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Prediction of rupiah exchange rate against Australian dollar using the Chen fuzzy time series method

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ABSTRACT

The exchange rate of the rupiah (IDR) to the Australian dollar is the price of one rupiah translated to the Australian dollar. Weakening or decreasing prices of the Rupiah to the Australian dollar are influenced by various factors, such as government policies and expectations. Therefore, the government or related parties must be careful in predicting the value of the rupiah exchange rate to the currency of the state, such as the Australian dollar. This report will discuss the prediction of the rupiah exchange rate to the Australian dollar for 223 days from December 2018 to July 2019 using the Chen fuzzy time series method. The results of this report are the prediction of the value of the exchange rate of the rupiah to the Australian dollar in December 2018 to July 2019 is be again in the interval 10,450 IDR to 10,920 IDR.

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1. INTRODUCTION

The exchange rate or currency exchange rate is the price of a country's currency against the currency of another country. In this case, the Indonesian currency exchange rate (rupiah) is the value of one rupiah which is translated into the Australian currency (dollar). The fluctuation of the exchange rate is influenced by several factors, such as government policies, inflation rates, differences in interest rates, the balance of payments activities, and expectations [1-5]. The value of the rupiah exchange rate against the Australian dollar until November 2018 can be said to have weakened or decreased [6-8]. This is due to the drop in global coal prices, which is a commodity as a national foreign exchange earner [9-12].

Forecasting is the art and science of predicting future events by involving taking historical data and projecting it into the future using a systematic approach model [13, 14]. In prediction or experience, the data processed is actual or historical data which is used as reference data.

Based on this, this report will discuss the prediction of the rupiah exchange rate against the Australian dollar from December 2018 to July 2019 (for 223 days).

2. RESEARCH METHODS

The methodology used in this research is a literature study by collecting various information related to this research, which is obtained from several journals, books, and articles. The following are the steps of this research.

a. Data collection and data analysis, the data that will be processed is the data on the exchange rate of the rupiah against the Australian dollar in January to November 2018 was obtained from the Bank Indonesia website.

b. The application of Chen's fuzzy time series
c. Defuzzification

2.1. Time Series

A time series is a set of consecutive observations taken based on certain time intervals. For example, a set of data is retrieved per minute, per hour, per day, per week, per month, per year, and so on [15-17].

2.2. Fuzzy Logic

Fuzzy logic was first introduced by Prof. Lofti Astor Zadeh in 1965 [18]. Fuzzy logic is a method of counting with the variable words (linguistic variable), instead of counting with numbers. The term fuzzy means vague or unclear, but the fuzzy system built to model the forecast still has a clear way of working and a description based on fuzzy logic theory [19, 20].

2.3. Fuzzy Time Series

Fuzzy time series (FTS) was first developed by Song and Chissom in 1993 [21]. FTS is a data forecasting method that uses fuzzy principles as the basis [22, 23]. In general, a fuzzy set is defined as a class of numbers with cryptic boundaries. If u is the set of universes, then the membership function is:

$$A_i = \mu_{A_i}(u_i)|u_i + \cdots + \mu_{A_P}(u_p)|u_p \quad (1)$$

where $\mu_{A_i}(u_i)$ represents the degree of membership of u_i to A_i and $\mu_{A_i}(u_i) \in [0,1]$ and $1 \leq i \leq p$.

The membership degree value of $\mu_{A_i}(u_i)$ determined according to the following rules:

Rule 1: If the data is actual X_t included in u_i, hence the degree of membership u_i is 1, u_{i+1} is 0.5, and if everything else is declared 0.
Rule 2: If the data is actual X_t included in u_i, $1 \leq i \leq p$ hence the degree of membership u_i is 1, and u_{i+1} is 0.5 and if everything else is declared 0.
Rule 3: If the data is actual X_t included in u_i, hence the degree of membership u_i is 1, u_{i-1} is 0.5 and if everything else is declared 0.

