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Web GIS-Based Forecasting of Earthquakes Using Fuzzy Time Series Method

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Abstract: Earthquake Forecasting is the process of predicting the possibility of an earthquake in a particular area using earthquake data from the previous year (this study uses earthquake data for 2017-2021). Aceh is one of the areas in Indonesia that is prone to disasters in terms of the frequent occurrence of earthquakes in several areas whose impacts are pretty severe. With this research, it is hoped that it can contribute to BMKG in particular and the community, in general, to find out the possibility of earthquakes occurring at several points in Aceh to be more alert in the future. This WebGIS-based Earthquake Forecasting application in Aceh was built using DFD (Data Flow Diagram) modeling and the PHP programming language and MySQL database as well as the Google Maps API. This Earthquake Forecasting Application uses the Fuzzy Time Series method in carrying out the calculation process. Fuzzy Time Series is a method with the solution being carried out in stages, and from that stage, the forecasting results for several areas in Aceh are found based on previous data; in this method, the process of searching for possible error values is also carried out using AFER (Average Forecasting Error Rate) if the value The smaller the error, the more accurate it is. So that the forecasting results are found with the data of strength (magnitude), latitude, and longitude.

Keywords: Forecasting, Earthquake, Fuzzy Time Series, AFER, Web GIS.

1. Introduction

Geographically, the territory of Indonesia has unique characteristics. Namely, Indonesia is located at the meeting area of three tectonic plates (triple junction plate converge) (Suda, 2016). The three plates are the Eurasian Plate, the Pacific Ocean Plate, and the Indo-Australian Plate, where the Indo-Australian Plate is actively moving to the north with a relative speed of V= 5-7 cm/year, as well as the Pacific Ocean Plate, which is actively moving westward with an almost the same speed (Mustafa, 2010). While the Eurasian Plate is relatively passive. The consequences of Indonesia's geography in the Triple Junction area make Indonesia an area prone to earthquakes (high seismicity) and tectonically unstable (Ghifari et al., 2018).

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One of the areas in Indonesia that have high seismicity is the Aceh Province. It is proven by the frequent occurrence of earthquakes with intervals between earthquakes that are not long enough with a range of medium to high magnitudes (Muyasaroh & Sudarmilah, 2019). This can happen, considering that the Aceh region is located at the confluence of two plates of the earth's crust, namely the Eurasian plate, which is relatively stationary, and the Indo-Australian plate, which moves northward and Aceh can be categorized as an earthquake-prone area (Hidayati et al., 2014).

At the confluence of the Eurasian and Indo-Australian plates, there is subduction or infiltration of each other, namely, the Eurasian plate infiltrates under the Indo-Australian plate. As a result of the interaction of the two crustal plates, there are many folds (mountains) and faults in the Aceh area, including the Tripa segment, the Aceh segment, and the Seulimeum segment. Two major earthquakes in the last ± 8 years that rocked Aceh and captured public attention were the Aceh Earthquake 26 December 2004 and the Aceh Earthquake which recently occurred on 11 April 2012 (Putri et al., 2016).

Now computer-based technology has penetrated almost all sides of human life. Various disciplines have used this technology to develop theories and applications through various information systems. One type of information system that is currently very popular, especially in mapping surveys is the Geographic Information System (GIS) ("Sistem Informasi Geografis Pemetaan Potensi Sma/Smk Berbasis Web (Studi Kasus : Kabupaten Kebumen)," 2014). GIS has been used by various government and private agencies for planning, monitoring, and evaluation of development results. GIS is a very useful tool for researchers, managers, decision makers to help solve problems, make choices or make spatial policies through map data analysis methods by utilizing computer technology (Ramadhani et al., 2013).

