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AVERAGE-BASED FUZZY TIME SERIES MARKOV CHAIN IN JCI FORECASTING

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Abstract

We employ average-based concept to calculate the value of an average interval of historical data, fuzziness to classify variables, time series to observe a certain period of data and Markov model in prediction process using transition probability. The analysis is applied to predict the currency exchange rates (USD-IDR).

1. Introduction

Fuzzy time series Markov chain model is used in Jakarta composite index (JCI) prediction that can generate predictive value calculations, especially the JCI closing price one day ahead. The result can assist users to make decision relating to the exercise of economic activity. Accuracy of this model is proportional to the interval range data. Small range interval data

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will minimize deviation of predictive value. A web based application is built so that the prediction process can be more efficient, thorough and practical, Rachmawati et al. [4].

The interval length of fuzzy time series Markov chain model is predetermined. Determination of interval length is very influential in fuzzy relationship formation because it would provide the differences in calculation results. Therefore, we need an effective method where interval length is based on average value of absolute difference data. This method is average-based fuzzy time series Markov chain model.

2. The Method

2.1. Average-based fuzzy times series Markov chain model (AFTMC)

Average-based fuzzy time series Markov chain model (AFTMC) uses the concept of *fuzzy time series Markov chain model* (FTMC) in Rachmawati et al. [4] in calculation process, except in determination of length *l*. In simulation, data tested using the same historical of JCI closing price December 2, 2013 - June 3, 2014 (http://finance.yahoo.com/q/hp?s=%5EJKSE+Historical+Prices). The table below is a sample taken from JCI closing price.

Table 1. JCI closing price

Date	JCI closing price
12/2/2013	4321.98
12/3/2013	4288.76
12/4/2013	4241.30
12/5/2013	4216.89
12/6/2013	4180.79
12/9/2013	4214.34
12/10/2013	4275.68
12/11/2013	4271.74
12/12/2013	4212.22
12/13/2013	4174.83

Length l will be calculated using average-based method. The steps are as follows:

1. Calculate the absolute difference between the time series data obtained from the 10 sample data, the values are 33.22, 47.46, 24.41, 36.1, 33.55, 61.34, 3.94, 59.52 and 37.39. After that, calculate the average value of the difference, that is, 37.44.
2. Determine half of the average as interval length, that is, 18.72.
3. According to Table 2, 18.72 is in 10 basis interval category.

Table 2. Basis interval

Range	Base
0.1-1.0	0.1
1.1-10	1
11-100	10
101-1000	100

4. Then 18.72 rounded off by a base in order to obtain a value of 10 as the effective interval length.
5. So the number of intervals can be obtained from the range divided by the interval l, 4330 (maximum value) minus 4170 (minimum value) is 160, then 160 divided by 10 we get 16, then the number of interval obtained is 16, that is, $u_i = u_1, ..., u_{16}$.

2.2. Prediction

By prediction process, according to Rachmawati et al. [4], we get the following results:

Table 3. Fuzzy set with $l = 10$

u_i	Range	Midpoint (m_i)	Fuzzy set
u_1	[4170, 4179]	4174.50	A_1
u_2	[4180, 4189]	4184.50	A_2
u_3	[4190, 4199]	4194.50	A_3
u_4	[4200, 4209]	4204.50	A_4
u_5	[4210, 4219]	4214.50	A_5
u_6	[4220, 4229]	4224.50	A_6
u_7	[4230, 4239]	4234.50	A_7
u_8	[4240, 4249]	4244.50	A_8
u_9	[4250, 4259]	4254.50	A_9
u_{10}	[4260, 4269]	4264.50	A_{10}
u_{11}	[4270, 4279]	4274.50	A_{11}
u_{12}	[4280, 4289]	4284.50	A_{12}
u_{13}	[4290, 4299]	4294.50	A_{13}
u_{14}	[4300, 4309]	4304.50	A_{14}
u_{15}	[4310, 4319]	4314.50	A_{15}
u_{16}	[4320, 4329]	4324.50	A_{16}