2.4. Fuzzy Time Series Chen

Forecasting steps use the Chen fuzzy time series method, which is as follows:

1. Determine the set of the actual data universe

$$U = [X_{min} - D_1; X_{max} + D_2] \quad (2)$$

2. Determine the length of the interval based on the average
   a. The average difference between absolute values

$$Mean = \frac{\sum_{i=1}^{n} |X_{t+1} - X_t|}{n} \quad (3)$$

   b. Calculate the length of the interval

$$l = \frac{Mean}{2} \quad (4)$$

   c. Count the number of intervals

$$p = \frac{(X_{max} + D_2 - X_{min} - D_1)}{l} \quad (5)$$

   d. Calculating the middle value

$$m_i = \frac{(upper\ limit + lower\ limit)}{2} \quad (6)$$

3. Defines a fuzzy set A_i and perform fuzzification on the actual observed data. Suppose $A_1, A_2, \dots, A_i$ is a fuzzy set that has linguistic value, then the definition of a fuzzy set in the universe of speech u is:

$$A_1 = \{u_1|1\} + \{u_2|0.5\} + \{u_3|0\} + \{u_4|0\} + \cdots + \{u_p|0\}$$

$$A_2 = \{u_1|0.5\} + \{u_2|1\} + \{u_3|0.5\} + \{u_4|0\} + \cdots + \{u_p|0\}$$

$$A_3 = \{u_1|0\} + \{u_2|0.5\} + \{u_3|1\} + \{u_4|0\} + \cdots + \{u_p|0\}$$

$$\vdots$$

$$A_p = \{u_1|0\} + \{u_2|0\} + \{u_3|0\} + \cdots + \{u_{p-1}|0.5\} + \{u_p|1\} \quad (7)$$

4. Creating a fuzzy logical relationship (FLR) tables based on actual data. FLR can be denoted by $A_i \rightarrow A_j$, where A_i called the current state and A_j called the next state.
5. Forming a fuzzy logical relationship group (FLRG) by grouping a fuzzy set that has the same current state into the next state.
6. Prediction Value Defuzzification in the Chen fuzzy time series method has several rules, namely:

Rule 1: If fuzzification results on a day to t are A_i and there are fuzzy sets that aredoes not have a fuzzy logic relationship, then the prediction results F_{t+1} is m_i.

Rule 2: If fuzzification results on a day to t are A_i and there is one FLR, then the resultpredictions F_{t+1} is m_j.

Rule 3: If fuzzification results on a day to t are A_j and t are A_j have multiple FLRs, hence the prediction results F_{t+1} is

$$F_{t+1} = \frac{m_{j1}+m_{j2}+\cdots+m_{jk}}{k} \quad (8)$$

7. Calculating Error

$$e_t = X_t - F_t \quad (9)$$

2.5. Measurement of the Accuracy of Prediction Results

The measurement of the accuracy of the predicted data is done by comparing the predicted data with the actual data to see the error rate that occurs. The lower the error rate (error) in the prediction data, the more feasible the predictive data will be used. The equations for the root mean of square error (RMSE) and mean absolute error (MAE) are shown as follows:

$$RMSE = \sqrt{\frac{1}{n}\sum_{t=1}^{n} {e_t}^2} \quad (10)$$

$$MAE = \frac{1}{n}\sum_{t=1}^{n} |e_t| \quad (11)$$

3. RESULTS AND DISCUSSION

The cash value of the initial lifetime annuity is the value influenced by the discount factor and the probability of death is calculated at the beginning of the period over the years, symbolized by $\ddot{a}_x$, with x which is the age of the insurance participant [24, 25].

Chen's fuzzy time series method is a method developed by Chen to predict future data by considering past data, and uses fuzzy principles as the basis and determines the interval based on the average. This method aims to predict the value of the rupiah exchange rate against the Australian dollar from January to July 2019 (for 223 days).

The data on the exchange rate of the Rupiah against the Australian dollar in January – November 2018 which can be seen in Table 1 in the appendix was obtained from the Bank Indonesia

website. From Table 1, it can be seen that the value of the rupiah exchange rate against the Australian dollar in January to November 2018 ranged from 10,450 IDR to 10,910 IDR per AUD.

The value of the rupiah exchange rate against the Australian dollar in January to November 2018 based on Table 1, can be presented in the form of a time series plot as in Figure 1 below.

