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The GEOSTAT Application version 2.0 Development for Determination of Aftershocks Earthquake Decay Based on MATLAB

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Abstract

The emergence of large magnitude earthquakes will certainly be followed by a series of aftershocks. Therefore, we need an application that is easy and simple to find out when the event ends. The GEOSTAT Application version 2.0 is the result of the development of The GEOSTAT Application which was redeveloped using MATLAB to solve problems with determining the end time of aftershocks. Applications that have a Graphical User Interface (GUI) display contain several methods such as Omori, Mogi I, Mogi II and Utsu method to determine the decay of aftershocks. The GEOSTAT Application version 2.0 can be operated properly on the user's device and helps the user in knowing the end of aftershocks simply and easily which is usually calculated manually.

Keywords*:* MATLAB, Omori, Mogi I, Mogi II, Utsu, Earthquake Decay Application

Introduction

The complex tectonic structure in Indonesia cause seismic activity in Indonesia to be classified as very high (Pusgen, 2017). This can be seen based on three major tectonic plates encounters in the world, namely The Eurasian Plate, The Indo-Australian Plate and The Pacific Plate (Ibrahim et al., 2010). So, this can result in a large magnitude earthquake followed by a collection of aftershocks (Riga and Balocchi, 2017). The emergence of a large earthquake followed by aftershocks will certainly cause panic in the community when the aftershocks end. Academics, researchers and related agencies will certainly conduct studies and research to determine the end time of aftershocks. In order to support and assist academics, researchers and related agencies to solve these problems, a simple and easy application is needed.

The GEOSTAT Application version 2.0 is here as a solution to answer these problems. This application is a development of The GEOSTAT Application which serves to determine the level of earthquake risk in an area. The GEOSTAT Application version 2.0 contained several facilities such as models to determine the end time of aftershocks such as the Omori model (1894), Mogi I (1962), Mogi II (1962) and Utsu (1957).

Data and Method

Application development is carried out to improve the existing facilities in The GEOSTAT Application version 2.0. One form of application development is to add functionality in this application. The upgraded facility in this application is the aftershocks decay. The application development process requires much software such as MATLAB as the main component in making source code and Graphical User Interface, Canva as a tool for designing application Microsoft Excel as a container for storing earthquake data. There are several stages carried out on developing the GEOSTAT application:

1. Literature study.
2. Create source code m-file, creating a fig-file for Graphical User Interface (GUI) independently or pure script and designing the latest application features.
3. System test and application validation.

Authors use data after Ambon earthquake on September 25 2019, at 23:46:44 Universal Time Coordinate (UTC) with a magnitude 6.5 Mw. This data used for system test and application validation. The data was obtained from the BMKG earthquake catalog data repository from 26 September 2019 to 25 October 2019, coordinate 2.21 until 5.35°LS and 125.28 until 132.12°BT. The test data is useful to find out if the system in the application can run smoothly, well and correctly.

Table 1. List of aftershocks earthquake after 30 minutes mainshock

Date	Time (UTC)	Depth (Km)	Magnitude
26/09/2019	00:00:08.7	10	3.9
26/09/2019	00:03:55.8	10	4.3
26/09/2019	00:04:45.0	10	4
26/09/2019	00:11:33.7	10	4
26/09/2019	00:12:40.3	10	4
26/09/2019	00:15:11.9	10	4.7
26/09/2019	00:23:29.2	10	4,.2
26/09/2019	00:27:43.8	10	3.9
26/09/2019	00:28.46.3	10	4

The latest features in The GEOSTAT Application version 2.0 require validation tests to re-check the

operation of the existing system in the application. In knowing this, some research results that have been done previously are needed to be re-tested using the application. The following research is used to test The GEOSTAT Application version 2.0:

1. Penentuan Waktu Berakhirnya Gempa Bumi Susulan untuk Gempa Bumi Biak 16 Juni 2010 (Awaludin, 2011).
2. Waktu Berakhirnya Gempa Bumi Susulan untuk Gempa Bumi Sulawesi 28 September 2018 (Pahlevi, 2020).

Foreshocks are some earthquake event that precedes the main earthquake in a series of earthquakes with magnitude smaller than the Mainshock. Mainshock. Mainshock is an earthquake event with the most energetic magnitude or the strongest due to the release of previously accumulated energy. Aftershocks are series of earthquake events that follow the mainshock with a smaller magnitude than the mainshock. Aftershocks can occur over a period of days, months or even years. The greater magnitude of the mainshock, the more the series of small earthquakes that follow it and the longer the aftershock event ends (Riga and Balocchi, 2017).

