Analysis and Design of Web Application Program for Predicting Jakarta Composite Index (JCI) Using Fuzzy Time Series Markov Chain Model

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ABSTRACT. By using Fuzzy Time Series Markov Chain Model in analitical process, a predictive representation of a time series data can be obtained. In this paper, predictive analysis of closing price of Jakarta Composite Index (JCI) will be applied using a method named Fuzzy Time Series Markov Chain Model. This method embraces 3 main concepts: Fuzzy concept, Time Series concept, and Markov Chain concept. Fuzzy concept is used to classify variables. Time Series concept is used to observe the JCI closing price within a certain period of time. Whereas Markov Chain concept is used in predicting process which exerts the transition probability matrix. To support the predicting analysis process, a web based application has been designed to analyze a time series data set of JCI closing price, then to predict the future price of JCI closing price so that these processes can be done easily, fast, more efficient and conscientiously. The result of this research is a next working day JCI closing prediction price using Fuzzy Time Series Markov Chain Model. The prediction price obtained is quite accurate and helps user, especially investor, in taking decision related to their economic activity.

Keywords: Fuzzy time series model, Markov chain, fuzzy logic, JCI, web
1. INTRODUCTION

Nowadays, shares are traded frequently and successfully attracted both foreign and local investors to invest their money. So that stock trading is one of the main wheels of economy. Activity of buying and selling shares on the stock market are influenced by various factors, one of them is the stock price.

Jakarta Composite Index (JCI) is a key indicator that describes the movement of stock prices in the stock market. JCI is a set of information about the historical stock price movement, up to a certain date and reflects a value that serves as a performance measurement of the joint-stock on the stock exchange (Sunaryoah, 2003). JCI can be used to assess the market situation in general or gauge whether stock prices rise or decline. JCI involves all shares listed on the stock.

Stock investors absolutely would like to get maximum benefit and minimal loss from the activity of buying and selling stocks that he did. This will be more easily achieved if the investors can anticipate the position of the stock price is currently underway and will be, for example by looking up the value and movement of JCI rate. JCI rate movements can be predicted and analyzed, one with the fuzzy time series approach, because the movement of the JCI has progressive movement over time. Beside using the fuzzy time series approach, predicting a value can also be done using Markov models approach. Thus the analysis of fluctuations in the stock index prediction from time to time is expected can be done more accurately using the combination of fuzzy time series method and the Markov model, resulting a method of Fuzzy Time Series Markov Chain Model.

Fuzzy Time Series Markov Chain Model was first proposed by Ruey-Chyn Tsa. In this study, the prediction accuracy of the analysis currency exchange with Taiwan Dollar was elaborated using Fuzzy Time Series Markov Chain Model. Ruey-Chyn Tsa. indicated that Fuzzy Time Series Markov Chain model gives a fairly good accuracy in forecasting calculations.

Prediction using Fuzzy Markov model was also used in analyzing the data export and foreign trade by Hsien-Lun Wong and Chi-Chen Wang (2011). The study stated that both Markov models used in the prediction and Fuzzy Markov model have a better accuracy at long forecasting period.

Based on statements above, this journal is structured to analyze the accuracy of the prediction method using Fuzzy Time Series Markov Chain Model on an object that has not been used before, which is the movement of the JCI. To facilitate the analysis process of JCI prediction using method Fuzzy Time Series Markov Chain Model in accordance described previously, a web-based application has been designed. This application facilitates the calculation and ultimately will issue the predicted results of which can be read by the user, so that the analysis can be done more efficiently, easily, and accurately.

2. METHODS

Fuzzy Time Series Markov Chain model used in the predicting calculation of the JCI value includes the steps described as follows:

Step 1. Define the universe of discourse \( U \) for the historical data. When defining the universe of discourse, the minimum data and the maximum data of given historical data are obtained as \( D_{\text{min}} \) and \( D_{\text{max}} \), respectively. On the basis of \( D_{\text{min}} \) and \( D_{\text{max}} \), we can define the universal discourse \( U \) as \( [D_{\text{min}} - D_1, D_{\text{max}} + D_2] \) where \( D_1 \) and \( D_2 \) are proper positive numbers.