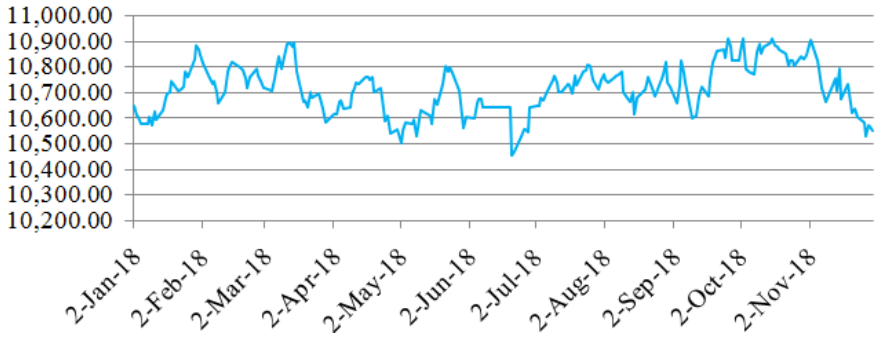

Figure 1. Value of rupiah exchange rate against AUD in January – November 2018.

From Figure 1, it is clear that the rupiah exchange rate against the Australian dollar from January to November 2018 weakened or decreased.

Based on the actual data presented in Figure 1, the results of descriptive statistical analysis are obtained as in Table 1 below.

Table 1. Descriptive value of the rupiah exchange rate against AUD.

Descriptive table	Actual data
The amount of data	223
Minimum value	10,451.50
Maximum value	10,909.46
Average	10,718.09

From Table 1 above, it can be seen that the data on the exchange rate of the rupiah against the Australian dollar from January to November 2018 (in the daily form) consists of 223 data with the lowest exchange rate of 10,451.50 IDR and the highest exchange rate of 10,909.46 IDR for each one AUD, and an average of 10,718.09 IDR. In the Chen fuzzy time series method, some steps will be taken, namely as follows.

3.1. The Set of Universes of Actual Data

Using the formula in Equation (2), where is the value D_1 and D_2 is any positive number. So that we obtain a universal set of actual data for the exchange rate of the rupiah against the Australian dollar in January – November 2018, as follows.

$$U = [X_{min} - D_1; X_{max} + D_2] = [10{,}451.50 - 51.50; 10{,}929.46 + 20.54] = [10{,}400; 11{,}000]$$

3.2. Average-Based Interval Lengths

Based on the formulas in Equations (3), (4), (5), and (6), the value is obtained $|X_{t+1} - X_t|$ shown below. So that the following values are obtained.

The average difference between absolute values:

$$Mean = \frac{\sum_{i=1}^{n}|X_{t+1}-X_t|}{n} = \frac{39.27+6.58+27.08+3.15+\cdots+38.46+1.37+17.21+10{,}548.85}{223} = 84.26$$

Interval length:

$$l = \frac{Mean}{2} = \frac{84.26}{2} = 42.13$$

Several intervals:

$$p = \frac{(X_{max}+D_2-X_{min}-D_1)}{l} = \frac{(10{,}929.46+20.54-20{,}451.50-51.50)}{42.13} = 10.61 \approx 11$$

3.3. The Set Fuzzy and Fuzzification

Based on the number of intervals, it is obtained:

