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A FUZZY TIME SERIES-MARKOV CHAIN MODEL TO FORECAST FISH FARMING PRODUCT

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Abstract

Price is one of the important things that need to concern as defining factor of the profit or loss of product selling as the result of price fluctuations that are very difficult to control. Price fluctuations are caused by many factors including weather, stock availability, demand and others. One of the steps to solve the price fluctuations problem is by making a forecast of fish incoming prices. The purpose of this study is to apply Markov chain's fuzzy time series to forecast farming fish prices. Markov chain fuzzy time series is one of the prediction methods to predict time series data that has advantages in the implementation of historical data, flexible, and high level of data forecasting accuracy. This study used fish prices at November 2018. The results showed that markov chain fuzzy time series showed very accurate forecasting results with a mean error percentage of absolute percentage error (MAPE) of 1.4% so the accuracy of the Markov chain fuzzy time series method is 98, 6%.

Key words: Fuzzy Time Series, Fuzzy Time Series Markov Chain, Price and Forecasting.

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INTRODUCTION

Forecasting is the process of estimating value in the future by using existing data in the past [1]. There are two types of approach that can be used in forecasting those are qualitative and quantitative approach. Qualitative approach is based on the assumption of a certain party while quantitative approach is based on time series. Time Series are sequence of events that happened on certain timesForecasting in time series is a prediction for the events in the future based on previous data [2]. There are plenty methods that can be used in time series forecasting including Naïve, Drift, Exponential Smoothing, Holt, Moving Average, Fuzzy Time Series and ARIMA [3].

Fuzzy Time Series (FTS) is a method that were introduced by Song and Chissom in 1993 which was a concept that can be used to predict problems where the actual data is formed in linguistic values. Alot of FTS methods were developed, including the FTS Chen method, FTS using percentage change, weighted FTS, Legitimate FTS and Degtiarev, FTS Cheng, FTS Markov Chain [4]. The advantages of Fuzzy Time Series Markov Chain (FST-MC) are the calculation process does not require a complex system as in genetic algorithms and neural networks, so it is certainly easier to develop, in addition this method can be solved the problem of forecasting historical data in the form of values linguistic value [5].

The fishing industry sector has an important role in supporting the food security chain, while the needs of protein in the world can be fulfilled by fisheries resources, either from captured fish or aquaculture [6]. Rather than saltwater fish, the cultivation of freshwater fish requires inexpensive costs and also it provides protein for our food supplies, affordable price, and easily digested by the body.

The number of freshwater fish farming is currently growing up along with with the need for consumption of fish. The problem is the harvest period in several areas are tend to be close or came in the similiar sort of time. This case will overflow the supply of fish in the market and give an indirect effect the fish price. Price is one of the important things that need to be considered, the price decline will give an impact on farmers income and possibly causing severe loss because the different number between the farming process costs and the outcome or the profit that they gained. Price fluctuation often affected by several factors that caused an imbalance condition between demand and supply. High price fluctuations often used by seller as an opportunity to manipulate the price information at the farmer level, causing financial loss for the farmer.

The prediction of fish price can be used as a first step to find out the price of upcoming fish. The predictions by using Fuzzy Time Series Markov Chain are developed into an appropriate tool for prediction systems that have important functions in planning and policy making [5]. In addition, Fuzzy Time Series Markov Chain has been used in research to predict the value of Taiwan currency against USD with forecasting results that have quite good accuracy [7], in addition it also has been used for forecasting the use of computer network bandwidth with the results of forecasting accuracy with the average based Fuzzy Time Series-Markov Chain (FTS-MC) model better than using average based FTS [13]. More accurate forecasting results obtained from the average based FTS-MC model, are caused by the application of probability calculations for each current state transfer to the next state on the Fuzzy Logical Relationship Group (FLRG), as well as adjusting the trend of forecasting values.

Based on this problems, a system is needed to predict the price of aquaculture fish so that farmers and business people can make decisions. In this study, the implementation of Fuzzy Time Series Markov Chain produces the price of forecasting information that can be used as input material and a strategy in the supply of fish in the next period.