Step 2. Partition universal discourse \( U \) into several equal intervals. Let the universal discourse \( U \) be partitioned into \( n \) equal intervals; the difference between two successive intervals can be defined as \( l \) as follows:

\[
l = \frac{D_{\text{max}} - D_{\text{min}}}{n}
\]

Each interval is obtained as:

\[
u_i = [D_{\text{min}} - D_i, D_{\text{min}} - D_{i+1}]
\]

\[
u_1 = [D_{\text{min}} - D_1, D_{\text{min}} - D_2 + l]
\]

\[
u_2 = [D_{\text{min}} - D_2 + l, D_{\text{min}} - D_3 + 2l], \ldots
\]

\[
u_n = [D_{\text{min}} - D_n + (n-1)l, D_{\text{max}} - D_1 + nl]
\]

Step 3. Define \( A_1, A_2, \ldots, A_n \) into a fuzzy sets of linguistic variables determined in accordance with the state of the universe.

Step 4. Fuzzyf the historical data. This step aims to find an equivalent fuzzy set for each input data. The used method is to define a cut set for each \( A_i (i = 1, \ldots, n) \). If the collected time series data belongs to an interval \( u_i \), then it is fuzzified to the fuzzy set \( A_i \).

Step 5. Determine fuzzy logical relationship group. If \( F_i \rightarrow A_j \) is caused by \( F_i \rightarrow A_j \), then the fuzzy logical relationship group is defined as \( A_j \rightarrow A_j \). If the fuzzy set now is \( A_j \) and \( A_j \)'s fuzzy logic relations group is unknown, e.g. \( A_j \rightarrow \neq \), \( \neq \) would then refer to the fuzzy set \( A_j \).

Step 6. Calculate the forecasted outputs. For a time series data, using the fuzzy logical relationship group, we can induce some regular information and try to find out what is the probability for the next state. Therefore,
we can establish Markov state transition matrices; \( n \) states are defined for each time step for the \( n \) fuzzy sets; thus the dimension of the transition matrix is \( n \times n \). If state \( A_i \) makes a transition into state \( A_j \) and passes another state \( A_k \), \( i, j, k = 1, 2, \ldots, n \), then we can obtain the fuzzy logical relationship group. The transition probability of state [17] is written as

\[
P_{ij} = (M_0)_{ij}M_j, \quad i, j = 1, 2, \ldots, n
\]

where \( P_{ij} \) is the probability of transition from state \( A_i \) to \( A_j \) by one step, \( M_j \) is the transition times from state \( A_i \) to \( A_j \) by one step, and \( M_i \) is the amount of data belonging to the \( A_i \) state. Then, the transition probability matrix \( R \) of the state can be written as

\[
R = \begin{bmatrix}
P_{11} & P_{12} & \cdots & P_{1n} \\
P_{21} & P_{22} & \cdots & P_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
P_{n1} & P_{n2} & \cdots & P_{nn}
\end{bmatrix}
\]

For the matrix \( R \), some definitions are described as follows:

- If \( P_{ii} > 0 \), then state \( A_i \) is accessible from state \( A_i \).
- If states \( A_i \) and \( A_j \) are accessible to each other, then \( A_i \) communicates with \( A_j \).

The transition probability matrix \( R \) reflects the transition rules of the system. For example, if the original data is located in the state \( A_1 \), and makes a transition into state \( A_j \) with probability \( P_{ij} \geq 0, j = 1, 2, \ldots, n \), then \( P_{ij} + P_{i2} + \cdots + P_{in} = 1 \).

**Step 7.** Determine predicted results using the transition probability matrix \( R \). If \( F(t) = A_x \), the process is defined to be in state \( A_i \) at time \( t - 1 \); then forecasting of \( F(t) \) is conducted using the row vector \( \{P_{ij}, P_{i2}, \ldots, P_{in} \} \). The forecasting of \( F(t) \) is equal to the weighted average of \( m_1, m_2, \ldots, m_n \), the expected forecasting values are obtained by the following Rules:

**Rule 1.** If the fuzzy logical relationship group of \( A_i \) is one-to-one (i.e., \( A_i \rightarrow A_k \)), with \( P_{ik} = 1 \) and \( P_{ij} = 0, j \neq k \), then the forecasting of \( F(t) \) is \( m_k \), the midpoint of \( u_i \), according to the equation \( F(t) = m_kP_{ik} = m_k \).

