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Smart System Monitoring of Gradient Soil Temperature at the Anak Krakatoa Volcano

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Abstract: Krakatoa volcano was erupted at 1883 which lead to tsunami and 36417 people died during this disaster. Now a days, it's volume growth rapidly and named the Anak Krakatoa volcano. This volcano is one of 129 active volcanoes in Indonesia. It is very important to monitor the volcanic activity such as identified of soil temperature gradient as one of the important parameters for predicting volcano eruptions. In this research, furthermore, we had develop system monitoring of soil gradient temperature used mini single board computer BCM2835. Sensor DS18B20 was used to measure the temperature. Data temperature was sent by SMS technology and recorded into data base server. The system has a report activity and can be accessed through web application, early warning system was also implemented, system will sent SMS notification if there any critical event founded during measurement. Modified waterfall model was used for software development life cycle. The result of gradient temperature monitoring shown that at depths of 30, 60 and 90 cm, temperature ranged was between 25-32°C, the deepest sensor position has highest temperature and at nearest surface has lowest temperature.

Key words: Single board computer BCM2835, monitoring system of gradient temperatur, the Anak Krakatoa volcano, position, development, surface

INTRODUCTION

The Anak Krakatoa volcano is located in the regency of South Lampung, Lampung Province Indonesia, exactly at Sunda Strait, around 130 km from the capital city of Indonesia, Jakarta (satellite image shown on Fig. 1). This volcano is one of the most active volcano among 129 others in Indonesia. This volcano is a volcanic island that composed of distraction layer between lava flows and pyroclastic sediment (Sutawidjaja, 2006).

Krakatoa volcano erupted in 1883, after almost 43 years not active, underwater eruption occurred again on December, 29, 1927. As a result of the eruption, there were a fountains on ocean sea occurred constantly at the center of the Krakatoa volcano area until 15 January, 1929. Then, on January 20, 1929 appeared the material that formed a small Island. This was beginning, of the formation of Anak Krakatoa volcano (Stehn, 1929).

The elevation of Anak Krakatoa since 1930-2005 has reached 315 m height above sea level with volume reaching 5.52 km^3 in years 2000 and in general the growth average rate was 4 m/ year (Stehn, 1929). Volcano eruption activity of Anak Krakatoa during 1992-2001 occurred almost every day, so that in 9 years, the volcano has increased more than a 100 m high with areas growth as 378527 m^2. If the increasing height and volume is consistent, it is predicted that by 2020 volume Anak Krakatoa volcano has exceeded the volume of Rakata, Danan volcano and volcano Perbuwatan (11.01 km^3). By observing the rapid growth of Anak Krakatoa, then it is possible that the same eruption will happen and even larger than the eruption of Krakatoa in 1883 which lead to the tsunami that claimed 36417 people died (Sutawidjaja, 2006).

Volcanic soil temperature is one of the important parameters for predicting volcanic eruptions in addition to thermal cloud, silent fire, avalanches, dome grows, seismic activity, magnetic, soil inflation, SO_2 activity, length symptoms, short symptoms and rains.With an increasing pattern of temperature changes in the soil can be interpreted into sign of eruption at the volcano (Noviar *et al*., 2006).

By looking at the growth of Anak Krakatoa and the importance of soil temperature gradient measurement, then it is necessary established a research of monitoring system to measure the soil temperature gradient at Anak Krakatoa. The gradient temperature of Anak Krakatoa soil area will be measured and transmitted to an application through SMS technology. The purpose of monitoring

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Fig. 1: The Anak Krakatoa volcano

application is to conducted the thermal soil measuring process, send and processing the data without having to be in the area of Mount Anak Krakatoa.

Literature review: Monitoring system is an environment that is intertwined and has a function as a tool to observe, supervise, control or verify the operation of a system (Anonymous, 2016) while single board computer BCM2835, well known as Raspberry Pi is a mini computer that has same size of a credit card and often times was used for system monitoring (Nama *et al*., 2014, 2015a,b; Despa *et al*., 2015). Noviar on work (Noviar *et al*., 2006) declared that soil temperature gradient is a temperature change with the distance or depth. This gradient is necessary to overview the pattern of temperature changes at some area including for Anak Krakatoa volcano area.

Sensor DS18B20 is a waterproof temperature sensor. This sensor is suitable for measuring temperatures at wet area and difficult to reach. The sensor output is on digital format (Akhyar, 2014). BCM2835 and DS18B20 used as the main component of system monitoring. While the data will store into database system, the database is a structured data storage integrated and interconnected with others connecting elements and can be accessed in various ways. Users can be grouped into three levels of abstraction when looked at the database such as: physical level, conceptual and views of users (Kristanto, 1994). Modified waterfall is one of the Software Development Life Cycle (SDLC) framework with several phase shown on diagram as follows.