The relationship between time and frequency to determine the level of aftershocks activity can be presented in the formula (Omori, 1894)

$$n(t) = \frac{a}{t+b} \qquad (1)$$

The time span for aftershocks to end if they occur ≥100 days can be determined using this formula Mogi I (Mogi, 1962)

$$n(t) = a.t^{-b} \qquad (2)$$

While the time span of the end of aftershocks that occurred within a period of < 100 days can be determined by the following formula Mogi II (Mogi, 1962)

$$n(t) = a.e^{-bt} \qquad (3)$$

In addition, the formula can be used to determine the end time of aftershocks (Utsu, 1957)

$$n(t) = \frac{a}{t+c^b} \qquad (4)$$

Where *n(t)* is the accumulation of aftershocks *n* calculated in the time span *t.* Then, *t* is the time span for aftershocks, while *a* and *b* are constants, while *c* is 0.01. Several formulas used to determine the end time of aftershocks provide a correlation between the frequency of aftershocks and the time of aftershocks. Both are expressed as the dependent variable (*y*) and the independent variable (*x*). Supranto (2008) explains that the dependent variables and the independent variables can be formulated into a linear relationship which is solved by the least squares method.

$$\bar{Y} = a + b\bar{X}_i$$

Supranto (2008) explains that to find out the constants *a* and *b*, it can be solved with the formula

$$a = \bar{Y} - b\bar{X}_i$$

and

$$b = \frac{n\Sigma X_i Y_i - \Sigma X_i \Sigma Y_i}{n\,\Sigma {X_i}^2 - (\Sigma X_i)^2}$$

Supranto (2008) also explains that to find out the correlation between constants *a* and *b*, it can be known by using the formula

$$r = \frac{n\Sigma X_i Y_i - \Sigma X_i \Sigma Y_i}{\sqrt{n\,\Sigma {X_i}^2 - (\Sigma X_i)^2}\sqrt{n\Sigma {Y_i}^2 - (\Sigma Y_i)^2}}$$

The interpretation of the correlation value between constants *a* and *b* can be seen through the following table (Sugiyono, 2007)

Table 2. The correlation value of the dependent variable and the independent variable (Sugiyono, 2007)

Value	Definition
0.00 - 0.19 or 0.00 - (-0.19)	Very Low
0.20 - 0.39 or (-0.20) - (-0.39)	Low
0.40 - 0.59 or (-0.40) - (-0.59)	Medium
0.60 - 0.79 or (-0.60) - (-0.79)	Strong
0.80 - 1.00 or (-0.80) - (-1.00)	Very Strong

Result and Discussion

When the system test process and application upgrade have been completed, the user can operate the GEOSTAT application in several stages:

1. Search for aftershocks earthquake
2. Save in excel that has been provided by the author.
3. Classify the magnitude frequency with the time of aftershocks and open this application, it will appear as shown in Figure 3 and Figure 4.

4. Select the method to use.
5. Enter parameters such as magnitude, classification of earthquake grouping time intervals, date and time of mainshock occurrence.
6. Calculate and the calculation results will appear as shown in Figure 6.

In the development process this application has advantages where the level of accuracy application calculation is more detailed by presenting specific end time of aftershocks in the area (Figure 4). This specific time can help people to find out more detailed information so that the people become more prepared and alert.

System validation test is needed to determine system performance in processing calculations. The following are the results of the application system validation test.

Table 3. The first comparison results of calculating end time aftershocks

Method	Awaludin (2011)	GEOSTAT
Omori	37 Days	387 Days
Mogi I	1056 Days	1057 Days
Mogi II	19 Days	19 Days
Utsu	1029 Days	1030 Days

Table 4. The first comparison results of correlation calculation

Method	Awaludin (2011)	GEOSTAT
Omori	5.26524	0.932
Mogi I	-0.8702	-0.87021
Mogi II	-0.94687	-0.93094
Utsu	-0.8707	-0.97072

Table 5. The second comparison results of calculating end time aftershocks

Method	Pahlevi (2020)	GEOSTAT
Omori	183 Days	184 Days
Mogi I	340 Days	340 Days
Mogi II	17 Days	17 Days
Utsu	334 Days	334 Days

Table 6. The second comparison of correlation calculation results

Method	Pahlevi (2020)	GEOSTAT
Omori	0.96	0.96369
Mogi I	-0.97	-0.97202
Mogi II	-0.95	-0.95586
Utsu	-0.97	-0.97206

From some the tables above, it can be seen that the system giving good results and accuracy. However, there was an error in Awaludin (2011) research. An error occurred on Awaludin (2011) research for the calculation of Omori with correlation results that exceeded the range of values between -1 to 1.

So, this affected the calculation with the expiration time of aftershocks for 37 days. Meanwhile, based on the calculation of The GEOSTAT Application version 2.0, it shows good accuracy results with a correlation value close to 1, which is 0.932. So the time for aftershocks to expire is 387 days.

The thing that needs to be considered in determining the independent and independent variables are the time interval for collecting earthquake frequency data and magnitude earthquake. The greater the magnitude of the mainshock, the longer the duration of the aftershock. This is because the duration of the aftershock loading is inversely related to the earthquake frequency.