**Rule 2.** If the fuzzy logical relationship group of \( A_i \) is one-to-many (i.e., \( A_j \rightarrow A_1, A_2, \ldots, A_n, j = 1, 2, \ldots, n \)), when collected data \( Y(t - 1) \) at time \( t - 1 \) is in the state \( A_i \), then the forecasting of \( F(t) \) is equal as \( F(t) = m_1P_{i1} + m_2P_{i2} + \cdots + m_nP_{in} + Y(t - 1)P_{i0} + m_1P_{i1} + m_2P_{i2} + \cdots + m_nP_{in} \), where \( m_1, m_2, \ldots, m_n \) are the midpoint of \( u_1, u_2, \ldots, u_i, u_{i+1}, \ldots, u_n \).

- **Step 8.** Adjust the tendency of the forecasting values. For any time series experiment, a large sample size is always necessary. Therefore, under a smaller sample size when modeling a fuzzy time series-

Markov chain model, the derived Markov chain matrix is usually biased, and some adjustments for the forecasting values are suggested to revise the forecasting error. First, in a fuzzy logical relationship group where \( A_i \) communicates with \( A_j \), and is one-to-many, if a larger state \( A_i \) is accessible from state \( A_j \), \( i, j = 1, 2, \ldots, n \), then the forecasting value for \( A_i \) is usually underestimated because the lower state values are used for forecasting the value of \( A_i \). On the other hand, an overestimated value should be adjusted for the forecasting value \( A_i \) because a smaller state \( A_i \) is accessible from \( A_j \), \( i, j = 1, 2, \ldots, n \). Second, any transition that jumps more than one step from one state to another state will derive a change-point forecasting value, so that it is necessary to make an adjustment to the forecasting value in order to obtain a smoother value. That is, if the data happens in the state \( A_i \), and then jumps forward to state \( A_{j+k} \) (\( k \geq 1 \)) or jumps backward to state \( A_{k+i} \) (\( k \geq 1 \)), then it is necessary to adjust the trend of the pre-obtained forecasting value in order to reduce the estimated error. The adjusting rule for the forecasting value is described below.

**Rule 1.** If state \( A_i \) communicates with \( A_j \), starting in state \( A_i \) at time \( t - 1 \) as \( F(t - 1) = A_i \), and makes an increasing transition into state \( A_j \) at time \( t \), \( i > j \), then the adjusting trend value \( D(t) \) is defined as \( D(t) = (l/2) \).

**Rule 2.** If state \( A_i \) communicates with \( A_j \), starting in state \( A_i \) at time \( t - 1 \) as \( F(t - 1) = A_i \), and makes a decreasing transition into state \( A_j \) at time \( t \), \( i < j \), then the adjusting trend value \( D(t) \) is defined as \( D(t) = -l/2) \).

**Rule 3.** If the current state is in state \( A_i \) at time \( t - 1 \) as \( F(t - 1) = A_i \), and makes a jump-forward transition into state \( A_j \) at time \( t \), \( 1 \leq s \leq n - i \), then the adjusting trend value \( D(t) \) is defined as \( D(t) = (l/2) \), \( 1 \leq s \leq n - i \), where \( l \) is the length that the universal discourse \( U \) must be partitioned into as equal intervals.

**Rule 4.** If the process is defined to be in state \( A_i \) at time \( t - 1 \) as \( F(t - 1) = A_i \), then makes a jump-backward transition into state \( A_i \) at time \( t \), \( 1 \leq s < i \), the adjusting trend value \( D(t) \) is defined as \( D(t) = -(l/2) \), \( 1 \leq s < i \).

**Step 9.** Obtain adjusted forecasting result. If the fuzzy logical relationship group of \( A_i \) is one-to-many, and state \( A_{i+k} \) is accessible from state \( A_i \), then the state \( A_i \) communicates with \( A_j \), then the adjusting forecasting result \( F(t) \) can be obtained as \( F(t) = F(t) + D(t) + D(t) = (l/2)+(l/2) \). If the fuzzy logical relationship group of \( A_i \) is one-to-many, and state \( A_{i+k} \) is accessible from state \( A_i \), but state \( A_i \) does not communicate with \( A_j \), then the adjusting forecasting result \( F(t) \) can be obtained as \( F(t) = F(t) + D(t) = F(t) + (l/2). \) If the fuzzy logical relationship group of \( A_i \) is one-to-many, and state \( A_{j+i} \) is accessible from state \( A_i \), but state \( A_i \) does not communicate with \( A_j \), then adjusted forecasting result \( F(t) \) can be obtained as \( F(t) = F(t) + D(t) = F(t) + (l/2). \)
result \( F'(t) \) can be obtained as \( F'(t) = F(t) - D_2 = F(t) - (l/2) \times 2 = F(t) - l \).

