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Forecasting the recovery of COVID-19 patients in East Java using the Fuzzy time series Cheng method

Tony Yulianto[1], Faisol[1], Fatimatus Zahroh[1], Sri Suryanti[2], Mohamad Tafrikan[3]
[1]Department of Mathematics, Universitas Islam Madura, Indonesia
[2]Department of Mathematics Education, Universitas Muhammadiyah Gresik, Indonesia
[3]Department of Mathematics, Faculty of Science and Technology, Universitas Islam Negeri Walisongo Semarang, Indonesia

Corresponding author:
fatimatus.zahroh.amin@gmail.com
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Abstracts

Coronavirus 2019 (COVID-19) has significantly impacted Indonesia. Social restrictions in Indonesia's major cities and rural areas have been put in place as the coronavirus spreads. The Indonesian government is more vigilant with the spread of COVID-19, namely by issuing a lockdown policy to PSBB (Large-Scale Social Restrictions). Almost all Indonesian people have complied with the guidelines set by the government, namely carrying out all activities in a WFH manner to minimize the chain of distribution of COVID-19 in Indonesia. The author of this work forecasts the recovery rate of Covid-19 patients in the East Java region using the Cheng Fuzzy Time Series approach. After checking the simulation with real in the field, it can be seen that using 51 data starting from February 4 2021 to March 26 2021 gives results MAPE = 0.4602%, which means the forecasting is very accurate.

Keywords: COVID-19, Fuzzy Time, Forecasting Recovery, East Java

1. Introduction

The world was deeply saddened at the start of 2020 by the breakout of a new virus, particularly the new coronavirus (SARS-Cov-2), and the epidemic is named Coronavirus Disease 2019 (COVID-19)[1][3][7]. It is well-known that this virus originated in Wuhan, China. It was discovered in late December of this year. So far, 65 countries have been identified as being affected by this virus. Covid-19 is a disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and was declared a global epidemic by the World Health Organization in March 2020[2][5][8].

COVID-19 is a novel coronavirus that has infected humans and spread worldwide. Currently, Indonesia has approximately 300,000

positive COVID-19 cases (as of October 5 2020) since the government announced the first case in early February 2020[9]. In Indonesia, this virus first spread on February 14, 2020 [10]. A person who first contracted the Covid-19 virus in Indonesia was a Japanese foreigner in Indonesia. The Indonesian government is more alert to the spread of COVID-19, namely by issuing a lockdown policy to PSBB (Large-Scale Social Restrictions). [11]. Almost all Indonesians have complied with the guidelines set by the government, namely carrying out all activities in a WFH manner to minimize the chain of distribution of COVID-19 in Indonesia. In contrast, the air quality in the environment is exceptional and notable since it is only minimally polluted by air pollution[9].

For a few weeks, the coronavirus disease COVID-19 (deployment-severe acute respiratory syndrome) has spread to more than 100 nations[4][6][12]. The coronavirus epidemic has struck several countries in the world, including Indonesia. The year 2019 (COVID-19)[13]. The Indonesian government has recorded 14,032 confirmed COVID-19 positives as of May 10, 2020[11]. Nine hundred seventy-three people have died from COVID-19, while 2,698 people have beaten the condition. Due to the rapidity with which the virus is spreading, the Indonesian government has enacted severe social restrictions throughout the country's most populous cities[14]. The Indonesian government is stepping up its efforts to isolate its citizens. To prevent the transmission of the Covid-19 virus, homeowners are urged to keep a distance of 1-2 metres from their neighbours[15].

Forecasting is the art and science of predicting the future by using historical data and a systematic method model to make predictions about future events[16]. In prediction or forecasting, the processed data is actual or historical data used as reference data. Businesses, risk managers, financial decision-makers, and many other stakeholders benefit from forecasting[17].