The method that is suitable for this problem is Fuzzy Time Series, Fuzzy time series is a new concept proposed by Song and Chissom based on fuzzy set theory and the concept of linguistic variables and their application by Zadeh. Fuzzy time series is used to solve forecasting problems where historical data are linguistic values (Mirzaei Talarposhti et al., 2016). For example, in forecasting problems, historical data is not in the form of real numbers, but in the form of linguistic data. In this case, there is no conventional time series model that can be applied, but the fuzzy time series model can be applied more precisely. In previous research, based on fuzzy set theory, fuzzy logic and approximate reasoning. Another strong reason this method has a smaller error value than other forecasting methods (Dewi et al., 2014).

2. Literature Review

In simple terms, the system can be interpreted as a collection or set of elements, components, or variables that are organized, interact with each other, depend on each other and are integrated. The structure of the system is the elements that make up the system, while the system process explains how each element works to form the system, a system can be formulated as any collection of components or subsystems designed to achieve a goal.

The general model of a system consists of inputs, processes, and outputs. This is a very simple concept of a system considering that a system can have several inputs and outputs at once. In addition, a system also has certain characteristics or properties that characterize that it can be said to be a system.

The system is a form of integration between one component and another because the system has different goals for each case that occurs in the system. Systems can be classified from several points of view, such as abstract systems, natural systems, deterministic systems, and open and closed systems.

The source of information is data. Data is a fact that describes an event and is a real entity, and is a form that is still raw so that it needs to be further processed through a model to produce information. It is clear that data is a source of information material. The change of data into information is carried out by information processors. Information processing is one of the key elements in the conceptual system. Information processing using can include computer elements, non-computer elements or a combination thereof.

GIS data represents real objects (buildings, islands, land elevations, etc.) in digital form. Types of data are grouped into two, namely vector data and raster data. Vector type maps store spatial data in the form of points, lines, polygons. The most common vector map format is a shapefile. Vector types are used to store discrete data, such as buildings, rivers, islands, and others. Raster maps are stored in the form of a matrix/grid consisting of many cells. The raster type is used to store continuous data (such as ground elevation, rainfall, etc.).

An earthquake is an event that vibrates the earth due to the sudden release of energy in the earth which is marked by the breaking of rock layers in the earth's crust. The accumulation of energy that causes earthquakes results from the movement of tectonic plates. The energy produced is emitted in all directions in the form of earthquake waves so that its effects can be felt to the earth's surface.

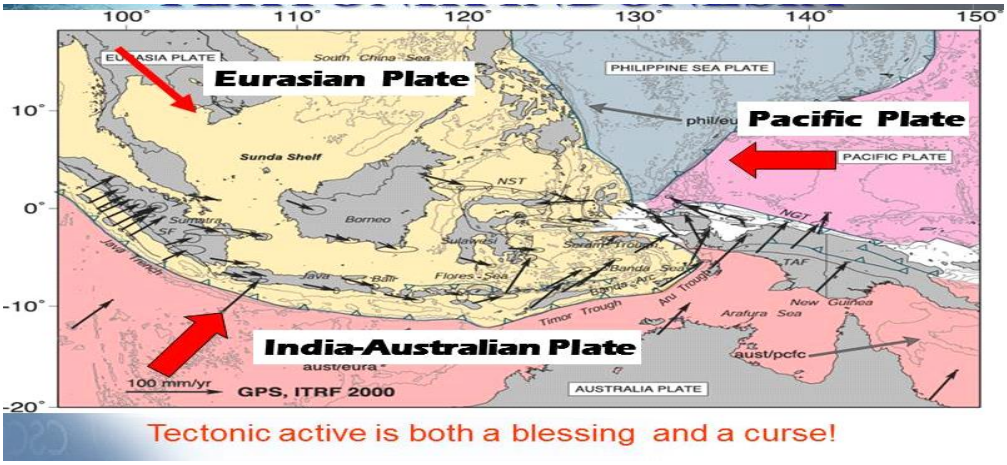

Fig 1. Indonesian Tectonics

The cause of earthquakes according to the theory that the earth's surface is split into several large tectonic plates, plate tectonics is a hard segment of the earth's crust that floats above the hot and liquid asthenosphere. Therefore, these tectonic plates are free to move and interact with each other. The border areas of tectonic plates, are places that have active tectonic conditions, which cause earthquakes, volcanoes and the formation of highlands. The theory of plate tectonics is a combination of the previous theories, namely: Continental Drift and Sea Floor Spreading.