Table 4. Fuzzy logical relationship of JCI closing price

Date	JCI closing price	Fuzzification	Date ($t-1$)	Date t	Fuzzy logical relationship
12/2/2013	4321.98	A_{16}	12/2/2013	12/3/2013	$A_{16} \rightarrow A_{12}$
12/3/2013	4288.76	A_{12}	12/3/2013	12/4/2013	$A_{12} \rightarrow A_8$
12/4/2013	4241.3	A_8	12/4/2013	12/5/2013	$A_8 \rightarrow A_5$
12/5/2013	4216.89	A_5	12/5/2013	12/6/2013	$A_5 \rightarrow A_2$
12/6/2013	4180.79	A_2	12/6/2013	12/9/2013	$A_2 \rightarrow A_5$
12/9/2013	4214.34	A_5	12/9/2013	12/10/2013	$A_5 \rightarrow A_{11}$
12/10/2013	4275.68	A_{11}	12/10/2013	12/11/2013	$A_{11} \rightarrow A_{11}$
12/11/2013	4271.74	A_{11}	12/11/2013	12/12/2013	$A_{11} \rightarrow A_5$
12/12/2013	4212.22	A_5	12/12/2013	12/13/2013	$A_5 \rightarrow A_1$
12/13/2013	4174.83	A_1	12/13/2013	12/16/2013	$A_1 \rightarrow \#$

If state A_i transition to state A_j $(i, j = 1, 2, ..., 16)$, then matrix transition probability is derived from P_{ij}. From *fuzzy logical relationship group*, we get the movement from:

A_1 to A_1 (M_{11}) is 1 time $(A_1 \rightarrow \#)$,

A_1 to A_2 (M_{12}) is 1 time $(A_1 \rightarrow \#)$.

Total movement from A_1 (M_1) are 16 times.

Then

$$P_{11} = \frac{M_{11}}{M_1} = \frac{1}{16} = 0.06,\ P_{12} = \frac{M_{12}}{M_1} = \frac{1}{16} = 0.06,\ ...,$$

$$P_{16\,16} = \frac{M_{16\,16}}{M_{16}} = \frac{0}{1} = 0.$$

To calculate the JCI closing price on the second day (12/3/2013), required price at 1 day earlier on 12/2/2013 is 4321.98 which has the fuzzification value A_{16}, where *fuzzy logical relationship group* A_{16} is *one-to-one* $(A_{16} \rightarrow A_{12})$. Then the prediction price for 12/3/2013 can be calculated as:

$$F(12/3/2013) = m_{12} \times P_{16\,12} = 4284.5 \times 1 = 4284.5.$$

To calculate the JCI closing price on the third day (12/6/2013), required value at 1 day earlier on 12/5/2013 is 4216.89 which has fuzzification value A_5, where *fuzzy logical relationship group* A_5 is *one-to-many* $(A_5 \rightarrow A_1, A_2, A_{11})$. Then the prediction price for 12/6/2013 can be calculated as:

$$\begin{aligned} F(12/6/2013) &= (m_1 \times P_{51}) + (Y(12/5/2013) \times P_{52}) + (m_{11} \times P_{5\,11}) \\ &= (4174.5 \times 0.33) + (4216.89 \times 0.33) + (4274.50 \times 0.33) \\ &= 4167.83. \end{aligned}$$

To calculate the adjustment value on the fifth day (12/6/2013), required fuzzification value at 1 day earlier on 12/5/2013 and 12/6/2013 itself. Fuzzification value on 12/5/2013 is A_5, where *fuzzy logical relationship group* A_5 is *one-to-many* $(A_5 \rightarrow A_1, A_2, A_{11})$. Fuzzification value on 12/6/2013 is A_2. Because of 12/5/2013 and 12/6/2013 have different fuzzification values, and fuzzification value on 12/5/2013 is *one-to-many*, then we can calculate the adjustment value D_t as follows:

A_5 does not communicate with A_5 in *fuzzy logical relationship group*, and A_5 (on 12/5/2013) is *decreasing transition* to A_2 (on 12/6/2013), then $D_{t1} = 0$.

A_5 (on 12/5/2013) is *jump-backward transition* to A_2 (on 12/6/2013), then $D_{t2} = -\left(\frac{10}{2}\right) \times 3 = -15$.

So, $D_t = D_{t1} + D_{t2} = -15$.

To calculate the adjustment value on 12/10/2013, required fuzzification value at 1 day earlier on 12/9/2013 and 12/10/2013 itself. Fuzzification value on 12/9/2013 is A_5, where *fuzzy logical relationship group* A_5 is *one-to-many* $(A_1 \rightarrow A_1, A_2, A_{11})$. Fuzzification value on 12/10/2013 is A_{11}. Because of 12/9/2013 and 12/10/2013 have different fuzzification values, and fuzzification value on 12/9/2013 is *one-to-many*, then we can calculate the adjustment value D_t as follows:

A_5 does not communicate with A_5 in *fuzzy logical relationship group*, and A_5 (on 12/9/2013) is *increasing transition* to A_{11} (on 12/10/2013), then $D_{t1} = 0$.