Researchers in East Java turned to the Cheng Fuzzy Time Series approach to anticipate how well Covid-19 patients may recover. The Fuzzy Time Series has been employed in forecasting in various sectors since its development. A study by Brata (2015) found that comparing the fuzzy-Chen time series and fuzzy Markov chain approaches for Indonesian inflation data, the Fuzzy Time Series Markov Chain produced the smallest MSE compared to the MSE using fuzzy-chen[22]. When Nogroho (2016) studied the use of the fuzzy time series Markov chain model to forecast inflation, the results showed that it was more accurate than the Classical FTS model[23]—using actual data on the number of patients who recovered from the East Java Provincial Government's IG (Instagram) from February 4, 2021, to March 26, 2021.

2. Research Method

2.1 Time Series

The term "periodic data" refers to a set of data organized either according to a periodic time scale or chronologically. All of these options are available to you when arranging dates in chronological sequence. Therefore, regular data is connected with statistical information recorded and observed over a set period, such as the trading of goods and services and the pricing of stock market shares and other financial instruments[16].

2.2 Fuzzy Time Series

Fuzzy Time Series (FTS) is a statistical time series analysis applied to fuzzy settings based on Fuzzy linguistics (FL)[18]. Fuzzification, defuzzification, and forecasting are the three main components of the FTS technique. First, the discourse universe is divided into clusters. Error-values indicate that the modification outperforms Cheng's original method in forecasting the recovery rate of Covid-19 patients. One way to represent an input that has been fuzzy-field is by using fuzzy sets and the member functions that go with them[19].

It is possible to utilize fuzzy time to foresee difficulties or circumstances where

historical data is generated in linguistic values, implying that the prior data in an ambiguous time series are linguistic data. In contrast, as a result, the actual data are real numbers[16].

2.2.1 Fuzzy Time Series Cheng

According to the Cheng technique, the Fuzzy Logical Relation (FLR) is used to determine intervals, and all relations are taken into account while allocating weights. Forecasting time series data with FTS Cheng goes through the following processes[21]:

1. Determine the universe set (U) of actual data, namely:
   $U = [d_{min}, d_{max}]$ (1)
2. Using a frequency distribution to determine the breadth of the interval:
   a. The range (range) can be determined by using the following formula.
      $R = d_{max} - d_{min}$ (2)
      Where R is the range:d_{max} is the largest data, is the smallest data.d_{min}
   b. The Sturges equation can be used to calculate the number of class intervals. Here's how to use it:
      $K = 1 + 3{,}322\ x \log n$ (3)
   c. Specifies the width of the interval. The formula is as follows:
      $I = \frac{Range\ data\ (R)}{Banyaknya\ interval\ kelas\ (K)}$ (4)
   d. determine the middle value. The formula is as follows:
      $m_i = \frac{(batas\ bawah + batas\ atas)}{2}$ (5)
      where m_i is the number of fuzzy sets that exist.
3. TThe fuzzy set is formed by looking at the number of different frequencies; then, the first highest frequency is divided into h equal intervals. Next, the second-highest frequency is divided into h – 1 equal interval, and the gap at the third-highest frequency is divided into h – 2 equal intervals. This is done up to a break with a frequency that cannot be further divided.
4. FFuzzy sets should be defined, and the observed data should be fuzzified. According to the fuzzy set definition, a fuzzy set is one in which the values of one or more linguistic variables are approximated $\boldsymbol{A_i}\ \boldsymbol{A_1}, \boldsymbol{A_2}, \dots, \boldsymbol{A_p} \boldsymbol{A_1}, \boldsymbol{A_2}, \dots, \boldsymbol{A_p} U$

$$\begin{aligned} A_1 &= {}^{1}/_{u_1} + {}^{0{,}5}/_{u_2} + {}^{0}/_{u_3} + \cdots + {}^{0}/_{u_p} \\ A_2 &= {}^{0{,}5}/_{u_1} + {}^{1}/_{u_2} + {}^{0{,}5}/_{u_3} + \cdots + {}^{0}/_{u_p} \\ A_3 &= {}^{0}/_{u_1} + {}^{0{,}5}/_{u_2} + {}^{1}/_{u_3} + \cdots + {}^{0}/_{u_p} \\ &\vdots \\ A_p &= {}^{0}/_{u_1} + {}^{0}/_{u_2} + {}^{0}/_{u_3} + \cdots + {}^{0{,}5}/_{u_p} + {}^{1}/_{u_p} \end{aligned} \quad (6)$$