When \( \nu \) is the jump step, the general form for forecasting result \( F'(t) \) can be obtained as

\[
F'(t) = F(t) \pm D_1 \pm D_2 = F(t) \pm (l/2) \pm (l/2)\nu.
\]

Finally, the MAPE is used to measure the accuracy as a percentage as follows.

\[
\text{MAPE} = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{P_i - F_i}{P_i} \right| \times 100\%.
\]

### 3. DISCUSSION

The application simulation will be done using historical data values JCI closing date of December 2, 2013 - June 3, 2014 (120 data) obtained from Yahoo! Finance website (http://finance.yahoo.com/q/hp?s=% SEJKSE + Historical + Prices). To simplify the writing of simulation prediction calculation process, here is taken 12 data sample in Table 1 below:

<table>
<thead>
<tr>
<th>Date</th>
<th>JCI Closing Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/2/2013</td>
<td>4321.98</td>
</tr>
<tr>
<td>12/3/2013</td>
<td>4288.76</td>
</tr>
<tr>
<td>12/4/2013</td>
<td>4241.3</td>
</tr>
<tr>
<td>12/5/2013</td>
<td>4216.89</td>
</tr>
<tr>
<td>12/6/2013</td>
<td>4180.79</td>
</tr>
<tr>
<td>12/9/2013</td>
<td>4214.34</td>
</tr>
<tr>
<td>12/10/2013</td>
<td>4275.68</td>
</tr>
<tr>
<td>12/11/2013</td>
<td>4271.74</td>
</tr>
<tr>
<td>12/12/2013</td>
<td>4212.22</td>
</tr>
<tr>
<td>12/13/2013</td>
<td>4174.83</td>
</tr>
<tr>
<td>12/16/2013</td>
<td>4125.96</td>
</tr>
<tr>
<td>12/17/2013</td>
<td>4182.35</td>
</tr>
</tbody>
</table>

Thus, for the 12 data sample used, using JCI Forecast application and data interval range \( l = 100 \), prediction results are obtained as follows:

<table>
<thead>
<tr>
<th>Date</th>
<th>JCI Actual Price</th>
<th>JCI Forecasted Price</th>
<th>Error</th>
<th>PE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/2/2013</td>
<td>4321.98</td>
<td>0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>12/3/2013</td>
<td>4288.76</td>
<td>4249.5</td>
<td>39.26</td>
<td>0.91542</td>
</tr>
<tr>
<td>12/4/2013</td>
<td>4241.3</td>
<td>4248.97</td>
<td>7.67</td>
<td>0.18084</td>
</tr>
<tr>
<td>12/5/2013</td>
<td>4216.89</td>
<td>4215.07</td>
<td>1.82</td>
<td>0.04316</td>
</tr>
<tr>
<td>12/6/2013</td>
<td>4180.79</td>
<td>4097.64</td>
<td>83.15</td>
<td>1.98886</td>
</tr>
<tr>
<td>12/9/2013</td>
<td>4214.34</td>
<td>4297.97</td>
<td>83.63</td>
<td>1.98442</td>
</tr>
<tr>
<td>12/10/2013</td>
<td>4275.68</td>
<td>4195.81</td>
<td>79.87</td>
<td>1.86801</td>
</tr>
<tr>
<td>12/11/2013</td>
<td>4271.74</td>
<td>4239.63</td>
<td>32.11</td>
<td>0.75168</td>
</tr>
<tr>
<td>12/12/2013</td>
<td>4212.22</td>
<td>4236.81</td>
<td>24.59</td>
<td>0.58378</td>
</tr>
<tr>
<td>12/13/2013</td>
<td>4174.83</td>
<td>4094.3</td>
<td>80.53</td>
<td>1.92894</td>
</tr>
<tr>
<td>12/16/2013</td>
<td>4125.96</td>
<td>4193.5</td>
<td>67.54</td>
<td>1.63695</td>
</tr>
<tr>
<td>12/17/2013</td>
<td>4182.35</td>
<td>4156.85</td>
<td>25.5</td>
<td>0.60971</td>
</tr>
</tbody>
</table>

Next Day - 4199.14 - -

MAD 47.78818

MAPE (%) 1.13561

Whereas with interval data range \( l = 10 \) for the same sample data using the application program, MAPE and MAD obtained are 0.24403% of 10.34091 consecutively, which means the deviation on Fuzzy Time Series Markov Chain Model occurs at 0.24403% of the actual data.