a. The Set Fuzzy

$A_1 = \{u_1|1\} + \{u_2|0.5\} + \{u_3|0\} + \{u_4|0\} + \{u_5|0\} + \{u_6|0\} + \{u_7|0\} + \{u_8|0\} + \{u_9|0\} + \{u_{10}|0\} + \{u_{11}|0\}$
$A_2 = \{u_1|0.5\} + \{u_2|1\} + \{u_3|0.5\} + \{u_4|0\} + \{u_5|0\} + \{u_6|0\} + \{u_7|0\} + \{u_8|0\} + \{u_9|0\} + \{u_{10}|0\} + \{u_{11}|0\}$
$A_3 = \{u_1|0\} + \{u_2|0.5\} + \{u_3|1\} + \{u_4|0.5\} + \{u_5|0\} + \{u_6|0\} + \{u_7|0\} + \{u_8|0\} + \{u_9|0\} + \{u_{10}|0\} + \{u_{11}|0\}$
$A_4 = \{u_1|0\} + \{u_2|0\} + \{u_3|0.5\} + \{u_4|1\} + \{u_5|0.5\} + \{u_6|0\} + \{u_7|0\} + \{u_8|0\} + \{u_9|0\} + \{u_{10}|0\} + \{u_{11}|0\}$
$A_5 = \{u_1|0\} + \{u_2|0\} + \{u_3|0\} + \{u_4|0.5\} + \{u_5|1\} + \{u_6|0.5\} + \{u_7|0\} + \{u_8|0\} + \{u_9|0\} + \{u_{10}|0\} + \{u_{11}|0\}$
$A_6 = \{u_1|0\} + \{u_2|0\} + \{u_3|0\} + \{u_4|0\} + \{u_5|0.5\} + \{u_6|1\} + \{u_7|0.5\} + \{u_8|0\} + \{u_9|0\} + \{u_{10}|0\} + \{u_{11}|0\}$
$A_7 = \{u_1|0\} + \{u_2|0\} + \{u_3|0\} + \{u_4|0\} + \{u_5|0\} + \{u_6|0.5\} + \{u_7|1\} + \{u_8|0.5\} + \{u_9|0\} + \{u_{10}|0\} + \{u_{11}|0\}$
$A_8 = \{u_1|0\} + \{u_2|0\} + \{u_3|0\} + \{u_4|0\} + \{u_5|0\} + \{u_6|0\} + \{u_7|0.5\} + \{u_8|1\} + \{u_9|0.5\} + \{u_{10}|0\} + \{u_{11}|0\}$
$A_9 = \{u_1|0\} + \{u_2|0\} + \{u_3|0\} + \{u_4|0\} + \{u_5|0\} + \{u_6|0\} + \{u_7|0\} + \{u_8|0.5\} + \{u_9|1\} + \{u_{10}|0.5\} + \{u_{11}|0\}$
$A_{10} = \{u_1|0\} + \{u_2|0\} + \{u_3|0\} + \{u_4|0\} + \{u_5|0\} + \{u_6|0\} + \{u_7|0\} + \{u_8|0\} + \{u_9|0.5\} + \{u_{10}|1\} + \{u_{11}|0.5\}$
$A_{11} = \{u_1|0\} + \{u_2|0\} + \{u_3|0\} + \{u_4|0\} + \{u_5|0\} + \{u_6|0\} + \{u_7|0\} + \{u_8|0\} + \{u_9|0\} + \{u_{10}|0.5\} + \{u_{11}|1\}$

So that the elements are formed u_1 of the set of universes U, namely as follows in Table 2.

Table 2. Set universal elements.

u_i	Lower limit	Upper limit
u_1	10,451.50	10,493.63
u_2	10,493.63	10,535.76
u_3	10,535.76	10,577.89
u_4	10,577.89	10,620.02
u_5	10,620.02	10,662.15
u_6	10,662.15	10,704.28
u_7	10,662.15	10,746.41
u_8	10,746.41	10,788.54
u_9	10,788.54	10,830.67
u_{10}	10,830.67	10,872.80
u_{11}	10,872.80	10,914.93

b. Fuzzification

Table 3. Fuzzification and linguistic value.

Fuzzification	linguistic value
A_1	Very down
A_2	Half down
A_3	Slightly down
A_4	Down
A_5	Half normal
A_6	Normal
A_7	Very normal
A_8	Up
A_9	Slightly up
A_{10}	Half up
A_{11}	Very up

3.4. Fuzzy Logical Relationship (FLR)

The fuzzy logical relationship was formed based on the number of intervals obtained in the previous stage. Fuzzification results and FLR data on the exchange rate of the rupiah against the Australian dollar in January – November 2018 can be seen in the attachment Table 3.

3.5. Fuzzy Logical Relationship Group (FLRG)

The fuzzy set that has the same current state is as follows in Table 4.

Table 4. Fuzzy logical relationship group.

Group	Relation	Prediction
1	$A_1 \rightarrow A_1, A_2$	10,493.63
2	$A_2 \rightarrow A_3, A_5$	10,598.96
3	$A_3 \rightarrow A_2, A_3, A_4, A_5, A_6$	10,598.96
4	$A_4 \rightarrow A_2, A_3, A_4, A_5, A_6$	10,598.96
5	$A_5 \rightarrow A_4, A_5, A_6, A_7$	10,662.15
6	$A_6 \rightarrow A_4, A_5, A_6, A_7, A_8, A_9$	10,704.28
7	$A_7 \rightarrow A_3, A_4, A_5, A_6, A_7, A_8, A_9$	10,683.22
8	$A_8 \rightarrow A_5, A_6, A_7, A_8, A_9, A_{10}$	10,746.41
9	$A_9 \rightarrow A_6, A_7, A_8, A_9, A_{10}, A_{11}$	10,788.54
10	$A_{10} \rightarrow A_9, A_{10}, A_{11}$	10,851.74
11	$A_{11} \rightarrow A_8, A_9, A_{10}, A_{11}$	10,830.67

3.6. Prediction Value Defuzzification

To predict the exchange rate of the rupiah against the Australian dollar from December 2018 to July 2019 (for 223 days) can use the formula in Equation (8). So that the prediction results (comparison with actual data) are obtained in Figure 2.