   The element of the universal set and the number given the symbol "represents the degree of membership to which the value is 0; 0.5 or $1.u_i(i = 1{,}2, \dots, p)(U)$ / $\mu_{A_i}(u_i)\ A_i(i = 1{,}2, \dots, p)$
5. Create an FLR table based on actual data. FLR can be denoted by which is called$A_i \rightarrow A_j A_i$*current state* and A_j*next state.*
6. Determine the weight of the FLR relation to be a *Fuzzy Logical Relation Group* (FLRG) by including all relationships (*all relationships*) and assigning weights based on the same iteration order. FLR, which has *a current state, is* combined into one group in the form of a weighting matrix. Then the weights obtained in the FLR relation are entered into the form of a weighting matrix whose equation is written as follows:$(A_i)(W(t))$

$$w(t) = \begin{bmatrix} W_{11} & W_{12} & \dots & W_{1p} \\ W_{21} & W_{22} & \cdots & W_{2p} \\ \vdots & \vdots & W_{ij} & \vdots \\ W_{p1} & W_{p2} & \dots & W_{pp} \end{bmatrix} \quad (7)$$

   The weighting matrix; is the weight of the matrix in the throw and the column with. Where is the interval class of Left Hands Slides (LHS), and is the interval class of Right Hands Slides (RHS).$Ww_{ij}iji = 1{,}2, \dots, p; j = 1{,}2, \dots, pij$
7. A standard weighting matrix equation is built to convert the FLRG weights into standard weights. $\left(w_n(t)\right)$

$$w_n(t) = \begin{bmatrix} {W_{11}}^* & {W_{12}}^* & \dots & {W_{1p}}^* \\ {W_{21}}^* & {W_{22}}^* & \cdots & {W_{2p}}^* \\ \vdots & \vdots & {W_{ij}}^* & \vdots \\ {W_{p1}}^* & {W_{p2}}^* & \dots & {W_{pp}}^* \end{bmatrix} \quad (8)$$

where $w_n(t)$ is a standardized weighting matrix with $w_{ij}{}^* = \frac{w_{ij}}{\sum_{j=1}^{p} w_{ij}}$

8. The predicted value should be calculated. The forecast value is generated by multiplying the standardized weighting matrix by the defuzzification matrix, namely the matrix. The symbol represents the midpoint of each interval. As a result, the calculation of the forecast gets more complicated. $(w_n(t))L_{df}L_{df} = [m_1, m_2, \dots, m_p]^T m_i$
$F_t = w_{i1}{}^*(m_1) + w_{i2}{}^*(m_2) + \cdots + w_{ip}{}^*(m_p)$ (9)
where is the result of the forecast; with $F_t w_{ij}{}^* = \frac{w_{ij}}{\sum_{j=1}^{p} w_{ij}}$

3. Results and Discussion

3.1 Data Stationary Check

Data on recovering Covid-19 patients in the East Java region will be predicted using the Cheng Fuzzy Time Series. Actual data recovered from Covid-19 patients are shown in Table 1.

Table 1. Actual data of recovered Covid-19 patients

No	Date	Healthy
1	04-Feb-21	100789
2	05-Feb-21	101658
3	06-Feb-21	102444
4	07-Feb-21	103219
⋮	⋮	⋮
50	25-Mar-21	125977
51	26-Mar-21	126272

The data plot for the addition of recovered cases for 51 days is shown in Figure 1. The time series model is identified and used to model the data properties in the initial stage. Identification is done simply through data plots such as Figure 1 to see trends, seasonal components, non-stationarity invariance, and others.