Here’s a visualization comparison chart of the actual value and the forecasted value using FTSMCM for 12 samples of closing JCI value data used (03/12/2013 until 17/12/2013) and data interval range \( l = 100 \):

![Figure 1 Comparison Chart of JCI Actual Value and Forecasted Value](image-url)
The next simulation is to compare the results of Fuzzy Time Series Markov Chain Model (FTSMCM) with the conventional Fuzzy Time Series methods introduced by Song & Chissom (S&C), where forecasting using JCI Forecast application program. With the help of an application program and using historical data from Dec 2, 2013- June 3 2014 and data interval range f = 10, the result of predictive accuracy for the next 7 days can be seen in Table 3 as follows:

<table>
<thead>
<tr>
<th>Date</th>
<th>JCI Actual Price</th>
<th>JCI Forecasted Price</th>
<th>JCI Error</th>
<th>JCI PE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/4/2014</td>
<td>4932.56</td>
<td>4944.5</td>
<td>11.94</td>
<td>0.24290</td>
</tr>
<tr>
<td>6/5/2014</td>
<td>4935.56</td>
<td>4944.5</td>
<td>11.94</td>
<td>0.24290</td>
</tr>
<tr>
<td>6/6/2014</td>
<td>4937.18</td>
<td>4934.5</td>
<td>1.06</td>
<td>0.02148</td>
</tr>
<tr>
<td>6/7/2014</td>
<td>4985.08</td>
<td>4937.18</td>
<td>0.32</td>
<td>0.02148</td>
</tr>
<tr>
<td>6/10/2014</td>
<td>4946.09</td>
<td>4984.5</td>
<td>61.59</td>
<td>1.00651</td>
</tr>
<tr>
<td>6/11/2014</td>
<td>4971.95</td>
<td>4993.95</td>
<td>51.35</td>
<td>0.63657</td>
</tr>
<tr>
<td>6/12/2014</td>
<td>4934.41</td>
<td>4968.23</td>
<td>33.82</td>
<td>0.68539</td>
</tr>
</tbody>
</table>

From the analysis and evaluation of simulation that has been done, it can be said that Fuzzy Time Series Markov Chain model has the advantages as follows:

a. Fuzzy Time Series Markov Chain model is not difficult to be explained.

b. Fuzzy Time Series Markov Chain Model calculate the predicted values using matrix (which represents the pattern of movement of the object to be predicted) and the value of the previous period, thus resulting a more accurate forecasted value.

c. This method does not require a lot of historical data to make predictions. Nevertheless, it is advisable to use more historical data to get a more accurate prediction value. Since the more historical data provided, the more representative the movement pattern of the predicted object.

While the weakness of this method is that it is only able to predict the value for 1 day ahead.

4. CONCLUSIONS

Based on the analysis and discussion we have come up to conclusions as follows:

1. The Fuzzy Time Series Markov Chain Model method can generate predictive value of JCI price, especially JCI closing price, to 1 day ahead optimally.

2. Accuracy of Fuzzy Time Series Markov Chain model is quite good and has better accuracy compared with Fuzzy Time Series method which was introduced by Song and Chissom.

3. Accuracy of Fuzzy Time Series Markov Chain Model is directly proportional to the data interval range. Smaller data interval range will minimize the deviations of the generated forecasted value.

4. Forecast JCI application allows users to obtain the forecasted value of the closing JCI and can be used as one of the instruments that assists in decision making in the field of stock.

Some suggestions may be submitted for further study are as follows:

1. For further research, it is suggested that researchers can enhance the existing formula in order to generate forecasting values for more than 1 day.

2. For further research, researchers are expected to develop a the existing formula in order to maximize the forecasting accuracy from the minimum historical data.

3. For further application development, it is expected that the application can be used to perform forecasting calculations using actual historical databases of JCI price that can be obtained in a real time mode.

REFERENCES


