Disaster Forecasting Approach In Indonesia: A Fuzzy Time Series - Markov Chain Model

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Abstract

The concept of Fuzzy Time Series to predict things that will happen based on the data in the past, while Markov Chain assist in estimating the changes that may occur in the future. With methods are used to predict the incidence of natural disasters in the future. From the research that has been done, it appears the change, an increase of each disaster, like a tornado reaches 3%, floods reaches 16%, landslides reaches 7%, transport accidents reached 25% and volcanic eruptions as high as 50%.

Key words: Fuzzy Time Series, Markov Chain, Forecasting, Disaster.

Introduction

Various kinds of natural disasters still occur in Indonesia. The disastrous events make people uneasy and lead to a health crisis. The availability of information on the past is not just a mere documentation, but can be used as a reference for predicting future events.

The concept of Fuzzy Time Series to predict things that will happen based on the data in the past, to learn how the variables change at any time. While the Markov Chain assist in estimating the changes that may occur in the future. Previous research conducted by Ruey-Chyn Tsaur that using fuzzy time series and Markov chain to predict currency of Taiwan with the US dollar (Ruey, 2012).

Using the concept of fuzzy time series and Markov chain, the researchers predicted the occurrence of natural disasters that occur in the future with quantitative forecasting techniques where such techniques use existing data in the past are taken directly from the national disaster management agency.

Research methods

The measures undertaken in this study are:

Fuzzy Time Series

Step - 1 : for the set of the universe $U = (D_{\min}, D_{\max})$ be the same number of odd intervals $(u_1, u_2, \dots, u_n)$.

Table 1. Table base interval

Interval	Bases
0.1 – 1.0	0.1
1.1 - 10	1
11 – 100	10
101 - 1000	100

Step - 2 : Make $(A_1, A_2, \dots, A_k)$ be a fuzzy set that is where the linguistic determined in accordance with the state of the universe.

$$A_1 = k_{11}/u_1 + k_{12}/u_2 + \dots + k_{1m}/u_m$$

$$A_2 = k_{21}/u_1 + k_{22}/u_2 + \dots + k_{2m}/u_m$$

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$$A_n = k_{n1}/u_1 + k_{n2}/u_2 + \dots + k_{nm}/u_m$$

Step - 3 : Forming fuzzy logical relationship

Step - 4 : Set weight fluctuation

Step - 5 : Calculating the value of linguistic distribution center

Step - 6 : Defuzzification process, with both vectors are multiplied to obtain initial estimates.

$$\text{Forecast}_{t+1} = v_t w_t \quad t = 1, \dots, n$$

Where :

Forecast_{t+1} = Forecast to Time t + 1

V_t = vector line $(1 \times k)$ to Time t

W_t = vector colum $(k \times 1)$ to Time t

Markov Chain

Step - 1 : Create a probability matrix of disasters

$$P = \begin{bmatrix} p_{00} & p_{01} & p_{02} & \dots \\ p_{10} & p_{11} & p_{12} & \dots \\ \vdots & \vdots & \vdots & \vdots \\ p_{i0} & p_{i1} & p_{i2} & \dots \end{bmatrix}$$

Step - 2 : Adjusting the inclination value

$$\pi(1) = \pi(0).P$$

Step - 3 : Determine the results of forecasting

Results and Discussion

Description Data

Data obtained from natural disaster relief agencies are taken in the period from July to September 2015.

Figure -1. Graph Natural Disaster Indonesia 2015

Based on the graph Indonesian natural disasters that occurred from the month of July until September 2015 that as many as 46 events tornado, flood as many as 21 events, landslides total of 18 events, transportation accidents as much as 7 events, and volcanic eruptions as many as three events.

Table 2. Data Disaster in september 2015

No	Province	District	Type Disaster	Date/Year
1	jawa tengah	pati	puting beliung	22/9/2015
2	bangka belitung	bangka	puting beliung	21/9/2015
3	jawa timur	situbondo	puting beliung	21/9/2015
4	pemerintah aceh	kota subulussalam	banjir	20/9/2015
5	jawa barat	sukabumi	tanah longsor	18/9/2015
6	sumatera utara	nias barat	banjir	15/9/2015
7	jawa timur	pamekasan	puting beliung	15/9/2015
8	pemerintah aceh	aceh barat	banjir	14/9/2015
9	sumatera utara	simalungun	puting beliung	14/9/2015
10	riau	kampar	puting beliung	14/9/2015
11	riau	kota pekanbaru	puting beliung	14/9/2015
12	pemerintah aceh	aceh barat daya	banjir	13/9/2015
13	pemerintah aceh	nagan raya	banjir	13/9/2015
14	pemerintah aceh	bener meriah	banjir	13/9/2015
15	pemerintah aceh	simeulue	banjir	12/9/2015
16	pemerintah aceh	aceh utara	banjir	12/9/2015