MATERIAL AND METHODS

This research was conducted through a methodology presented on Figure 1. Modeling process was begun by data preparation, because Susenas data was large and complex (containing from 21 attributes).

Forecasting

Forecasting is the process of estimating value in the future by using existing data in the past [1]. The previous data is systematically combined and processed to estimate a value in the future. There are two approaches to forecasting, those are qualitative approach and quantitative approach

- Qualitative forecasting methods combine some factors such as intuition of decision making, emotion, and personal experience.
- Quantitative forecasting methods that use one or more mathematical models with previous data and causal variables to forecast demand. Basically the quantitative forecasting method is divided into two, namely time series models (time series), and causal models.

Fuzzy Time Series

According to Tsaur (2012) steps to complete the FTS model, as follow:

Step 1. Find the set of universes U, where U is historical data. When defining the universe set, the minimum data and maximum data from the given historical data are D_{min} and D_{max}. Basically from D_{min} and D_{max}, defined a set of universes U such as $[D_{min} - D_1; D_{max} + D_2]$ where D_1 and D_2 are the corresponding positive numbers.

Step 2. Divide (partition) the universe set U into several parts with the same interval (n) using the following sturges formula;

$$n = 1 + 3{,}322\ log\,N \qquad (1)$$

With N is historical data. The interval difference is defined as l as follows:

$$l = \frac{[(D_{max}+D_1)-(D_{min}-D_2)]}{n} \qquad (2)$$

Step 3. Find the fuzzy set for the entire universe U. There is no limit to find the number of linguistic variables that can be a fuzzy set. To make it simple, each fuzzy set Ai (i = 1,2, ..., n) defined in the number of n intervals, namely $_1$ = $[d_1; d_2]$, u_2 = $[d_2; d_3]$, u_3 =$[d_3; d_4]$, u_4 = $[d_4; d_5]$, … , u_n = $[d_n; d_{n+1}]$.

According to Boaisha and Amaitik (2010), all fuzzy sets can be determined where $A1$, $A2$, ..., An are defined as follows:

$$A_1 = \{1/u_1 + 0{,}5/u_2 + 0/u_3 + 0/u_4 + 0/u_5 + \cdots + 0/u_n\}$$
$$A_2 = \{0{,}5/u_1 + 1/u_2 + 0{,}5/u_3 + 0/u_4 + 0/u_5 + \cdots + 0/u_n\} \qquad (2.7)$$
$$\vdots$$
$$A_n = \{0/u_1 + 0/u_2 + 0/u_3 + 0/u_4 + 0/u_5 + \cdots + 0{,}5/u_{n-1} + 1/u_n\}$$

Step 4. Fuzzify historical data. This step is aimed to find the fuzzy set that is appropriate for each data.

Step 5. Defining FLR (Fuzzy Logical Relationship) and FLRG (Fuzzy Logical Relationship Group)

Markov Chain

Markov Chain *(Markov Chain)* was first developed by a Russian expert named AA Markov in 1906. Conceptually Markov chains can be illustrated by assuming {Xn, n = 0, 1, 2, ...} as a finite stochastic process or chance value which can be calculated. The set of chance values of this process is denoted by a positive integer set {0, 1, 2, ...} [6].

Transitional probability for these states can be written as follows:

$$P_{ij} = \frac{M_{ij}}{M_i}, i, j = 1,2,3, .. n \qquad (3)$$

with,

Pij is a transitional probability from state Ai to Aj with one step.

Mij is the transitional time from state Ai to Aj with one step.

Mi is the amount of data from the state Ai.

So the transitional probability matrix **R** can be written as follows:

$$\begin{Bmatrix} P_{11} & P_{12} & \cdots & P_{1n} \\ P_{21} & P_{22} & \cdots & P_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ P_{n1} & P_{n1} & & P_{nn} \end{Bmatrix}$$

Fuzzy Time Series Markov Chain

According to Tsaur (2012) the forecasting steps from Step 1 to Step 5 on the Fuzzy Time Series-Markov Chain (FTS-MC) model are the same as the classic FTS model. While the difference between the FTS-MC model and the classic FTS is in Step 6 to Step 8 below.

