be in the form of pore water, crater lake water or other lakes [5]. Based on the research, it can be concluded that the indicators of cold lava flood that occur in the Boyong River have a minimum rainfall intensity of 48 mm / hour and the White River has a minimum rain intensity of 47.5 mm / hour. Rainfall parameters that occur in the upper reaches of the Boyong River and the White River of Mount Merapi can be used in designing an early warning tool for cold lava floods [6]. Creating a remote monitoring station Early Warning System (EWS) system in river basins to provide early warning of cold lava
floods to the community will be faster [7]. This flow is known to have the power to destroy and the speed of its flow is very fast [8]. Even though BPPTKG has monitored several aspects of disaster, the cold lava flood early warning system is not yet available on the website, so the need for a cold lava flood early warning system that is easily accessible to the wider community [9]. With current technological advances, it can utilize the internet as a medium for data transfer. Internet of Things (IoT) technology can be used for an early warning system for Mount Merapi cold lava flood using a reed switch sensor based on the microcontroller ATMega328P and the Internet of Things.

2. Circuit and Fundamental Theory

2.1. Sensor Reed Switch
Reed Switch is an electric switch that is operated by a magnetic field. This object was discovered at Bell Telephone Laboratories in 1936 by WB Ellwood. Its parts consist of a pair of metal contacts tightly closed in glass. Under normal circumstances an open contact, when a magnetic field is detected, metal contacts will connect to one another and deliver an electric current. After the magnetic field is pulled from the switch, the reed switch will return to its original position [10]. Material resistivity is a physical quantity which states how much the ability of a material to withstand the flow of electric current, especially the movement of electrons so that the electric current flowing in the material decreases and creates a potential difference at the two ends of the material with which the electric current flows [11].

2.2. Tipping Bucket
The tipping bucket shown in Figure 1 has a working principle that is when rainwater is collected on tipping tipping. The mechanical process can be separated into two, namely: the stationary stage and the bucket rotation stage. First, the bucket does not move until the full rainwater is greater than the volume of water on one side of the bucket. As the volume of water increases, the center of mass of water gradually moves away from the axis. If the water fills the tipping container which is equivalent to the high rainfall, the tipping will be tipped and the water is removed. There are two tipping that alternately collect rainwater. Every tipping movement is mechanically recorded on a microcontroller (counter) that uses a reed switch sensor [12].

![Figure 1. Tipping Bucket](http://www.indiawrm.org)

2.3. Arduino Uno
Arduino Uno is a combination of hardware, programming language and IDE (Integrated Development). IDE is a software that has functions for writing programs, storing and uploading to microcontroller memory, the microcontroller used is the ATmega328P on the Arduino Uno R3 output from atmel which has a RISC (Reduce Instruction Set Computer) architecture where each data execution process is faster than the CISC (Completed Instruction Set Computer) architecture [13].
2.4. Modul esp8266
The ESP8266 module is a SoC (System on Chip) with an integrated TCP/IP protocol stack, so that it is easily accessed using a microcontroller via 802.11b/g/n Direct (P2P) serial communication. The ESP8266 WiFi module can function as a host or as a data transfer module in a WiFi network. This module has good data processing and storage capabilities making it possible to be integrated with sensors and other special devices via GPIO pins. Until now ESP8266 has had many types that have been added various modules that can make it easy for the development of the IoT system. Of the many ESP8266 variants, this study will use ESP8266-01. ESP8266 settings have three access modes as WiFi access using AT commands, usually used by Arduino Uno for WiFi connections, as a stand-alone system using NodeMCU and using the LUA language, as a stand-alone system using the Arduino IDE which can already be connected to the ESP8266 [14].

2.5. Android application
The structure of an Android application or application fundamentals is written in the Java programming language. Java code is compiled together with resource files needed by the application. Where the process is package by a tool called the Software Development Kit (SDK) into the Android package. So that it produces files with an apk extension. This apk file is called an application, and can later be run on mobile devices. To create an Android application, Google provides an Android Studio platform. Android Studio is an Integrated Development Environment (IDE) specifically for building applications that run on the Android platform. This Android studio is based on IntelliJ IDEA, an IDE for the Java programming language [15].