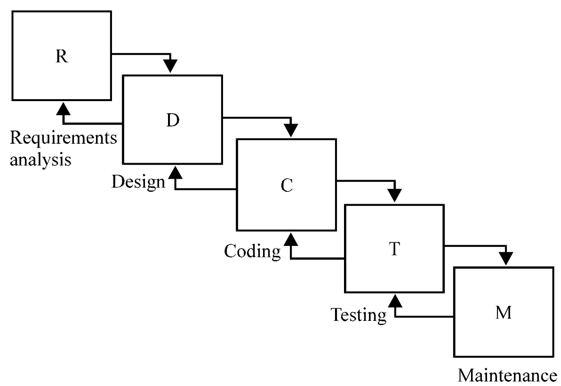


Fig. 2: Modified waterfall model, Xiong (2011)

Figure 2 shown that the modified waterfall models have five main stages; requirements analysis, design, coding, testing and maintenance. Each stage is performed sequentially in accordance with the down arrow and can feedback to earlier stages. For describing the data flow, one of famous method was using Data Flow Diagram (DFD), it illustrates the flow of information and transformation data from input to output (Puntambekar, 2009).

Asri (2014) on research said that Gammu is a software that aims to help programmers create applications on a system and able to use all the functions available on cell phones. Gammu Software can provide multiple features to database system such as SMS incoming, outgoing SMS, call list, phonebook list, calendar and MMS. Some open source application usually used to develop application

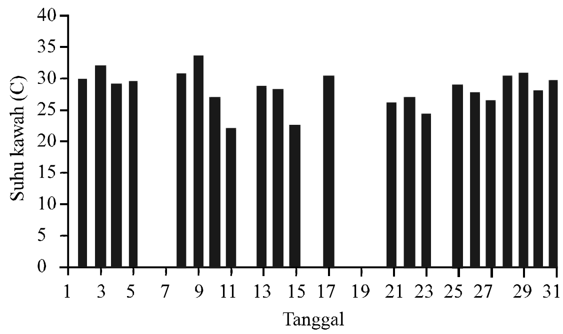


Fig. 3: Daily graph temperature, Kawah Sangean surface on May 2002 (Noviar *et al*., 2006)

such as Python, PHP programming language can be used and work well described on research by Nama *et al*. (2015a, b).

Some researches related to temperature measurement was conducted by Marpaung and Ervianto (2012) on their research they used sensors DS162 to gather the temperature data, processed by microcontroller 8535 and sent via. RS-232 serial communication to Personal Computer (PC). The measurement results in graph and table format shown on PC screen and the data was also stored in to PC hard disk (Nama *et al*., 2014).

Noviar *et al*. (2006) on research proposed a method to identify surface temperature using satellite data, Fig. 3 shown that the author used and explores canals image of National Oceanic and Atmospheric Administration (NOAA), implemented land surface temperature algorithms in order to observe the pattern of temperature changes on volcano. From the data result (Fig. 3) shown there were a chart patterns of temperature change but unfortunately that there was missing data for a few days due to the recording of data was corrupted or not recorded and are can't monitored due to the thick cloud (Noviar *et al*., 2006).

This research conducted a gradient temperature monitoring using a single board computer BCM2835 and temperature sensor DS18B20. The results of data monitoring display on graphical format through web interface, Python programming language and MySQL engine used to processing the data. The advantages of this application is the monitoring process can be carried out over long distances, the monitoring process is not influenced by cloud conditions because the sensor placed directly on Anak Krakatoa area and there were early warning system used SMS notification (if the sensor not work or the temperature exceed maximum threshold).

MATERIALS AND METHODS

In this research, modified waterfall model framework was used to identify requirement and develop the gradient temperature monitoring both to implementing the hardware and software. There were several phase according to this framework that are given.

