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Hybrid Fuzzy Time Series for Two Factors High-order based on Intervals Ratio

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ABSTRACT

Fuzzy time series (FTS) firstly introduced by Song and Chissom has been developed to forecast in many field such as enrollment data, stock index, air pollution, etc. In forecasting FTS data several authors define universe of discourse using coefficient values with any integer or real number as a substitute. In this study proposed another way to get coefficient values using intervals ratio algorithm. Coefficient values analyzed and compared in unequal partition intervals and equal partition intervals with base and triangular fuzzy membership functions. nother way to get coefficient values applied in two factors high-order. The study implemented in the Shen-hu stock index data and rubber production Indonesia data. The models evaluated by average forecasting error rate (AFER) and compared with existing methods. AFER value 0.28% for Shen-hu stock index daily data and 1.87% for rubber production Indonesia yearly data.

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A. INTRODUCTION

Forecasting plays an important role in making decisions in many fields such as enrolment data, stock indexes, air pollution, agriculture, economics, climatology, etc. Fuzzy time series (FTS) forecasting is a sequence of consecutive values in a particular domain to predict the future with a precise forecast to prevent losses with uncertainty, imprecision, and ambiguity that emergent research area using linguistic values (Qiang & Brad S., 1993), (Bose & Mali, 2019). Song and Chissom was laid the fuzzy time series forecasting requires complex calculations (Qiang & Brad S., 1993). Chen (S.-M. Chen, 1996) simplified using arithmetic operations in first order for enrolment data of Alabama University. There is one process in FTS forecasting regarding selection of interval very urgent because it effects in forecast results then there are many approaches proposed. One of the frequently used is random

approach called manual approach to choose the interval (S.-M. Chen, 1996; S. M. Chen, 2002; S. M. Chen & Chen, 2011; Gautam et al., 2018; Jilani et al., 2007; Lee et al., 2006; F. Li et al., 2021; F. Li & Yu, 2018; Mashuri et al., 2018; Qiang & Brad S., 1993). Huarng (Huarng, 2001a) investigated for FTS forecasting in one order that the length of the intervals at the fuzzification phase affects the performance.

In Chen's paper (S. M. Chen, 2002) improved accuracy in to be high-order to reduce ambiguity for enrolment data of Alabama University. The prediction can be cause by other factors, Lee (Lee et al., 2006) increase accuracy consider more effect with construct two factors in high-order. Li (F. Li et al., 2021; F. Li & Yu, 2018, 2020) construct new fuzzy logical relationship (FLR) with cross association to increase accuracy. Gautam (Gautam et al., 2018) approach one factor high-order took grades of membership using triangular fuzzy sets.

Huarng (Huarng & Yu, 2006) proposed different method in the length of intervals with named ratio-based lengths of intervals (intervals ratio algorithm) that applied in one factor first-order in grades of membership 1, 0.5, 0 more accurate forecast for enrolment, TAIEX stock price, and inventory demand data. Actually, FTS forecasting models can calculate in first-order (Bai et al., 2011; Bisht & Kumar, 2016; Bisognin & Lopes, 2009; S. M. Chen & Tanuwijaya, 2011; Cheng et al., 2006, 2008; Chu et al., 2009; Huarng, 2001b; Izakian et al., 2015; Kuo et al., 2009; S. T. Li & Cheng, 2007; Lu et al., 2015; Mirzaei Talarposhti et al., 2016; Peng et al., 2015; P. Singh & Borah, 2013a; Teoh et al., 2008; L. Wang et al., 2013; H. K. Yu, 2005; T. H. K. Yu & Huarng, 2010) and high-order (Bai et al., 2011; M. Y. Chen, 2014; S. M. Chen & Jian, 2017; S. M. Chen & Tanuwijaya, 2011; Deng et al., 2016; Egrioglu, Aladag, Yolcu, Basaran, et al., 2009; Egrioglu, Aladag, Yolcu, Uslu, et al., 2009; Gangwar & Kumar, 2012; Hsu et al., 2010; Jilani & Burney, 2008a, 2008b; Kuo et al., 2010; Lee et al., 2008; Leu et al., 2009; Park et al., 2010; P. Singh & Borah, 2013a, 2013b, 2014; S. R. Singh, 2009; Sun et al., 2015; N. Y. Wang & Chen, 2009; W. Wang et al., 2015; Ye et al., 2016). Intervals ratio algorithm few studies in cases of more than one factor and high-order. Based on that literature, in this study review our proposed methods by comparing the performance of the selecting coefficient values using intervals ratio algorithm in two factors high-order then compare the performance with the selections manually of coefficient values. In addition, it examines in fuzzification stage the uses of took grades of membership 1, 0.5, 0 and triangular fuzzy sets. The performance of triangular fuzzy sets is good in high-order (Gautam et al., 2018). This study performed in the Shen-hu stock index data and rubber production Indonesia data. The accuracy compared using average forecasting error rate (AFER).