One of the areas in Indonesia that has high seismicity is the Aceh Province. It is proven by the frequent occurrence of earthquakes with not long time intervals between earthquakes with a range of medium to high magnitude. This can happen, considering that the Aceh region is located at the confluence of two plates of the earth's crust, namely the Eurasian plate which is relatively stationary and the Indo-Australian plate which moves northward.

Forecasting is a process to predict what will happen in the future. The forecasting process is carried out by the scientific method and systematically. Qualitative properties such as feelings, experiences and others are important in the forecasting process in addition to using scientific or organized procedures. If you want to estimate a variable, it must be considered and studied in advance. To study how the history of the development of a variable, we will observe a series of variable values according to time.

Time series is data collected from time to time to describe the development of a mass activity, the development of a production, population, sales results, and so on. Periodic data analysis makes it possible to know the development of one or several events and their relationship or influence on other events. For example, whether the increase in fertilizer use is followed by an increase in rice production; whether the number of salary increases is followed by an increase in work performance. The forecasting process in the time series does not involve other independent variables other than the time index (t) itself, thus ignoring other independent factors. Therefore, what is sought is a model of data behavior, and not what factors cause data fluctuations.

A time series is a set of observations in which the variables used are measured in order of time periods, such as yearly, monthly, quarterly, and so on. With time series data, data movement patterns or variable values can be followed or known.

Time Series Data Forecasting predicts what will happen based on past historical data. A time series is a collection of regular observations on a variable over the same and successive time periods. By studying how a variable changes over time, a relationship between demand and time can be formulated and used to predict future demand levels.

3. Method

The research was conducted at several BMKG offices in several points or areas prone to earthquakes, namely BMKG Sabang, BMKG Banda Aceh, BMKG Meulaboh, BMKG Sigli, BMKG Tamiang and BMKG Tapaktuan in Aceh Province.

1. The first step: inputting data that will be used as forecasting data in this experiment is carried out on earthquake data in 2012,2013,2014,2015,2016
2. The second step is to define the universal set of discourse U up to which the fuzzy set is defined. After the actual data is calculated, the minimum and maximum data will be obtained. Based on the value

obtained, the universal set of speech U can be defined as U = [A,B].

3. The third step: Counting the number of intervals and the length of each interval from the universal set (U). In this step, it is done to determine the number of intervals that divide the universal set (U) into several parts, the following is the formula for determining the number of intervals:
   BK = 1+3,3 log n (1)
   Where n is the number of data. The number of intervals must be an odd number. Then to find the length of each, namely the difference between the maximum and minimum data divided by the number of classes.
4. Fourth step: Determine the linguistic set based on the predetermined interval length.
5. Fifth step: Fuzzification of historical data values, where fuzzy logical relationship Aj => Ak means that if the enrollment value in year i is Aj, then year i+1 is Ak. Aj as the left side of the relationship is referred to as the current state and Ak as the right side of the relationship is referred to as the next state. And if there is a repetition of the relationship then it is still counted once.
6. Sixth Step: Divide the fuzzy logical relationship that has been obtained into several parts based on the left side (current state).
7. Step 7 : Determine the Fuzzy Logic Relationship Group (FLRG)
8. Step 8 : Carry out the forecasting and defuzzification process based on the established FLRG.
9. Step 9 : find the error value with Average Forecasting Error Rate (AFER) Obtained from the sum of all error values for each period squared and then divided by the number of periods. In general, the smaller the percentage of the AFER value, the more accurate the forecasting method, with the following calculation formula:

$$\text{AFER} = \frac{|A_i - F_i|/A_i}{n} * 100\ \% \quad (2)$$

Where :
Ai = Actual value on the data to - i
Fi = Forecasting result value for data to - i
n = total number of data

4. Result and Discussion

In the process of designing this earthquake level forecasting application system, problem analysis plays an important role in making details of the application to be built. Problem analysis is a step in understanding the problem before taking action or final resolution decisions. System analysis aims to identify a number of problems that cover all aspects of the designed system including the operating environment from inputting earthquake data to forecasting results from each point sought.