Requirements analysis: The results of requirement analysis based on interviews activity with the managers of Anak Krakatoa volcano, there were a several feature that should be implemented on application, those such:

- The system should able to display the information of temperature, temperature gradient and system performance in graphical format in real-time
- The system should able to display the information of temperature, temperature gradient and system performance in graphical format according with the time parameters set on system
- The system should able to display the data of temperature, temperature gradient and system performance in accordance with the time interval set on system
- The system can send notification via. SMS when the sensor not work and the temperatures have exceeded maximum threshold

Design

Hardware design: Figure 4 shown the architecture of hardware design, on Fig. 4a displayed a component of system monitoring such as: 1) Solar cell; 2) Solar cell charger controller; 3) Accu; 4) DC step down regulator; 5) Modem wavecom; 6) RTC DS3231; 7) Sensor temperature DS18B20; 8) Resistor; 9) Cooler; 10) USB modem alcatel; 11) Laptop/Server and b) Sensor placement shown the scenario of sensor position under the volcano land surface, there are 3 sensor with 3 different depth, 90, 60 and 30 cm.

Software design: At this stage of software design we used Data Flow Diagram (DFD) to identify the workflow of data during the whole monitoring temperature process.

Figure 5 shown the whole workflow data on this system, consists of four entities (user, manager, sensor DS18B20 and single board computer BCM2835) and

5 processes (system real-time temperature and temperature gradients, measurement systems and the delivery of data, real-time systems single board computer BCM2835, a system of monitoring the temperature, temperature gradient and performance BCM2835 single board computer and temperature early warning system.

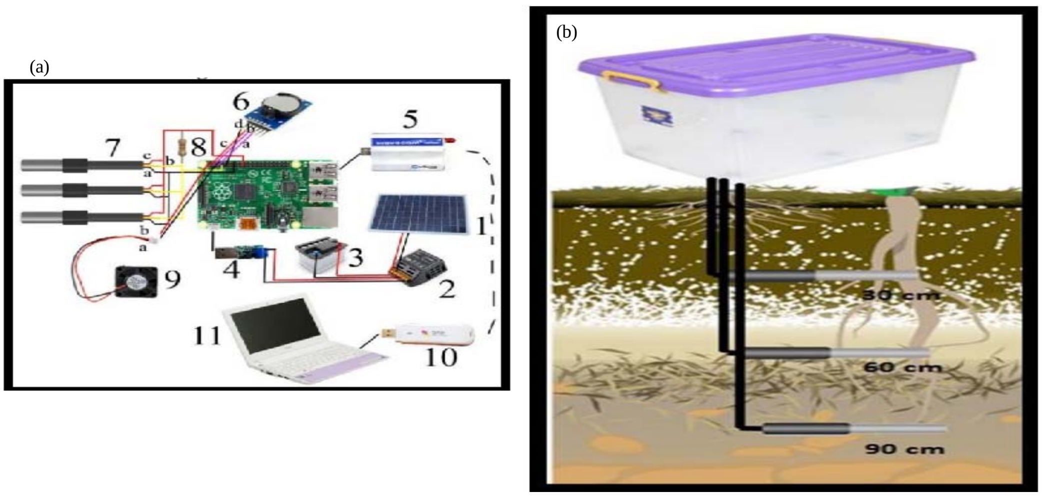


Fig. 4: Design architecture of hardware: a) Sensors and hardware and b) Sensor placement

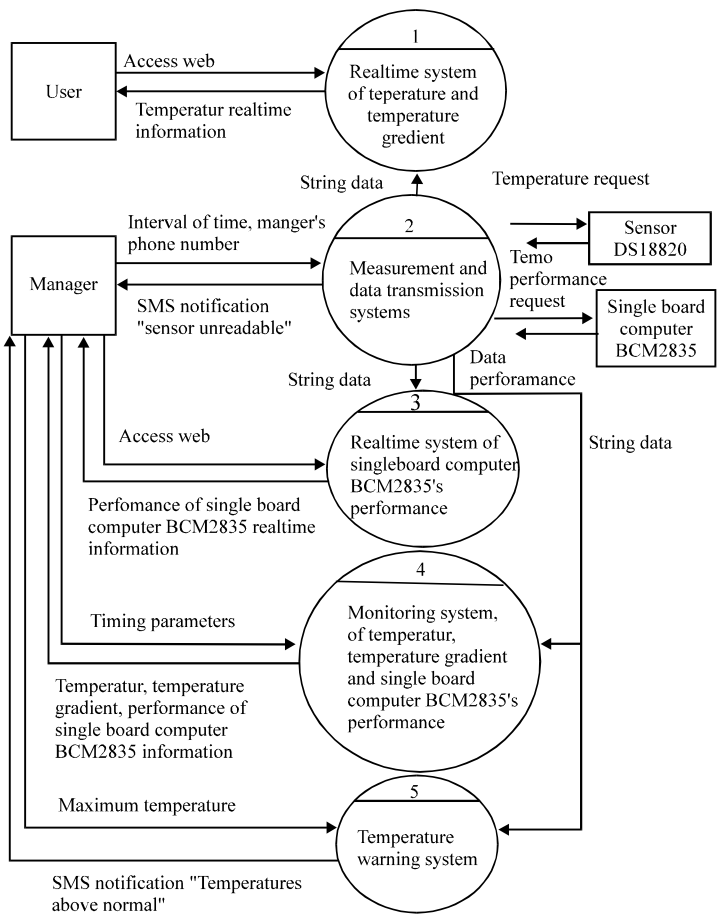


Fig. 5: Data Flow Diagram (DFD)