Step 6. Calculating the results of the initial forecasting. For time series data, Fuzzy Logical Relationship Group (FLRG) is applied, which the information can be used to obtain the next state probability. So that the Markov transition matrix is obtained; state n is defined for each time step the fuzzy set n so that the dimensions of the matrix transition are $n \times n$

From the probability matrix that obtained in the previous stage, the initial forecasting value can be calculated by the following rules:

Rule 1. If FLRG of Ai is zero ($Ai \rightarrow \emptyset$) then the forecasting result F (t) is mi, which is the mid value of ui with the equation:

$$(t) = m_i \qquad (4)$$

Rule 2. If FLRG Ai is one to one ($Ai \rightarrow Ak$ with Pij = 0 and Pik = 1, $j \neq k$), the forecasting result F (t) is mk which is the middle value of uk with the equation:

$$(t) = m_k P_{ik} = m_k \qquad (5)$$

Rule 3. If FLRG Aj is one to many ($Aj \rightarrow A1, A2, ..., An, j = 1,2, ...$), if the data set is Y $(t$ - 1) when $t - 1$ is in *state* A_j , then the forecasting results are as follows:

$$F(t) = m_1 P_{j1} + m_2 P_{j2} + \cdots + m_{j-1} P_{j(j-1)} + Y(t-1) P_j + m_{j+1} P_{j(j+1)} + \cdots + m_n P_{jn} \qquad (6)$$

with $m_1, m_2, \ldots, m_{j-1}, m_{j+1}, \ldots, m_n$ is the mid point of $u_1, u_2, \ldots, u_{j-1}, u_{j+1}, \ldots, u_n$ and mj substituted to Y $(t$ - 1) to obtain information from the state Aj when t - 1.

Step 7. Complete the forecasting value trend. For *time series* experiments, large samples are always needed. Therefore, the small sample size when modeling the FTS-MC model is obtained by the *Markov Chain* matrix which is always biased, and some adjustments to predict values are recommended to review forecasting errors. Adjustment rules for forecasting values are explained as follows:

Rule 1. If state Ai communicates with Ai, starting from *state* Ai at t - 1 as (t - 1) = Ai and the transition moves up to *state* Aj at t, (i <j), then the adjustment value Dt is determined as:

$$D_{t1} = \left(\frac{l}{2}\right) \qquad (7)$$

Rule 2. If state Ai communicates with Ai, starting from *state* Ai at t - 1 as (t - 1) = Ai and the transition moves down to *state* A at t, (i> j), then the adjustment value Dt is determined as:

$$D_{t1} = -\left(\frac{l}{2}\right) \qquad (8)$$

Rule 3. If *state* A_i at t - 1 as (t - 1) = A_i and the forward transition to *state* A_i + s at t, 1 ≤ s ≤ n - i, then the adjustment value of Dt is determined as:

$$D_{t1} = \left(\frac{l}{2}\right)s, \qquad i \le s \le n-1 \quad (9)$$

With s is dominant forward transition.

Rule 4. If *state* Ai at t– 1 as (t– 1) = Ai and backward transition occurs to *state* $Ai - v$ when t, 1 ≤ v ≤ i, then the adjustment value of Dt is determined as:

$$D_{t1} = -\left(\frac{l}{2}\right)s, \qquad 1 \le v \le i \quad (10)$$

with v is the number of reverse transition moves.