The use of this forecasting system is expected to have a good impact on the BMKG Aceh, because until now there has been no forecasting application for earthquakes used by the BMKG Aceh so that it cannot predict earthquakes for the coming year and cannot know areas that are prone to earthquakes. earth. In terms of forecasting, the fuzzy time series method can be used to predict/predict earthquake-prone areas with greater strength than before, with this application it is hoped that this application can help in the earthquake forecasting process so that people in general can find out more quickly about earthquakes in the future and more quickly watch out.

The problem is in taking data on current earthquake conditions and earthquake data from the past and then predicting these conditions in the future with the assumption that the past will happen again in the future.

To build an earthquake level forecasting application, it is designed according to the concept rules that exist in the Fuzzy Time Series method. The application to be built is arranged into 2 parts, namely the admin section and the user section.

The admin section is the section that will fully control the application. All activities using earthquake forecasting applications will be carried out in this section. Therefore this section cannot be accessed by users other than admin. While the user section can be used by anyone.

At this stage of system design, it aims to determine the steps for the operation of the overall system application starting from the context diagram design, DFD (Data Flow Diagram) design, ERD (Entity Relationship Diagram), table structure and interface design.

In the manual calculation of the Fuzzy Time Series method, there are several steps to be taken, the following is an explanation.

1. Step 1: input actual data
   This experiment was carried out on earthquake data from 2012 to 2016 earthquake data. In table 1 the following is the actual earthquake data taken as a forecast.

Table 1 : Aceh Earthquake Actual Data Table

Date	Time	Latitude	Longitude	Mag(strength)
06/01/2012	13.58.33	2,16	96,25	3
14/02/2012	02.20.38	3,14	96,66	7
29/03/2012	09.27.11	1,32	95,61	4,9
14/04/2012	08.23.51	2,13	96,74	5
14/06/2012	22.59.26	2,23	95,97	4,2
17/08/2012	06.06.32	3,25	96,79	4,4
19/08/2012	01:57:02	1,18	96,32	4
09/09/2012	09:13:06	2,94	96,01	4,6
24/11/2012	14:04:56	2,53	97,68	4,3
27/11/2012	12:00:27	2,11	96,5	4,4
28/11/2012	23:03:22	4,77	96,65	3,5
06/12/2012	18:22:33	2,25	95,6	2,7
05/01/2013	03:24:32	2,47	96,5	3,2
06/02/2013	00:43:52	1,09	97,32	3,3
16/03/2013	11:55:05	4,76	96,2	2,8
29/04/2013	13:43:00	3,89	97,32	4,3
31/05/2013	19:52:42	2,41	97,83	2,9
07/06/2013	14:12:21	2,61	97,91	4,1
06/07/2013	10:06:54	2,46	95,94	3,8
30/08/2013	09:01:44	1,65	96,81	4,2
24/09/2013	07:03:04	2,1	95,45	5
04/10/2013	10:10:09	2,33	96,66	3,4
22/11/2013	10:43:42	4,76	95,84	5,1
10/12/2013	07:37:26	5,94	95,9	1
18/02/2014	10:15:54	1,07	96,95	3,4
19/02/2014	07:36:04	4,74	96,12	3
05/05/2014	15:06:26	2,47	96,13	4
09/05/2014	16:40:55	4,42	97,01	3
09/05/2014	20:00:47	2,57	95,95	4,4
29/06/2014	08:11:54	4,42	95,93	4
05/07/2014	14:50:31	4,87	96,91	4,9
07/09/2014	13:31:37	4,95	97,25	2
14/09/2014	10:28:19	5,3	97,16	2,6
08/10/2014	11:15:39	5,23	94,73	4,5
03/11/2014	05:05:53	5,02	84,78	3,6
17/12/2014	16:28:37	2,7	95,7	3,6
27/01/2015	10:59:58	2,32	94,42	4,8
02/02/2015	20:13:59	1,4	95,72	4,5
06/03/2015	14:03:54	1,62	97,15	4,8
09/03/2015	11:47:42	1,05	97,27	3,6
21/05/2014	02:42:07	2,65	97,13	6