RESULTS AND DISCUSSION

Coding/implementation

Implementation of system measurement and data transmission: In this implementation phase, we have performed system test at two locations, those are: in Bandar Lampung City, Anak Krakatoa volcano. Implementing system in Bandar Lampung area was to provide the sensor calibration and to make sure the system running well before implementing on Krakatoa Mountain, the result of sensor calibration shown on Table 1.

Beside perform a sensor calibration, we also made a test for data transmission using SMS technology and still in Banda Lampung area, the result of data sending using Gammu daemon run well, the temperature data successfully transmited from Raspberry to server, Fig. 6 shown the delivery status data when application implemented in Bandar Lampung and being success marked by flagging sending ok No. report.

While the implementation system at Mount Anak Krakatoa founded several obstacles, there was a weak GSM signal and several times the data transmission failed due to lost GSM signal on modem, single board BCM2835 forced to stop sending the data after several time failed trying send the data through GSM modem, log of failed sending show on Fig. 7.

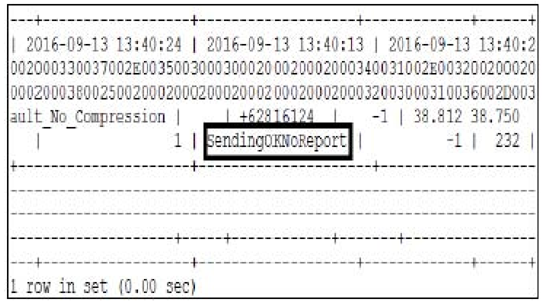
Figure 7 indicated the failed data delivery when system was being implemented at Anak Krakatoa. Sometime, the data couldn't sent and marked as sending error which it means the system failed to transmit data mainly due of signal lost during transmission process.

Collecting the data near of monitoring station (heading to the sea): Temperature sensor was placed near the monitoring station on September 24, 2016 until September 26, 2016. The electrical power supply depend on the supply of solar panel and antimonial battery that installed together with temperature sensors with 50 WP solar panel capacity it's enough to supply the battery and made the system running 24 h nonstop, the data sent to server using GSM modem connected to Raspberry installation process nearby the station control shown of Fig. 8.

Collecting the data near seismograph (heading to the top of mountain): Temperature sensor was placed near the seismograph station on September 28, 2016 until September 30, 2016. Still same with previous system, the electrical power supply also depend on solar panel and antimonial battery that installed together with temperature

Table 1: Sensor calibration conducted in Bandar Lampung area

Sensor detection (°C)	Krisbow (°C)	Error (%)
30.187	30.4	0.70
30.187	30.3	0.37
30.250	30.1	0.50
30.250	30.2	0.17
30.562	30.5	0.20
Average error (%)		0.39



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| 2016-09-13 13:40:24 | 2016-09-13 13:40:13 | 2016-09-13 13:40:2
002000330037002E003500300030002000200020003400310002E003200200020
00020003800250020002000200020002000200020002000320030003100360020003
ault_No_Compression |        | +62816124  |    -1 | 38.812 38.750
   |                 1 | SendingOKNoReport |          -1 |  232 |
1 row in set (0.00 sec)
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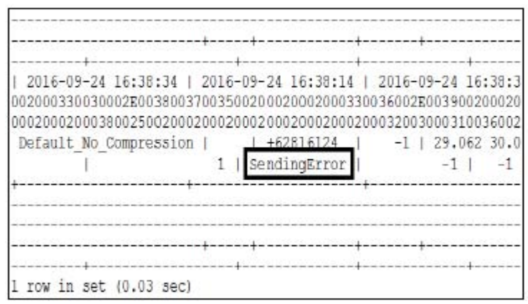
Fig. 6: Status successful SMS deilvery



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| 2016-09-24 16:38:34 | 2016-09-24 16:38:14 | 2016-09-24 16:38:3
002000330030002E003800370035002000200020003300360002E003900200020
0002000200038002500200020002000200020002000200020003200300031003600
 Default_No_Compression |       | +62816124  |    -1 | 29.062 30.0
    |                 1 | SendingError |          -1 |   -1
1 row in set (0.03 sec)
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Fig. 7: Status failed SMS delivery

Fig. 8: Set-up the device nearby the monitering station

sensors, at this scenario the device was placed higher than monitoring station before. Unfortunately, sometime an obstacle occur when Raspberry failed sending the data. Installation process shown on Fig. 9.