Conclusions

The GEOSTAT Application version 2.0 can runs well and assist users in calculating the end time of aftershocks which are calculated manually. In addition this application can calculate and knowing the end time of aftershocks simply and easily.

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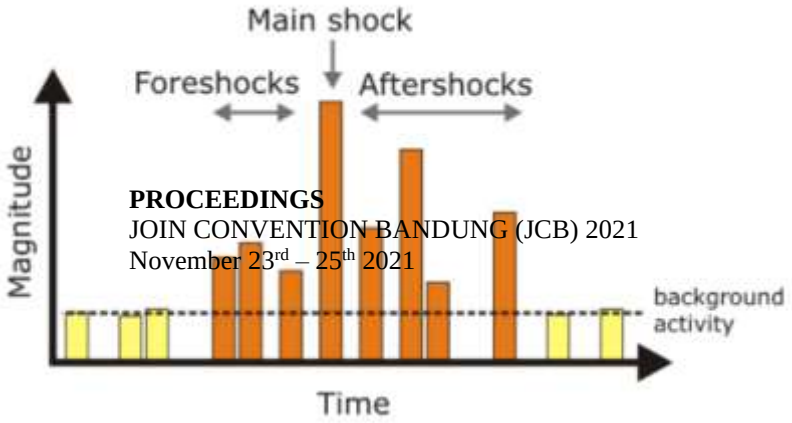

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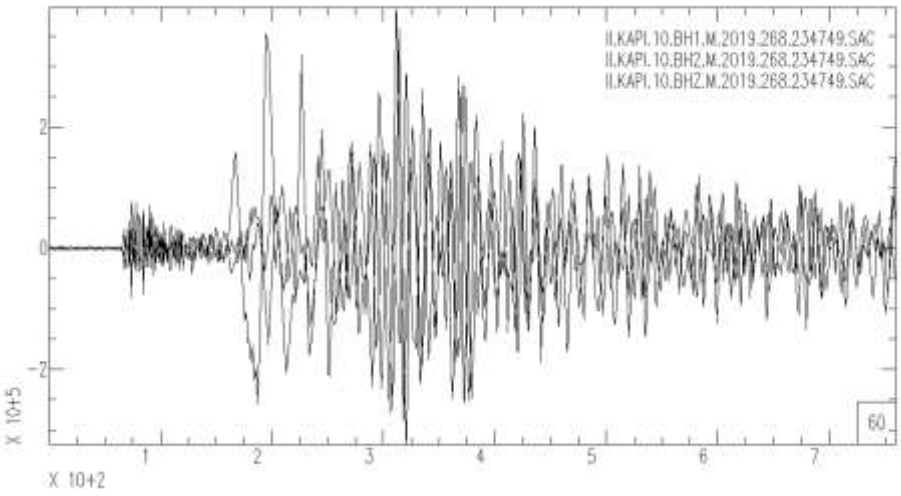
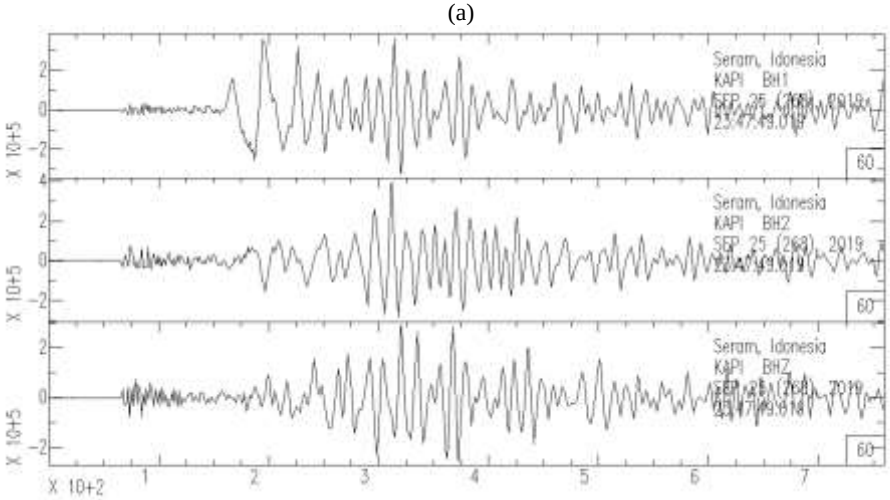
Figure 1: Sequence of foreshocks, mainshock and aftershocks earthquake events (Abdelnaby, 2012)



(a)



(b)

Figure 2. (a) Mainshock earthquake seismogram magnitude 6.5 Mw and (b) Mainshock earthquake recording on 3 components seismogram.

Figure 3: The splash screen of the GEOSAT Application version 2.0

Figure 4: Main menu display

Figure 5: Earthquake decay menu display

Figure 6: Calculation result display