01/06/2015	14:07:50	4,54	96,29	3,8
11/06/2015	01:18:19	4,15	94,95	4
19/08/2015	00:46:40	2,65	95,93	5
04/09/2015	08:02:12	4,81	97,64	3,3
28/10/2015	04:57:12	4,62	96,07	3,4
02/11/2015	11:10:24	2,02	95,7	3,4
07/12/2015	16:35:15	3,22	96,39	4,5
30/01/2016	23:25:13	3,19	95,64	3,9
12/02/2016	15:33:45	2,02	97,07	4,1
31/03/2016	19:38:45	3,03	96,11	3,1
01/05/2016	07:08:22	4,57	95,84	3,6
06/05/2016	04:54:04	4,52	96,42	3,5
27/06/2016	03:50:51	3,48	95,84	4,9
03/07/2016	23:10:59	3,98	95,45	4,8
31/08/2016	13:13:35	1,23	96,17	4,7
21/09/2016	21:13:01	2,09	95,08	3,8
28/10/2016	01:47:54	1,23	96,83	3,5
04/11/2016	09:22:52	3,82	97,23	4,4
18/12/2016	19:24:45	5,36	94,54	5,1

2. Step 2: Define the universal set of discourse U up to which the fuzzy set is defined. After the actual data mentioned above are calculated, the minimum data is 1 and the maximum data is 7. Based on the values obtained, the universal set of speech U can be defined as U = [1,7].
3. Step 3: Calculate the number of intervals and the length of each interval from the universal set (U).
   In this step, it is done to determine the number of intervals that divide the universal set (U) into several parts, the following is the formula for determining the number of intervals:

   BK = 1+3.3 log n

   Where n is the number of data. The amount of data used is 60, then the result is 6.54 because the number of intervals must be an odd number, then it is rounded up to the nearest odd number, which is 7. interval class length is 0.87.
4. Step 4: Determine the linguistic set based on the specified interval length.
   Based on the length of the interval obtained, the class that will be divided into 9 intervals is obtained after the data has been sorted previously, namely U1 = [1,3], U2 = [3,3.4], U3 = [3.4,3.6], U4 = [3.6,3.9], U5 = [4,4.2], U6 = [4.2,4.4], U7 = [4.5,4.8], U8 = [4.8,5], U9 = [5.1,7]. Then 9 linguistic values are determined that make up 9 fuzzy sets A1, A2, A3, A4, A5, A6, A7, A8, A9 which in the universe of U talk are A1 = 1, A2 = 3, A3 = 3.4, A4 = 3.6, A5 = 4, A6 = 4.2, A7 = 4.5, A8 = 4.8, A9 = 5.1.
5. Step 5: Fuzzification of values from historical data.
   Based on the linguistic values formed, each of them is obtained from fuzzified historical data as shown in the following table:

Table 2 : Historical Data Fuzzification Table

Date	Time	Latitude	Longitude	Mag	Fuzzified
06/01/2012	13:58:33	2,16	96,25	3	A2
14/02/2012	02:20:38	3,14	96,66	7	A9
29/03/2012	09:27:11	1,32	95,61	4,9	A8
14/04/2012	08:23:51	2,13	96,74	5	A8
14/06/2012	22:59:26	2,23	95,97	4,2	A6
17/08/2012	06:06:32	3,25	96,79	4,4	A6