Temperature and the gradient data: Figure 10 shown the web base application graph report of real-time temperature monitoring, the data trend at a depth of 30 cm tend to decreased in the early afternoon and turn increased on evening because the temperature sensor was placed close enough to the surface, so the temperature data was influenced by the weather on the top of the land. While the trend of temperature at a depth of 60 and 90 cm decreases due to the temperature derived from volcanic activity and was not affected by surface conditions.

Figure 11 described the web base application graph report of real-time gradient temperature monitoring, the data trend at a depth of 30-60 cm and 30-90 tend to increase in the afternoon and get decreased at night because the temperature sensor was placed close enough to the surface, the gradient temperature data was influenced by surface condition. While the trend of temperature at a depth of 60-90 cm tend stable due to the temperature derived from volcanic activity and was not affected by surface conditions.

Fig. 9: Set-up the device nearby the seismograph station

Real-time single board computer BCM2835 performance monitoring: Figure 12 shown the performance monitoring of single board computer BCM2835 CPU temperature, the pattern of data indicated that the CPU temperature tend to increase at day and will decreased at night. While the trend of RAM usage some often get increased and decreased due to the flushing of cache memory each hours. The CPU and disk usage was stable due the application not consumed large of CPU nor storage.

Web based temperature monitoring, gradient temperature and single board computer BCM2835 performance: At this stage, discuss about web base data resulted during the soil temperature monitoring, administrator can set the date time range of data and displayed the graph on web.

Result of obtained the data near of monitoring station (heading to the sea): Figure 13a indicated that the trend of temperature decreased significantly due to the temperature was influenced by the weather conditions around the sites while Fig. 13b indicated the temperature gradient trend was also increased significantly due to the temperature was still influenced by the weather conditions around the sites. Figure 13c shown the trend of CPU temperature, the average was 34.350°C, CPU usage average was 1.03%, RAM usage had an average of 97.51MB and the disk usage average was 8%.

Result of collecting the data near of seismograph station (heading to the top of mountain): Figure 14a shown the trend of temperature at depth of 30 cm was unstable and sometime going increased and decreased because the temperature was still influenced by the weather conditions around the sites. Based on Fig. 14b, trend of gradient

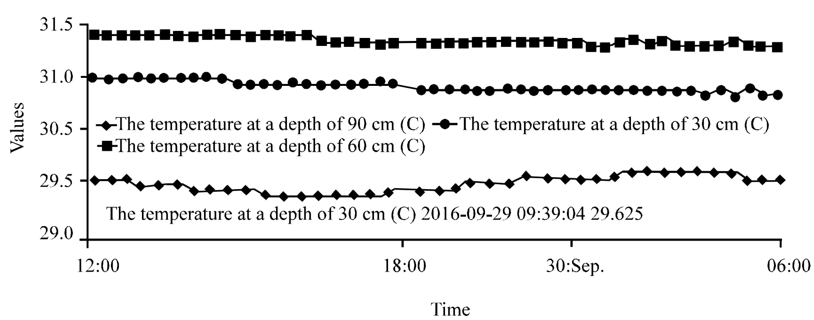

Fig. 10: Real-time temperature monitering (Anak Krakatoa volcano)

temperature at depth of 30-90 and 30-60 cm was also unstable sometime increased and decreased, it happen because the temperature at depth 30 cm was also influenced by the weather conditions around the sites.

While Fig. 14c display the CPU temperature measured with average of 35.06 0°C, CPU usage with average 1.31%, RAM usage with average of 98.47 MB and the disk usage average of 8%.