Step 8. Determine the final forecasting results. If FLRG from Ai is one to many, and state Ai + 1 can be obtained from state Ai where state Ai communicates with Ai, then adjustment of forecasting results $F'(t)$ can be obtained $F'(t) = F(t) + D_{t1} + D_{t2} = F(t) + \frac{l}{2} + \frac{l}{2}$ If Ai FLRG is one to many, and state Ai + 1 can be obtained from state Ai but state Ai does not communicate with Ai, then adjusting forecasting results $F'(t)$ can be obtained $F'(t) = F(t) + \frac{l}{2}$ If FLRG of Ai is one to many, and state Ai-2 can be obtained from state Ai, but state Ai does not communicate with Ai, then adjustment forecasting results $F'(t)$ can be obtained as $F'(t) = F(t) - D_{t2} = F(t) - \frac{l}{2}x2 = F(t) - l$ And obtained the common form of forecasting results $F'(t) = F(t) \pm D_{t1} \pm D_{t2} = F(t) \pm \frac{l}{2} \pm \frac{l}{2}, v$

With l is the median of interval gap and v is the transition.

Forecast Measure

The implementation of forecasting techniques that produce the smallest diversion / error is the best forecasting technique to use. Tsaur (2012) by using the MAPE method *(Mean Absolute Percentage Error)* to define the amount of the diversions that occur in the data of forecasting result toward the actual data. MAPE that used for the accuracy measure is as follows:

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\frac{|Y(t) - F'(t)|}{Y(t)} * 100\%$$

According to Chang, Wang and Liu (2007) in Halimi, et al (2013) the accuracy criteria of MAPE can be seen in table 1:

Table 1. Error Percentage

Very Good Forecasting	MAPE < 10%
Good Forecasting	MAPE 10%-20%
Average Forecasting	MAPE 20%-50%
Innacurate Forecasting	MAPE > 50%

RESULT AND DISCUSSION

This research took place at PD Pasar Jaya Lamongan and used data on the price of fish during November 2018.

From the data in the fish price table, it will be processed using the Markov Chain Fuzzy Time Series method.

The first step is to define the universe sets and get U = {24000; 33000}, then continue to divide (partition) the universe set U into several parts according to the formula in equations 2 and 3 so that n = 5,9≈6 and l = 1500. Then the 6 obtained intervals obtained are u1= {24000; 25500},u2={25500;27000},u3={27000;28500}, u4={28500;30000},u5={30000;31500} dan u6= {31500 ;33000}. Next, determine FLR and FLRG and collected as follows Table 3 and Fuzzy Logical Relationship Group shown in Table 4.

After finding FLR and FLRG then the markov matrix is formed $n \times n$, so the matrix is produced as follows:

$$\begin{bmatrix} 1/2 & 1/2 & 0 & 0 & 0 & 0 \\ 1/5 & 2/5 & 2/5 & 0 & 0 & 0 \\ 0 & 1/7 & 4/7 & 1/7 & 1/7 & 0 \\ 0 & 0 & 1/4 & 2/4 & 1/4 & 0 \\ 0 & 0 & 0 & 1/8 & 5/8 & 2/8 \\ 0 & 0 & 0 & 0 & 1/3 & 2/3 \end{bmatrix}$$

Table 2. Fish Price Data

Year	Price Data
1 November	26000
2 November	26000
3 November	26500
4 November	27000
5 November	28000
6 November	29000
7 November	29000
8 November	28000
9 November	27500
10 November	26000
11 November	25000
12 November	25000
13November	26500
14 November	27000
15 November	27000
16 November	28000
17 November	30000
18 November	31000
19 November	32000
20 November	32000
21 November	32000
22 November	31000
23 November	31000
24 November	30000
25 November	28500
26 November	29500
27 November	30000
28 November	31000
29 November	31000
30 November	31500

After finding the matrix n x n then the initial forecasting value can be calculated. The initial forecasting is based on the rules found in equations (4), (5), and (6). Forecasting calculations provide previous historical data, so the forecasting starts from the 2nd of the date, or the second data. then the FTS-MC method has a step to adjust the trend of forecasting value as a step to reduce the amount of diversion of forecasting results based on the rules found in equations (7), (8), (9) and (10).