The prediction results of Figure 2 can be presented in graphical form by comparing it with the actual data. The following is a comparison graph between actual data and the predicted value of the rupiah exchange rate against the Australian dollar for 223 days.

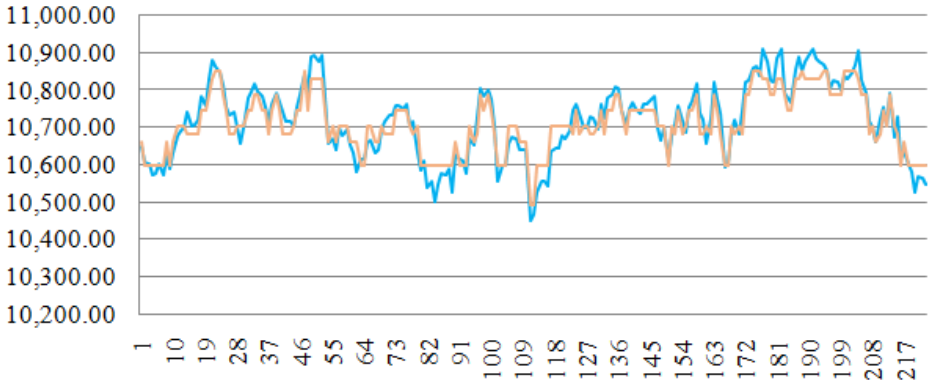

Figure 2. Comparison of actual data (blue line) and prediction (red line) of rupiah exchange value against the Australian dollar.

Based on the graph above, it can be seen that the prediction of the exchange rate of the rupiah against the Australian dollar from December 2018 to July 2019 (for 233 days) followed the same pattern as the actual data on the exchange rate of the rupiah against the Australian dollar in January to December 2018. This means that the predicted exchange rates are still at fairly close intervals. The prediction results ranged from 10,450 IDR to 10,920 IDR.

3.7. Measurement of the Accuracy of Prediction Results

Based on Equation (9), the error value or error rate in the prediction of the rupiah exchange rate against the Australian dollar is obtained as in Table 5 in the attachment.

By using the formulas in Equation (10) and Equation (11), the results of the measurement of the accuracy of the predicted value are obtained rupiah exchange rates against Australian dollars from December 2018 to July 2019 (for 223 days), are as follows.

Table 5. The measurement value of the accuracy of the prediction results.

Data	Total	RMSE	MAE
January – November 2018	223	34.80	28.47
May – November 2018	140	40.66	29.59
August – November 2018	84	34.95	28.35

Based on Table 5, it can be concluded that the best (most feasible) data used to predict the value of the rupiah exchange rate against the Australian dollar in December 2018 to July 2019 for 233 days is data from January – November 2018 or August – November 2018, because both data it has the smallest root mean of square error (RMSE) and mean absolute error (MAE) values compared to data in May – November 2018.

4. CONCLUSION

From the results of the discussion regarding value prediction of the rupiah exchange rate against the Australian dollar from December 2018 to July 2019 (for 223 days), several conclusions can be drawn, namely as follows. Prediction results are obtained score rupiah exchange rate against Australian dollars in December 2018 – June 2019 (223 days), namely 10,696.81 IDR (December), 10,736.22 IDR (January), 10,657.64 IDR (February), 10,658.07 IDR (March), 10,725.35 IDR (April), 10,740.21 IDR (May), 10,796.82 IDR (June), and 10,644.60 IDR (July). Based on the test results of measuring the accuracy of the error rate (error), the best data used to predict the rupiah exchange rate against the Australian dollar from December 2018 to July 2019 is data from January – November 2018 (223 data) with an RMSE value of 34.80 and MAE of 28.47. or data from August – November 2018 (84 data) with an RMSE value of 34.95 and an MAE of 28.35.

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