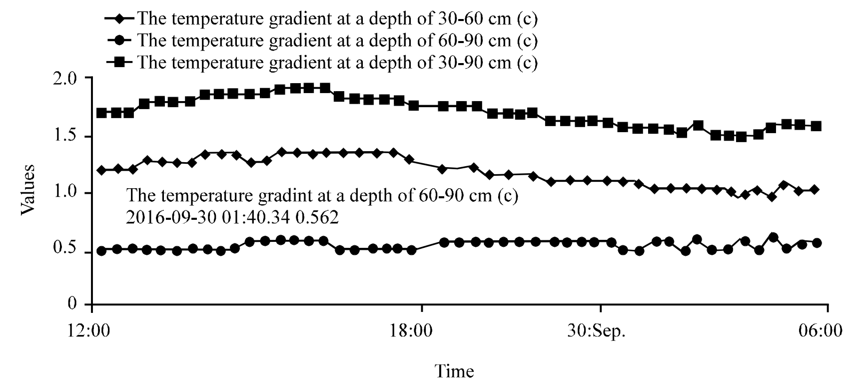

Fig. 11: Real-time gradient temperature (Anak Krakatoa volcano)

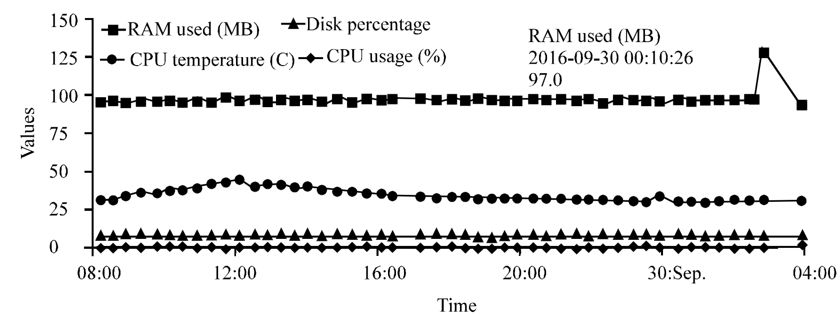

Fig. 12: Real-time the performance monitering of single board computer BCM2835

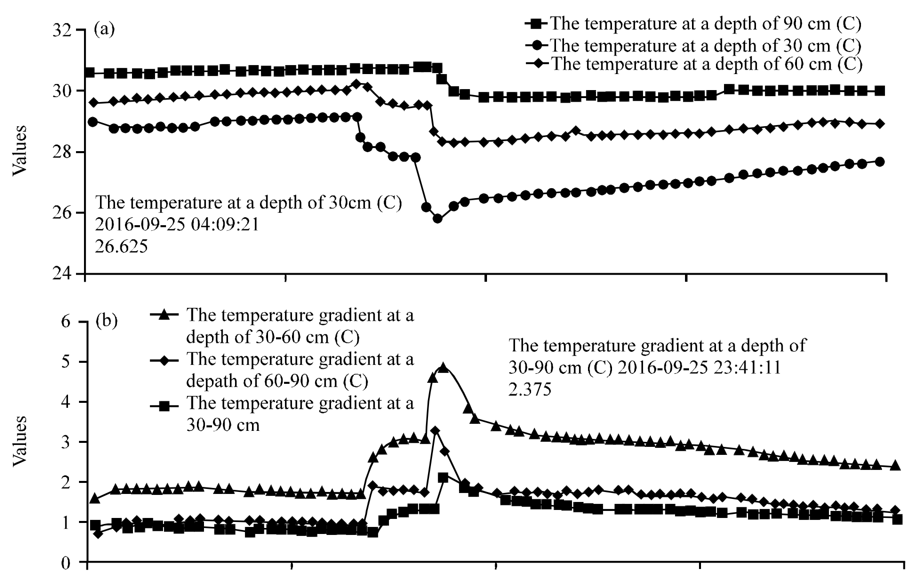

Fig. 13: Continue

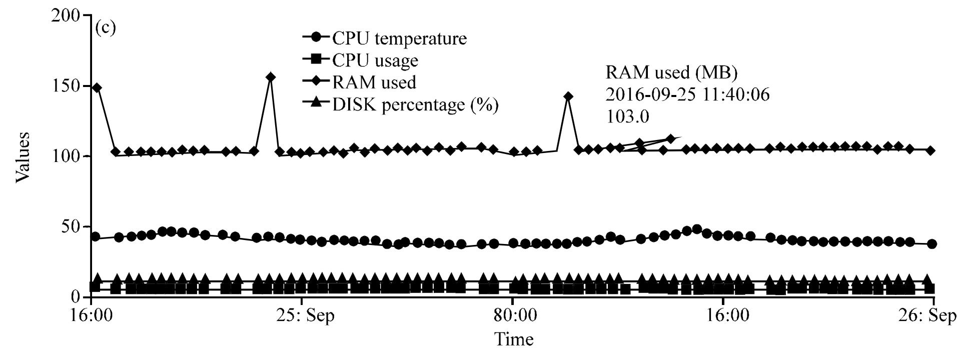

Fig. 13: Data results: a) Monitering the temperature of Anak Krakatoa volcano; b) Monitering the temperature gradient of Anak Krakatoa volcano and c) Monitering the performance of single board computer BCM2835