3. Working Principle
Early warning system for Merapi Volcano Cold Lava flood consists of 3 blocks, namely sensor block reed switch, Automatic rain gauge block, internet of things block. The way the early warning system works is as follows:
- The tipping bucket accepts artificial rainwater supplied to the tipping bucket mouthpiece
- The reed switch sensor on the tipping bucket is connected when tipping moves
- Microcontroller calculates the amount of tipping and converts it in rainfall
- ESP8266-01 sends rainfall data to the web server and is forwarded to the android application
- Rainfall data is displayed in graphical form and warning alarm in the form of sound

4. Materials, Components and Device’s Construction
The tools and materials used in this research are Power supply, Shinhwa Multimeter, Scissors, Hacksaw, Solder Winner, Glue Gun, Solder Tin Suction, Acer Laptops, Measuring Cups, Arduino IDE 1.8.5 Software, Android Studio 3.6.1 Software, Fritzing Software 0.9.4, Android Mobile. The components used in this circuit are PCB, Arduino Uno Board with ATMega 328P microcontroller chip, 1 WiFi transmitter module or ESP8266 receiver, Jumper Cable, 1 roll of solder solder, Alteco glue, Acrylic, Gun glue. The use of power supplies, with components namely: rafo 1 A, capacitors with capacitance of 100 nF and 10 uF, Resistor 10k ohms, white LEDs 1 piece, Connecting Cable, IC Regulator LM7805, LM7812, and LD33V each 1 piece, PCB, Diode 1N4002. Tipping bucket circuit, with the following components: Reed switch sensor with a length of 1 cm, Aluminum funnel with a height of 35 cm and a diameter of 15 cm, Tipping of aluminum with a length of 11 cm and width of 2 cm, Connecting cable, PCB , 2 Bearings with a diameter of 0.9 mm, Supporting bolts, Magnets 0.8 cm in diameter, Iron shaft with a length of 8 cm.

5. Result and Discussion
The power supply circuit is used to adjust the source voltage to the voltage in accordance with the needs of the components that require the power source. The components used include the CT
transformer, IC regulator, capacitors, resistors, and diodes. The power supply is used as a voltage source for the reed switch, arduino and ESP8266 sensor circuits, each of which requires a voltage of 3 volts, 5 volts, and 12 volts. Based on the test results, the power supply can produce an output voltage of 3.3 volts with an error value of 1.2 %, 5 volts with an error value of 1.4 %, and 12 volts with an error value of 0.6 %. The output has a good stability value despite the voltage drop in several measurements. Reed switch sensor characterization is done by measuring the distance between sensor detection and magnetism. This measurement is carried out by varying the distance of the permanent magnet from the reed switch sensor. The measurement results can be seen in Table 1.

| Distance (cm) | V input (volt) | Condition | V output |
|--------------|---------------|-----------|----------|
| 0            | 5             | Connected | 4.85     |
| 0.2          | 5             | Connected | 4.85     |
| 0.4          | 5             | Connected | 4.85     |
| 0.6          | 5             | Connected | 4.85     |
| 0.8          | 5             | Connected | 4.85     |
| 1            | 5             | Disconnected | 0    |

Based on the measurement table above, the data is analyzed that the reed switch sensor will be connected if the distance of the magnet and the sensor reed switch is 0-0.8 cm with an output voltage of 4.85 V. The reed switch and magnet sensor installation is done by regulating distance sensor reed switch at the farthest reading is 0.8 cm, thus the distance sensor reed switch and magnet when facing conditions is 0.8 cm and when not facing 1.6 cm.

Tipping bucket is designed as a tool to collect rainwater and affect the sensor reed switch. The effect occurs when the surface of the reed switch sensor is exposed to a magnetic field on the bucket, so that the two thin contact plates contained inside the reed switch sensor will be attracted by the magnetic field, so the contact will be connected.