A_5 (on 12/9/2013) is *jump-forward transition* to A_{11} (on 12/10/2013), then $D_{t2} = \left(\frac{10}{2}\right) \times 6 = 30$.

So, $D_t = D_{t1} + D_{t2} = 30$.

To calculate the adjustment value on 12/12/2013, required fuzzification value at 1 day earlier on 12/11/2013 and 12/12/2013 itself. Fuzzification value on 12/11/2013 is A_{11}, where *fuzzy logical relationship group* A_{11} is *one-to-many* $(A_{11} \rightarrow A_5, A_{11})$. Fuzzification value on 12/12/2013 is A_5. Because of 12/12/2013 and 12/11/2013 have different fuzzification values, and fuzzification value on 12/11/2013 is *one-to-many*, then we can calculate the adjustment value D_t as follows:

A_{11} communicates with A_{11} in *fuzzy logical relationship group*, and A_{11} (on 12/11/2013) is *decreasing transition* to A_5 (on 12/12/2013), then $D_{t1} = -\frac{10}{2} - 5$.

A_{11} (on 12/11/2013) is *jump-backward transition* to A_5 (on 12/12/2013), then $D_{t2} = -\left(\frac{10}{2}\right) \times 6 = -30$.

So, $D_t = D_{t1} + D_{t2} = -35$.

Thus, for the 10 samples of data used, the prediction results obtained after adjustment are as follows:

Table 5. Adjustment value

Date	JCI actual closing price	JCI prediction closing price (before adjustment)	Adjustment value (D_t)	JCI prediction closing price (after adjustment)
12/2/2013	4321.98	0.00	0	0.00
12/3/2013	4288.76	4284.50	0	4284.50
12/4/2013	4241.3	4244.50	0	4244.50
12/5/2013	4216.89	4214.50	0	4214.50
12/6/2013	4180.79	4167.83	–15	4152.83
12/9/2013	4214.34	4184.50	0	4184.50
12/10/2013	4275.68	4149.20	30	4179.20
12/11/2013	4271.74	4245.09	0	4245.09
12/12/2013	4212.22	4273.12	–35	4238.12
12/13/2013	4174.83	4181.50	–20	4161.50

We compare results from AFTMC method with FTMC (fuzzy time series Markov chain model) algorithm in Rachmawati et al. [3] and the simulation

from Rachmawati et al. [4]. The comparison results from the two methods can be seen in Table 6 as follows:

Table 6. The comparison results of JCI closing price prediction

Date	Actual price	Prediction price		| Error |		| PE | (%)	
		AFTMC	FTMC	AFTMC	FTMC	AFTMC	FTMC
12/2/2013	4321.98	0.00	0	0.00	-	0.000993	-
12/3/2013	4288.76	4284.50	4249.5	4.26	39.26	0.000754	0.91542
12/4/2013	4241.3	4244.50	4248.97	3.20	7.67	0.000567	0.18084
12/5/2013	4216.89	4214.50	4215.07	2.39	1.82	0.006688	0.04316
12/6/2013	4180.79	4152.83	4097.64	27.96	83.15	0.007081	1.98886
12/9/2013	4214.34	4184.50	4297.97	29.84	83.63	0.022564	1.98442
12/10/2013	4275.68	4179.20	4195.81	96.48	79.87	0.006239	1.86801
12/11/2013	4271.74	4245.09	4239.63	26.65	32.11	0.006149	0.75168
12/12/2013	4212.22	4238.12	4236.81	25.90	24.59	0.003192	0.58378
12/13/2013	4174.83	4161.50	4094.3	13.33	80.53	0.000993	1.92894
				MAD		MAPE (%)	
				25.56	48.07	0.60252	1.13834

3. Conclusions

Based on Table 6, the JCI prediction price using AFTMC method is closer to the actual price than that of the FTMC method. In other words, AFTMC has better accuracy. It is because AFTMC calculates the average-based to determine the interval length *l*. AFTMC is not difficult to explain and does not require a lot of historical data to predict, although it is advisable to use a lot of historical data to get more accurate prediction.

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