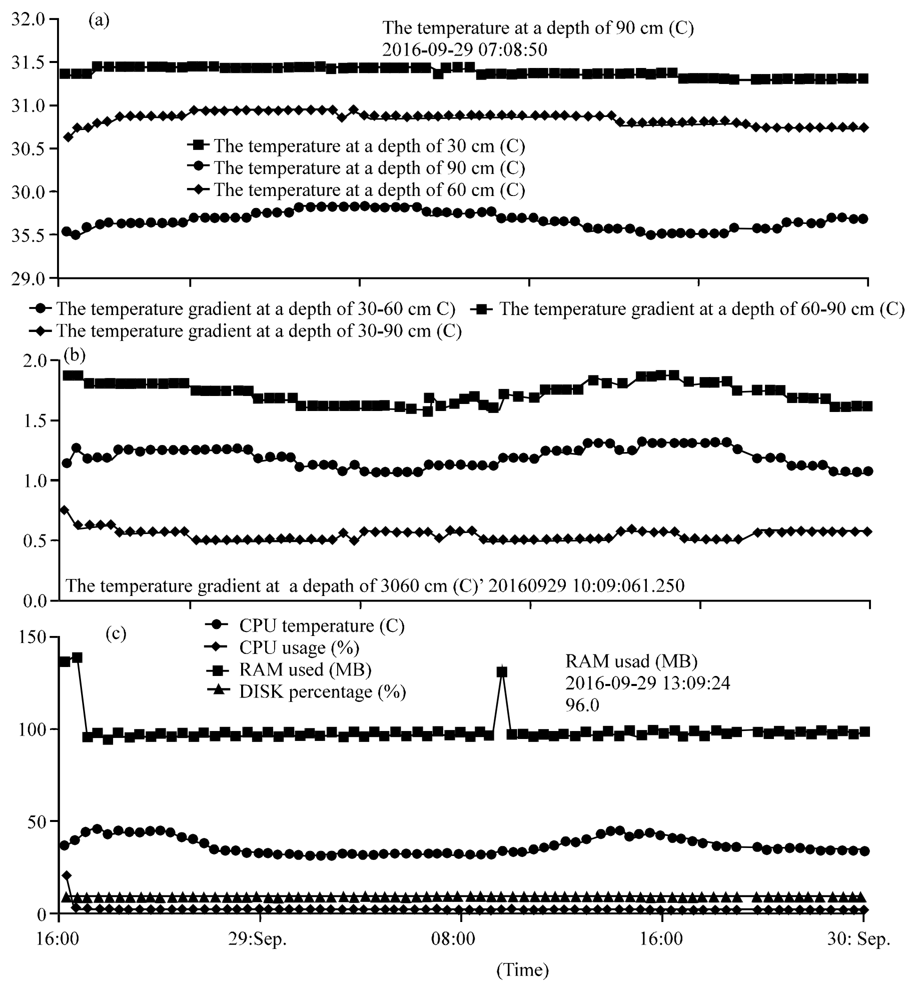

Fig. 14: Data results: a) Monitering the temperature of Anak Krakatoa volcano; b) Monitering the temperature gradient of Anak Krakatoa volcano and c) Monitering the performance of single board computer BCM2835

From the previous charts explanation above, we conclude that the soil temperature (at nearby station monitoring and at seismograph station) at a depth of 30, 60 and 90 cm has a range between 25-32°C. According to Muffler, the geotherma temperature <90°C this temperature result categories as low temperatures. The

Table 2: User test

Point test	Total items tested	Success	Failed	Achievement(%)
User web page	1	v	-	100

Table 3: Manager test

Point test	Total items tested	Success (√)	Failed (x)	Achievement(%)
The main webpage manager	3	√	-	100
Notification ofsensors is not readable	1	√	-	100
SMS notification of temperature changing interval	1	√	-	100
Measurement and data delivery	1	√	-	100
Changing the maximum temperature values	1	√	-	100

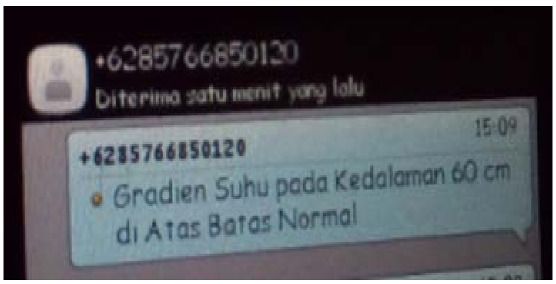

Fig. 15: SMS early warning system notification

temperature at the deepest depths has the highest temperature and measuring result nearest the surface has the lowest temperature which related to the research data conducted by Putranto *et al*. (2009). While the result of BCM2835 single board computer performance monitoring indicated that all process running on this board not resource consumed and the system can running well at all time without any major issue.