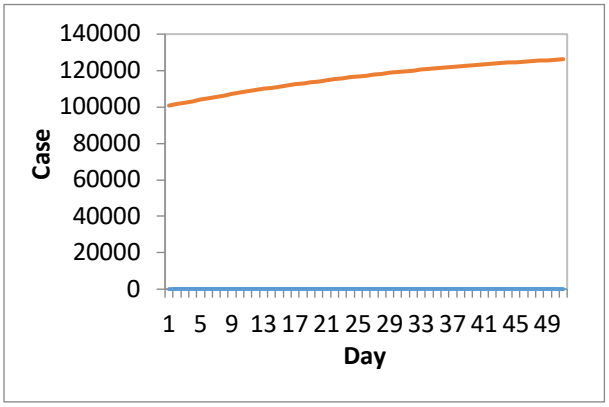

Figure 1. Time Series Plot of COVID-19 Healed Cases

3.2 Data Identification in the Cheng Fuzzy Time Series method

Furthermore, data identification will be carried out using the correct Fuzzy Time Series Cheng method to describe the simulation data using the following Matlab R2013a program:

3.3 Diagnostic Check

Validation checks are carried out to determine the results of calculations from each actual data, including error calculations and forecasting results on day two and day 3 data.

2nd data $Y = 101658 \rightarrow \hat{Y} = 103337{,}3$.

Error =1679.3

3rd data: $Y = 102444 \rightarrow \hat{Y} = 103337{,}3$.

Error =893.3

3.4 Forecasting

The simulation results of 51 recovered Covid-19 patient data using Matlab R2013a software can be seen in Table 1.

3.5 Results of Application of Fuzzy Time Series Cheng in Matlab

In this step, the data that has been applied using the cheng fuzzy time series method is solved using Matlab R2013a. The simulation results of 51 recovered Covid-19 patient data using Matlab R2013a software can be seen in Figure 2.

Table 1. Data for Forecasting Recovery Rates for Covid-19 Patients

No	Date	Healthy	Fuzzification	Forecasting
1	04-Feb-21	100789	A_1	
2	05-Feb-21	101658	A_1	103337.3
3	06-Feb-21	102444	A_1	103337.3
4	07-Feb-21	103219	A_1	103337.3
⋮	⋮	⋮	⋮	⋮
50	25-Mar-21	125977	A_{14}	125816,946
51	26-Mar-21	126272	A_{14}	125816,946
52	27-Mar-21			125816,946

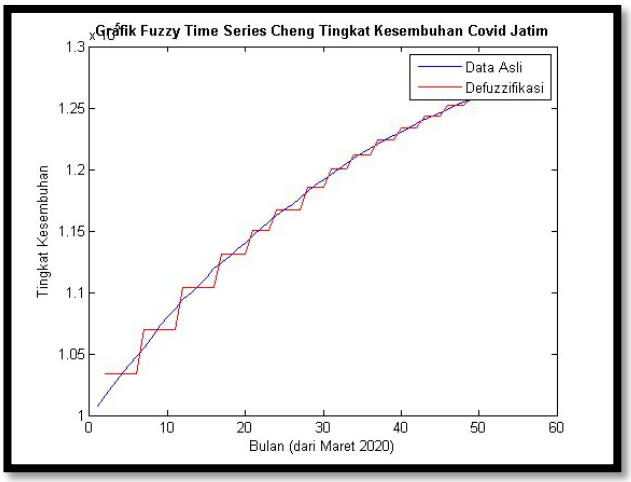

Figure 2. Graph of actual data and forecasting results of recovered Covid-19 patients

The figure shows that the Fuzzy Time Series Cheng method for forecasting the recovery rate of Covid-19 patients using 51 daily data starting from February 4, 2021 to March 26, 2021 gives results, which means the forecasting is very accurate [20].

4. Conclusion

After checking the simulation with real in the field, it can be seen that the fuzzy time series cheng method for forecasting the recovery rate of Covid-19 patients in the East Java region using 51 data starting from February 4, 2021, to March 26 2021, gives results MAPE = 0,4602%, it means the forecasting is very accurate [20].

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