B. METHODS

In this section discuss intervals ratio algorithm (Huarng & Yu, 2006) and some basic definitions of fuzzy time series (S.-M. Chen, 1996), base fuzzy set (S.-M. Chen, 1996), triangular fuzzy number (Gani & Assarudeen, 2012), and two factors high-order fuzzy logic relationship (FLR) (Lee et al., 2006).

Intervals ratio algorithm as follows:

1. Calculate $r_t = |x_t - x_{t-1}|/x_{t-1}$ for all t.
2. Mapping MIN$(r_1, \dots, r_{n-1})$ and plot the cumulative distribution.
3. Determine a ratio sample percentile percentile α is set as the 50th percentile.
4. Determine the interval as follows:
   i. Truncate the smallest amount of observation to the two left most numbers and represent it as $truncate(MIN(x_t)$, for all $x_t) = c.d \times 10^z$ where c and d be any number from 0 to 9 and z can be integer number or 0.
   ii. Subtract d by 1 as $d' = d - 1$.

iii. Set the initial value as $initial = c.d' \times 10^z$.

iv. The intervals increase by the ratio as $upper_0 = initial$, for $j \geq 1$, $lower_j = upper_{j-1}$ and $upper_j = (1 + ratio)^j \times upper_0$ so get intervals $interval_j = [lower_j, upper_j]$.

v. From (iv) this paper gets coefficient values D_1 and D_2 then build universe of discourse.

vi. From (iv) this paper gets partitions automatically.

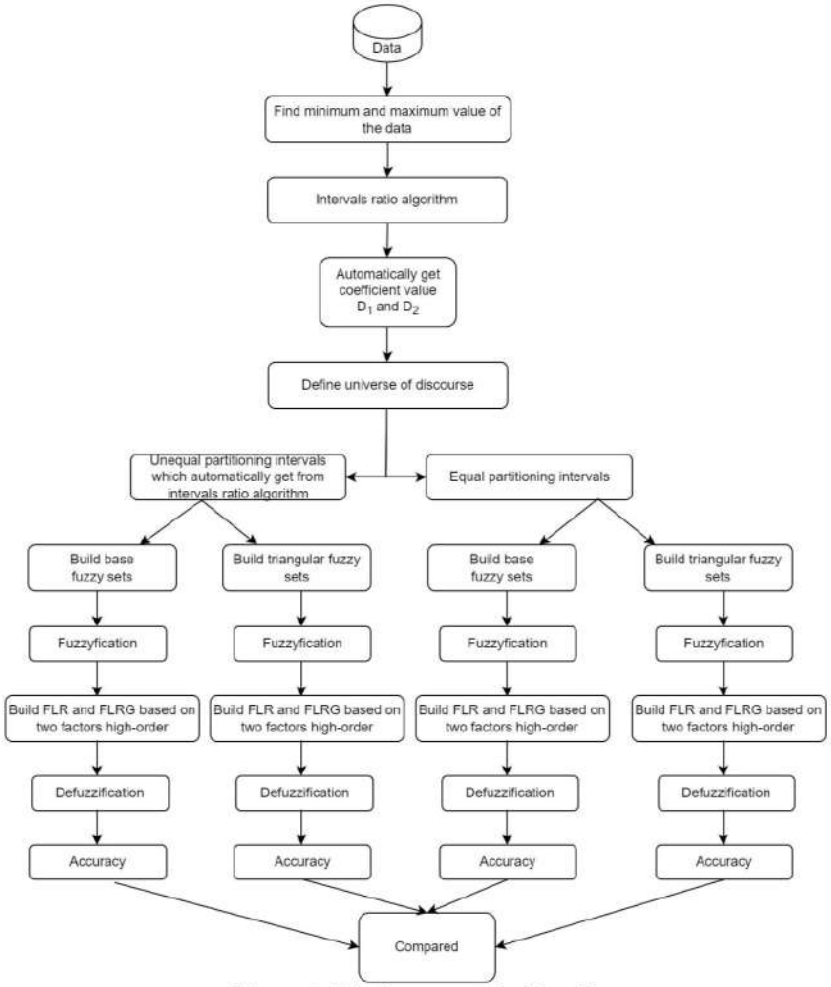

Figure 1. The framework of study

Model tested using AFER obtained from (F. Li & Yu, 2018) to know the error value. The formula of AFER as follow:

$$AFER = \frac{\Sigma_{\theta=1}^{n} \left| \frac{F_j - A_j}{A_j} \right|}{n} \times 100\% \qquad (1)$$

where n is amount of data, A_j is actual data result and F_j is forecasting result.

In this study proposed another way to get coefficient value using intervals ratio algorithm (Huarng & Yu, 2006) with ratio sample percentile α is set as the 50th percentile.