The magnetic field to move the reed switch, comes from a magnet found in the bucket tipping, which moves left and right. The type of bucket used has the following specifications
1. Funnel cross section diameter of 22 cm
2. Bucket resolution for 4.2 ml single tipping
3. The input voltage is 5 V

To calculate the funnel cross-sectional area, the circle formula is used as follows

$$ l = \pi r^2 $$  \hspace{1cm} (1)

From the calculation of the funnel cross-sectional area, it is then used in the equation to find the tipping bucket constant. From the tipping bucket constant data can be used to measure the value of rainfall.
The design results show that the tipping bucket is working well, the resolution of the tipping bucket is 0.1 mm per tipping and the maximum capacity of the tipping bucket is 9.4 mm per minute. ARG testing is done to determine the error value, the error value sought at the testing stage is an error in percent. Error values in percent can be calculated using equation (3).

\[ Error = 100\% - \frac{\text{Measured Water Level (mm)}}{\text{High Water Intake (mm)}} \times 100\% \] (3)

| Input Volume (ml) | Tipping Amount | Output Volume (ml) | Rainfall (mm) | Error (%) |
|-------------------|----------------|-------------------|---------------|-----------|
| 100               | 24             | 24                | 100 ± 0       | 2.4 ± 0   | 0 ± 0     |
| 200               | 47             | 46                | 196.56 ± 1.3  | 4.68 ± 0.032 | 1.72 ± 0.6 |
| 300               | 70             | 69                | 293.16 ± 1.3  | 6.98 ± 0.032 | 2.28 ± 0.6 |
| 400               | 93             | 92                | 390.60 ± 1.68 | 9.3 ± 0.040 | 2.35 ± 0.4 |
| 500               | 114            | 114               | 477.96 ± 2.77 | 11.38 ± 0.06 | 4.4 ± 0.5 |

From the test data of Table 2, it is known that the largest error value is 4.4 ± 0.5 % with the maximum intensity of the tipping bucket, namely 9.4 mm / minute or 564 mm / hour. Acceptable tolerance values for tipping buckets are 6 % for intensities < 250 mm / hour and 8 % for intensities > 250 mm / hour [16]. By using the rainfall data can be classified the level of cold lava flood disaster in the Boyong and White rivers. The level of disaster classification for the cold lava flood of Boyong and Putih rivers is shown in Table 3.

| Rainfall Intensity | Boyong River | Putih River | Classification |
|-------------------|--------------|-------------|----------------|
| 0-15 mm           | 0-15 mm      | Normal      |
| 16-20 mm          | 16-20mm      | Alert       |
| 21-48 mm          | 21-47.5mm    | Standby     |
| >48 mm            | >47.5mm      | Watch out   |

Cold lava flood level classification is used to program the work of Arduino and Android applications so that it can provide output in accordance with the level of classification. Previously, a series of equipment tests that have included power supply, ARG, and IoT system have been tested before, each section has been run properly.
From Figure 3 it can be seen that the rainfall data was successfully sent on the android application with the rainfall value on the Y axis and time on the X axis. The rainfall value on the android application will be automatically displayed every hour at 01:00 to 24:00, the data rainfall will be reset once every hour. Has designed an ARG prototype as an indicator of IoT-based mountain cold lava flood which consists of three blocks, namely the reed switch sensor block. ARG block consisting of tipping bucket and microcontroller. IoT block with ESP8266-01 wifi module and op-amp voltage amplifier. ARG has a tipping bucket resolution of 0.1 mm per tipping, a maximum intensity of 9.4 mm per minute and a cross-sectional area of 380 cm$^2$ funnel. The results of the ARG prototype testing as an early warning indicator of Mount Merapi’s cold lava flood have provided a display in the form of graph lines and indication in the form of a sound alarm when testing with artificial rainfall.

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