19/08/2012	01:57:02	1,18	96,32	4	A5
09/09/2012	09:13:06	2,94	96,01	4,6	A7
24/11/2012	14:04:56	2,53	97,68	4,3	A6
27/11/2012	12:00:27	2,11	96,5	4,4	A6
28/11/2012	23:03:22	4,77	96,65	3,5	A3
06/12/2012	18:22:33	2,25	95,6	2,7	A1
05/01/2013	03:24:32	2,47	96,5	3,2	A2
06/02/2013	00:43:52	1,09	97,32	3,3	A2
16/03/2013	11:55:05	4,76	96,2	2,8	A1
29/04/2013	13:43:00	3,89	97,32	4,3	A6
31/05/2013	19:52:42	2,41	97,83	2,9	A1
07/06/2013	14:12:21	2,61	97,91	4,1	A5
06/07/2013	10:06:54	2,46	95,94	3,8	A4
30/08/2013	09:01:44	1,65	96,81	4,2	A6
24/09/2013	07:03:04	2,1	95,45	5	A8
04/10/2013	10:10:09	2,33	96,66	3,4	A3
22/11/2013	10:43:42	4,76	95,84	5,1	A9
10/12/2013	07:37:26	5,94	95,9	1	A1
18/02/2014	10:15:54	1,07	96,95	3,4	A3
19/02/2014	07:36:04	4,74	96,12	3	A2
05/05/2014	15:06:26	2,47	96,13	4	A5
09/05/2014	16:40:55	4,42	97,01	3	A2
09/05/2014	20:00:47	2,57	95,95	4,4	A6
29/06/2014	08:11:54	4,42	95,93	4	A4
05/07/2014	14:50:31	4,87	96,91	4,9	A8
07/09/2014	13:31:37	4,95	97,25	2	A1
14/09/2014	10:28:19	5,3	97,16	2,6	A1
08/10/2014	11:15:39	5,23	94,73	4,5	A7
03/11/2014	05:05:53	5,02	84,78	3,6	A4
17/12/2014	16:28:37	2,7	95,7	3,6	A4
27/01/2015	10:59:58	2,32	94,42	4,8	A8
02/02/2015	20:13:59	1,4	95,72	4,5	A7
06/03/2015	14:03:54	1,62	97,15	4,8	A8
09/03/2015	11:47:42	1,05	97,27	3,6	A4
21/05/2014	02:42:07	2,65	97,13	6	A9
01/06/2015	14:07:50	4,54	96,29	3,8	A4
11/06/2015	01:18:19	4,15	94,95	4	A5
19/08/2015	00:46:40	2,65	95,93	5	A8
04/09/2015	08:02:12	4,81	97,64	3,3	A2
28/10/2015	04:57:12	4,62	96,07	3,4	A3
02/11/2015	11:10:24	2,02	95,7	3,4	A3
07/12/2015	16:35:15	3,22	96,39	4,5	A7

30/01/2016	23:25:13	3,19	95,64	3,9	A4
12/02/2016	15:33:45	2,02	97,07	4,1	A5
31/03/2016	19:38:45	3,03	96,11	3,1	A2
01/05/2016	07:08:22	4,57	95,84	3,6	A4
06/05/2016	04:54:04	4,52	96,42	3,5	A4
27/06/2016	03:50:51	3,48	95,84	4,9	A8
03/07/2016	23:10:59	3,98	95,45	4,8	A8
31/08/2016	13:13:35	1,23	96,17	4,7	A7
21/09/2016	21:13:01	2,09	95,08	3,8	A4
28/10/2016	01:47:54	1,23	96,83	3,5	A3
04/11/2016	09:22:52	3,82	97,23	4,4	A6
18/12/2016	19:24:45	5,36	94,54	5,1	A9

Table Description 2:

a. On December 6, 2012 data 2.7 is included in group A1 in the range of values [1,2.9]
b. 9 May 2014 data 4.4 is included in group A6 in the range of values [4.2,4.4]
c. 27 June 2016 data 4.9 is included in the A8 group in the range [4.8.5]