17	sumatera utara	kota medan	banjir	12/9/2015
18	sumatera utara	kota binjai	banjir	12/9/2015
19	pemerintah aceh	aceh utara	banjir	11/9/2015
20	sumatera utara	serdang bedagai	puting beliung	11/9/2015
21	jawa timur	tuban	kecelakaan transportasi	11/9/2015
22	jawa timur	bojonegoro	puting beliung	10/9/2015
23	kepulauan riau	bintan	puting beliung	9/9/2015
24	maluku utara	kota ternate	letusan gunung api	8/9/2015
25	jawa barat	kota bogor	tanah longsor	7/9/2015
26	kalimantan timur	kota bontang	puting beliung	5/9/2015

Analysis Fuzzy Time Series

From the data obtained in the specified set of rules $U = (D_{\min}, D_{\max})$ be the same number of odd intervals $(u_1, u_2, \dots, u_n)$. Where the number of intervals is 7. From the data obtained history $D_{\min} = 1, D_{\max} = 19$.

7 interval in the universe U is:

$$U_1 = (11, 19) \quad U_5 = (1, 7)$$

$$U_2 = (11, 16) \quad U_6 = (2, 4)$$

$$U_3 = (3, 7) \quad U_7 = (1, 2)$$

$$U_4 = (2, 9)$$

Based on the results of the universe U can be determined fuzzy linguistic namely:

$$A_1 = 1/u_1 + 0,5/u_2 + 0/u_3 + 0/u_4 + 0/u_5 + 0/u_6 + 0/u_7$$

$$A_2 = 0,5/u_1 + 1/u_2 + 0,5/u_3 + 0/u_4 + 0/u_5 + 0/u_6 + 0/u_7$$

$$A_3 = 0/u_1 + 0,5/u_2 + 1/u_3 + 0,5/u_4 + 0/u_5 + 0/u_6 + 0/u_7$$

$$A_4 = 0,5/u_1 + 1/u_2 + 0/u_3 + 0/u_4 + 0/u_5 + 0/u_6 + 0,5/u_7$$

$$A_5 = 0/u_1 + 0,5/u_2 + 0/u_3 + 1/u_4 + 0/u_5 + 0/u_6 + 0/u_7$$

$$A_6 = 0/u_1 + 0/u_2 + 0/u_3 + 0,5/u_4 + 1/u_5 + 0/u_6 + 0/u_7$$

$$A_7 = 1/u_1 + 0/u_2 + 0/u_3 + 0/u_4 + 0,5/u_5 + 0/u_6 + 1/u_7$$

The next stage of the process is done by natural disasters defuzzification based on data from the month of July to September 2015. Based on the results of the set U, the universe can be generated from the data fuzzyfikasi natural disasters which can be seen in the table fuzzyfikasi following:

Table 3. Table defuzzyfikasi

Month	Case	Data	Fuzzyfikasi
July	Puting Beliung	16	A ₂
	Flooding	3	A ₃
	Landslide	7	A ₃
	Accidents Transportation	2	A ₆
	Vulcanic Eruption	1	A ₇
Agust	Puting Beliung	19	A ₁
	Flooding	7	A ₃
	Landslide	9	A ₄
	Accidents Transportation	4	A ₆
	Vulcanic Eruption	1	A ₇
September	Puting Beliung	11	A ₁
	Flooding	11	A ₁
	Landslide	2	A ₇
	Accidents Transportation	1	A ₅
	Vulcanic Eruption	1	A ₅

For example, the data in July with tornado occurrence is 16. Because 16 including U2 interval then difuzzyfikasinya to A₂.

Markov Chain

Based on the data table natural disasters can be created matrix as follows:

$$P = \begin{bmatrix} 3,2 & 0,6 & 1,4 & 0,4 & 0,2 \\ 3,8 & 1,4 & 1,8 & 0,8 & 0,2 \\ 2,2 & 2,2 & 0,4 & 0,2 & 0,2 \end{bmatrix}$$

$$\pi(1) = \pi(0).P$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \end{bmatrix} \times \begin{bmatrix} 3,2 & 0,6 & 1,4 & 0,4 & 0,2 \\ 3,8 & 1,4 & 1,8 & 0,8 & 0,2 \\ 2,2 & 2,2 & 0,4 & 0,2 & 0,2 \end{bmatrix}$$

$$= [3,2 \quad 0,6 \quad 1,4 \quad 0,4 \quad 0,2]$$

For forecasting results in the next year, the tornado reached 3%, reaching 16% of flood, landslides reaches 7%, reaching 25% of transportation accidents and volcanic eruptions as high as 50%.

Figure - 2. Graph the results forecast in the next year

Conclusions

Based on research that has been done, using fuzzy time series and Markov chain, the prediction of natural disasters following year for tornado reached 3%, floods reaches 16%, landslides reaches 7%, transport accidents reached 25% and a volcanic eruption reaches 50% , By combining fuzzy time series with Markov chain, better accuracy rate than the usual fuzzy time series.

Acknowledgements

The advice given by the author is to experiment with larger data using fuzzy time series and Markov chain.

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