Tabel 3. Fuzzy Logical Relationship

Data Sequence	FLR
1 -2	A2-A2
2-3	A2-A2
3-4	A2-A3
4-5	A3-A3
5-6	A3-A4
6-7	A4-A4
7-8	A4-A3
8-9	A3-A3
9-10	A3-A2
10-11	A2-A1
11-12	A1-A1
12-13	A1-A2
13-14	A2-A3
14-15	A3-A3
15-16	A3-A3
16-17	A3-A5
17-18	A5-A5
18-19	A5-A6
19-20	A6-A6
20-21	A6-A6
21-22	A6-A5
22-23	A5-A5
23-24	A5-A5
24-25	A5-A4
25-26	A4 -A4
26-27	A4-A5
27-28	A5-A5
28-29	A5-A5
29-30	A5-A6

Tabel 4. Fuzzy Logical Relationship Group

State Awal		State Akhir
A1	→	A1, A2
A2	→	A1, 2(A2), 2(A3)
A3	→	A2, 3(A3),A4, A5
A4	→	A3, 2(A4), A5
A5	→	A4,5(A5),2(A6)
A6	→	A5,2(A6)

Table 5. Final Price Forecast Data

Price Data	Final Prediction Data
26000	
26000	25850
26500	25850
27000	27250
28000	27751
29000	29072
29000	29563
28000	28813
27500	28322
26000	27286
25000	25100
25000	25500
26500	26250
27000	26800
27000	27750
28000	27750
30000	29822
31000	30936
32000	31688
32000	31750
32000	31750
31000	31000
31000	30938
30000	30938
28500	30188
29500	29438
30000	28938
31000	30938
31000	30938
31500	31688
	30938

After obtaining the results of the initial forecasting and the adjustment value then the conduting the final forecasting like equation (11) and get the following results and from the table above the price of 30938 is the future forecasting price.

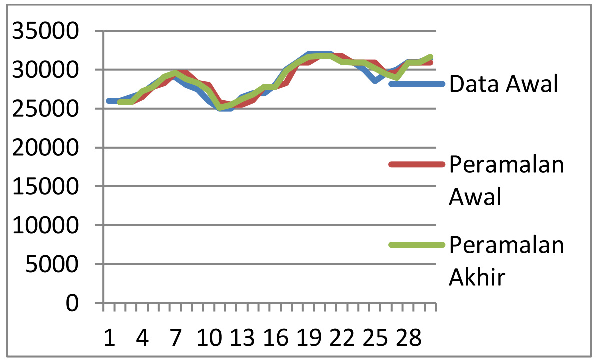

Figure 1. Forecast Comparison Chart

After knowing the final forecasting value, the next step is to measure the accuracy of FTS-MC which was conducted by equation (12) and the error rate is 1.4%, so the accuracy of FTS-MC to predict fish prices reaches 98.6% and included into the very accurate category forecasting.

The test were conducted to determine the accuracy of the Fuzzy Time Series-Markov Chain model. As a comparison model, the classic Fuzzy Time Series model is used. Testing the level of accuracy using the calculation criteria for Mean Absolute Percentage Error. As for the comparison of calculation as in table 6

Table 6. Result forecast

	Fuzzy Time Series Markov Chain	Fuzzy Time Series Klasik
MAPE	1,4 %	2,3%

In table 6 shows that the FTS-MC method obtained a MAPE value of 1.4% which means a deviation of 1.4% or an accuracy rate of 98.6% of the actual data.

While the classic FTS method obtained and a MAPE value of 2.3%, which means the accuracy rate reached 97.7% and there was a deviation of 2.3%. Therefore, forecasting using the proposed method has outdone ordinary FTS method.

Whereas in previous studies, FTS-MC was applied in several cases, including predicting historical data on the number of traffic accidents which resulted in an accuracy of 85.5% [7], forecasting the exchange rate of Taiwan dollar to US dollar has an accuracy of 99.4% [18], it can be said that the FTS-MC can be applied in forecasting fish prices because it has optimal performance and the forecasting accuracy is not that much different from previous studies.

CONCLUSION

Forecasting results using the FTS-MC method on fish price data for December 1st, 2018 30938 are based on the MAPE error value of 1.4% stating that the FTS-MC method has a very good performance, because it has a MAPE value below 10%, with a value the accuracy of forecasting results is 98.6%.

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