Another way applied in four cases based on two factors high-order. From intervals ratio algorithm this paper get coefficient values D_1 and D_2 to applied in first case is unequal partitioning base on intervals ratio with base fuzzy sets, second case is unequal partitioning base on intervals ratio with triangular fuzzy, third case is equal partitioning using coefficient values D_1 and D_2 from intervals ratio algorithm with base fuzzy sets, fourth case is equal partitioning using coefficient values D_1 and D_2 from intervals ratio algorithm with triangular fuzzy sets. The demonstrated of four cases in the Shen-hu stock index daily data in March-September 2021 and rubber production Indonesia yearly data in 2000-2020. Generally, the framework of this research can be shown in Figure 1.

C. RESULT AND DISCUSSION

In this section explained the results of research the Shen-hu stock index data (Finance, 2021) and rubber production Indonesia data (Statistika, 2021). Firstly, discussed of this research using the Shen-hu stock index daily data with two factors. The main factor is the opening prices and the second factor is highest prices. They are from March 11, 2021 to September 05, 2021. The data is consisting of 179 data, can be seen in the Figure 2. The simulation is using Microsoft excel. From data shown for main factor that minimum value is D_{min} = 4641.813 and maximum value is D_{max} = 5348.340 meanwhile for second factor minimum value is E_{min} = 4660.519 and maximum value is E_{max} = 5360.280.

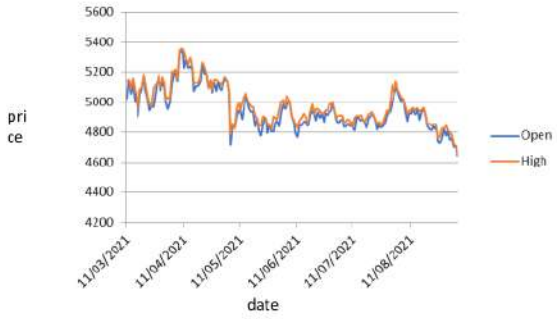

Figure 2. The Shen-hu stock index daily data

Table 1. Increasing interval using intervals ratio algorithm of main factor

Index	Interval
u_1	[4500, 4534.92]
u_2	[4534.92, 4570.101]
u_3	[4570.101, 4605.560]
⋮	⋮
u_{23}	[5334.069, 5375.455]

After known the minimum value of the data, next step is defining the ratio using intervals ratio algorithm then this paper get ratio for main factor is 0,776 and second factor is 0,505.

For main factor using formula in intervals ratio algorithm this paper has intervals shown in Table 1 and for second factor shown in Table 2.

Table 2. Increasing interval using intervals ratio algorithm of second factor

Index	Interval
v_1	[4500, 4522.709]
v_2	[4522.709, 4545.533]
v_3	[4545.533, 4568.472]
⋮	⋮
v_{35}	[5340.010, 5366.958]

From Table 1 this paper can automatically get coefficient value and build universe of discourse for main factor is U = [4500, 5375.455] which is coefficient value D_1 = 141.813, D_2 = 27.115 and for second factor is V = [4500, 5366.958] which is coefficient value E_1 = 160.519, E_2 = 18.618. After that fuzzification take maximum grade of membership. Next build FLR and FLRG based on Definition 2.4. Then defuzzification using formula in Lee's method. Analog for rubber production Indonesia data. Then compared using AFER shown in Table 3 and Table 4.

Table 3. Comparison of four cases in Shen-hu stock index data

Evaluated criteria	Lee's method	Case 1	Case 2	Case 3	Case 4
AFER	0.95%	0.28%	0.39%	0.46%	0.99%

When this paper gets coefficient value automatically, then this paper calculate in
Case 1: automatically get unequal partition interval of universe of discourse with base fuzzy sets,
Case 2: automatically get unequal partition interval of universe of discourse with triangular fuzzy sets,
Case 3: partition universe of discourse into several intervals in equal length with base fuzzy sets,
Case 4: partition universe of discourse into several intervals in equal length with triangular fuzzy sets.

Table 4. Comparison of four cases in rubber production Indonesia data

Evaluated criteria	Lee's method	Case 1	Case 2	Case 3	Case 4
AFER	2.09%	1.87%	4.63%	2.06%	5.65%

When this paper gets coefficient value automatically, then this paper calculates in
Case 1: automatically get unequal partition interval of universe of discourse with base fuzzy sets,
Case 2: automatically get unequal partition interval of universe of discourse with triangular fuzzy sets,
Case 3: partition universe of discourse into several intervals in equal length with base fuzzy sets,

Case 4: partition universe of discourse into several intervals in equal length with triangular fuzzy sets.

Based on Table 3 and Table 4 fuzzification using base fuzzy set is more accurate than triangular fuzzy sets with AFER value for Shen-hu stock index daily data and rubber production Indonesia yearly data are 0.28% and 1.87%, respectively.

D. CONCLUSION AND SUGGESTIONS

This study is modified Li's method in partition of universe of discourse and determining two arbitrary positive number using intervals ratio. Proposed method applied in third-order (h=3) with long relation h+1. Modification has smaller error than existing methods with AFER value 3.59%.

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