Early warning system notification: Figure 15 shown the notification of early warning system implemented on system. If the temperature data exceeds the maximum threshold set by system, then the application will automatically sent a notification to manager by SMS technology.

Testing

User acceptance test: According to Table 2 result indicated that the whole application for user run well with 100% achievement, all module function correctly.

According to Table 3 result indicated that the whole application for manager was also run well with 100% achievement, all module function correctly.

Calculation of database storage consumption on single board computer BCM 2835 and server: According to Table 4, the usage of data for one time measurement was 15.848 Byte, and in one year estimated will spend 8448000 Byte storage or 8.05 MB (noted: the data record every 30 min).

Table 4: Estimation of database storage consumption on BCM2835

Table name	Total lenght data table (bytes)	Total lenght index table	Total bytes	Total (MB)
Sent items	488	-	15848	0.01511
1:Time	488		15848	0.01511
Measurement	23424	15.360	38784	0.03699
Storage in one day (24 h)				
Storage in one month (30 days)	702720	-	718080	0.68481
Storage in one year (12 months)	8432640	-	8448000	8.05664

Table 5: Estimation of database consumption on server

Table name	Total lenght data table (bytes)	Total lenght index table (bytes)	Total (bytes)	Total (MB)
Inbox	452	2048	2500	0.00238
Monitoring	52	2048	2100	0.00200
One-time measurement	504	4096	4600	0.00439
Storage in 1 day (24 h)	24192	-	28288	0.02698
Storage in 1 month (30 days)	725760	-	729856	0.69604
Storage in 1 year (12 months)	8709120	-	8.713.216	8.30957

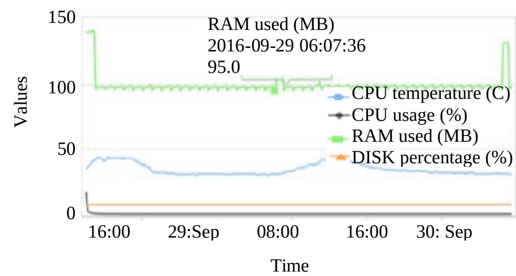

Fig. 16: Performance single board computer BCM 2835

According to Table 5, the usage of data for one time measurement was 4600 Byte, and in one year estimated will spend 8713216 Byte storage or 8.30 MB (noted: the data record every 30 min).

Test the performance of single board computer BCM2835: Hardware specification of main system monitoring placed on Anak Krakatoa Volcano was processor: single-core ARM, 512 MB of RAM and 16 GB storage. Figure 16 shown statistic of CPU temperature, CPU usage, RAM usage and percentage disk usage with data was collected every 10 min.

According to information from Fig. 16, it shown the resource usage BCM2835 was categories as low utilization due the whole application program not hardware resource consumed.

Table 6: Maintenance

Bug application	Corrective maintenance
Web managers no security features	Create a login for manager
The mechanism of changing the time interval data retrieval, the maximum temperature values and manager's number less comfortable	Changing all via. SMS
SMS notification include real-time	The addition of the real-time in SMS notification

Maintenance: Table 6 shown the maintenance table during implementing system development using corrective maintenance to improve and fixed the bugs or new requirement.

CONCLUSION

Modified waterfall models was successful implemented for system development, especially on design phase was divided into two parts: hardware design and software design. Overall, the system was running well and able to monitoring the temperature and its gradient at three different level of depth (30, 60, 90 cm), from the data result denote that the temperature range was between 25-32°C, concluded that Anak Krakatoa temperature categorized as low temperature. The use of single board computer BCM2835 was very effective indicated from the excellent result of performance monitoring including CPU, DISK and RAM utilization. We made a calculation of storage estimation for 1 year on the single board computer BCM2835 (sender of data) was 8.05 MB and the server (data receiving) is 8.30 MB (data sent every 30 min).

SUGGESTIONS

For future works, we suggest the next level research by improving the transmission data model with advance technology combine with existing SMS technology in addition there need to extend the system with more sensor integrated with application such CO, H_2S to obtained more complex data for monitoring the behavior of Anak Krakatoa volcano.

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