6. Step 6: Establish a Fuzzy Logic Relationship (FLR)

Table 3 : FLR (Fuzzy Logic Relationship) table

Date	Time	Lat	Long	Mag	Fuzzified	FLR
06/01/2012	13.58.33	2,16	96,25	3	A2	A2 -> A9
14/02/2012	02.20.38	3,14	96,66	7	A9	A9 -> A8
29/03/2012	09.27.11	1,32	95,61	4,9	A8	A8 -> A8
14/04/2012	08.23.51	2,13	96,74	5	A8	A8 -> A6
14/06/2012	22.59.26	2,23	95,97	4,2	A6	A6 -> A6
17/08/2012	06.06.32	3,25	96,79	4,4	A6	A6 -> A5
19/08/2012	01.57.02	1,18	96,32	4	A5	A5 -> A7
09/09/2012	09.13.06	2,94	96,01	4,6	A7	A7 -> A6
24/11/2012	14.04.56	2,53	97,68	4,3	A6	A6 -> A6
27/11/2012	12.00.27	2,11	96,5	4,4	A6	A6 -> A3
28/11/2012	23.03.22	4,77	96,65	3,5	A3	A3 -> A1
06/12/2012	18.22.33	2,25	95,6	2,7	A1	A1 -> A2
05/01/2013	03.24.32	2,47	96,5	3,2	A2	A2 -> A2
06/02/2013	00.43.52	1,09	97,32	3,3	A2	A2 -> A1
16/03/2013	11.55.05	4,76	96,2	2,8	A1	A1 -> A6
29/04/2013	13.43.00	3,89	97,32	4,3	A6	A6 -> A1
31/05/2013	19.52.42	2,41	97,83	2,9	A1	A1 -> A5
07/06/2013	14.12.21	2,61	97,91	4,1	A5	A5 -> A4
06/07/2013	10.06.54	2,46	95,94	3,8	A4	A4 -> A6
30/08/2013	09.01.44	1,65	96,81	4,2	A6	A6 -> A8
24/09/2013	07.03.04	2,1	95,45	5	A8	A8 -> A3
04/10/2013	10.10.09	2,33	96,66	3,4	A3	A3 -> A9
22/11/2013	10.43.42	4,76	95,84	5,1	A9	A9 -> A1

10/12/2013	07.37.26	5,94	95,9	1	A1	A1 -> A3
18/02/2014	10.15.54	1,07	96,95	3,4	A3	A3 -> A2
19/02/2014	07.36.04	4,74	96,12	3	A2	A2 -> A5
05/05/2014	15.06.26	2,47	96,13	4	A5	A5 -> A2
09/05/2014	16.40.55	4,42	97,01	3	A2	A2 -> A6
09/05/2014	20.00.47	2,57	95,95	4,4	A6	A6 -> A4
29/06/2014	08.11.54	4,42	95,93	4	A4	A4 -> A8
05/07/2014	14.50.31	4,87	96,91	4,9	A8	A8 -> A1
07/09/2014	13.31.37	4,95	97,25	2	A1	A1 -> A1
14/09/2014	10.28.19	5,3	97,16	2,6	A1	A1 -> A7
08/10/2014	11.15.39	5,23	94,73	4,5	A7	A7 -> A4

Table Description 3:

a. 6 January 2012 and 14 February 2012 obtained from the number of range A2 3 and range A9 7 which will form a fuzzy logic relationship as in the FLR table is A2 => A9 to unite each period to be related.
b. 14 June 2012 and 17 August 2012 obtained from the number of range A6 4.2 and range A6 4.4 which will form a fuzzy logic relationship as in the FLR table is A6 => A6 to unite each period to be related.
c. 21 May 2014 and 01 June 2015 obtained from the number of range A9 6 and range A4 3.8 which will form a fuzzy logic relationship as in the FLR table is A9 => A4 to unite each period to be related.
d. 28 October 2016 and 06 December 2016 obtained from the number of range A3 3.5 and range A6 4.4 which will form a fuzzy logic relationship as in the FLR table is A3 => A6 to unite each period to be related.

7. Step 7 : Determine the Fuzzy Logic Relationship Group (FLRG)
   Based on the Fuzzy Logic Relationship (FLR) table in table 4.10, then a Fuzzy Logic Relationship Group (FLRG) is formed by eliminating identical or repeated FLRs, then FLRs that have the same LHS (left hand side) or current state, are combined into one group as in the following table 4.

Table 4 : FLR (Fuzzy Logic Relationship)

Current state	Next state
A1	A1,A2,A3,A5,A6,A7
A2	A1,A2,A3,A4,A5,A6,A9
A3	A1,A2,A3,A6,A7,A9
A4	A3,A4,A5,A6,A8,A9
A5	A2,A4,A7,A8
A6	A1,A3,A4,A5,A6,A8,A9
A7	A4,A6,A8
A8	A1,A2,A3,A4,A6,A7,A8
A9	A1,A4,A8

Table Description 4:

a. Formation of Fuzzy Logic Relationship (FLRG) by eliminating identical or repeated FLRs, then FLRs that have the same LHS (left hand side) or current state, are combined into one group such as: A1 => A1, A2, A3 , A5, A6, A7
b. Formation of Fuzzy Logic Relationship (FLRG) by eliminating identical or repeated FLRs, then FLRs that have the same LHS (left hand side) or current state, are combined into one group such as: A2 => A1, A2, A3 , A4, A5, A6, A9
c. Formation of Fuzzy Logic Relationship (FLRG) by eliminating identical or repeated FLRs, then FLRs that have the same LHS (left hand side) or current state, are combined into one group such as: A3 => A1, A2, A3 , A6, A7, A9 and so on.
b. To make the forecasting process easier, it is possible to first calculate all possible values from the fuzzification results for each group. For groups with

current state A1 => 3.35, A2 => 3.47, A3 => 3.53 and so on for other groups as can be seen in table 5 below:

Table 5 : FLRG (Fuzzy Logic Relationship Group)

Current State	Forecasted
A1	3,35
A2	3,471428571
A3	3,533333333
A4	4,183333333
A5	3,975
A6	3,728571429
A7	4,2
A8	3,5
A9	3,133333333

Table Description 4.12

a. The value of A1 => 3.35 is obtained from (A1,A2,A3,A5,A6,A7)/6 = 3.35
b. The value of A2 => 3.47 is obtained from (A1,A2,A3,A4,A5,A6,A9)/7 = 3.47
c. The value of A3 => 3.53 is obtained from (A1,A2,A3,A6,A7,A9)/6 = 3.53
d. The value of A4 => 4.18 is obtained from (A3,A4,A5,A6,A8,A9)/6 = 4.18

The calculation steps in determining the fuzzification results for each group to determine the fuzzy logic relationship group (FLRG) are the same.

8. Step 8 : Carry out the forecasting and defuzzification process based on the established FLRG.

9. Step 9 : calculate the error value with AFER
In this step, the calculated error value is the average error value with the AFER of each data that you want to predict. An example for calculating the error value from forecasting results on January 6, 2012 is:

$$\begin{aligned} \text{AFER} &= \frac{|A_i - F_i|}{n} * 100\% \\ &= \frac{|3-3{,}47|/3}{60} * 100\% \\ &= \frac{0{,}1566}{60} * 100\% \\ &= 0{,}0026\ \% \end{aligned}$$

Then the AFER value obtained is 0.0026% for forecast data on January 6, 2012. After calculating for monthly forecasts, the average obtained for AFER is 0.0034%.

Conclusion

Based on the description that has been discussed in this study, it can be concluded:

1. Applications for forecasting the level of earthquakes in Aceh based on WebGIS using the Fuzzy Time Series method built with DFD (Data Flow Diagrams), using the PHP programming language and MYSQL database, Mapping using the Google Map API to display peda to webgis.
2. The Fuzzy Time Series forecasting method used in earthquake forecasting applications is a good method because the search has an error value with Afer, where the smaller the error value, the more accurate it is.
3. Forecasting results show that in some areas in Aceh, the value of forecasting results is greater than the magnitude value of previous years

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