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Cheng's Fuzzy Time Series Method Implementation In Predicting The Number Of Covid-19 Positive Cases In Indonesia

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Abstract

At the beginning of 2020, citizens all around the world were streaked by the Corona Virus (Covid-19) pandemic which caused terror far and near. Millions of people were infected and thousands more died ever since the World Health Organization or WHO has declared the Corona Virus (Covid-19) as a global pandemic. Following up on this, the Indonesian government also stated that the Corona Virus problem had become a non-natural national disaster. The President of the Republic of Indonesia and the Regional Government along with their staffs worked hand in hand to take several tactical steps as an effort to prevent the spread of the Corona Virus (Covid-19) in the community. In this study, authors use one method to make predictions or forecasting, that is the Cheng Fuzzy Time Series method, to predict the number of Covid-19 cases in Indonesia so that the government can take tactical steps after knowing the predicted number of the case. The actual data used is the number of Covid-19 case from July 2020 up until October 2020. From the results of calculations that have been carried out using this method, the conclusion is that the performance is splendid, in the range of MAPE <10, whose error value is 5%. With 95% value of accuracy.

Keywords: Fuzzy Time Series Cheng, Prediction, Covid-19

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1. Introduction

The outbreak of Coronavirus Diseases 2019 (COVID-19) is currently becoming horrendous news globally. The World Health Organization (WHO) has declared that the virus is a global pandemic. Millions of people were infected and thousands died as a result of this plague. Policies such as lockdowns have even been carried out in several countries to prevent the spread of Covid-19.

In Indonesia, the government is trying to take various actions or policy measures to prevent the spread of Covid-19 cases. If the government can predict the number of positive cases of Covid-19 in the future, it will be easier to make tactical steps to reduce the number of positive cases of Covid-19 that occurred in the country. In case there were research on methods or algorithms such as Cheng's Fuzzy Time Series to predict the number of positive cases of Covid-19 that occurred in Indonesia, it would be useful for the government to combat the Covid-19 outbreak that occurred in Indonesia.

However, there has been no research conducted yet on the FTS Cheng method that has been carried out to predict the number of positive cases of Covid-19 in Indonesia. From the many existing methods or algorithms, the Fuzzy Time Series Cheng could possibly be

By using data on positive cases of Covid-19 in Indonesia in the form of numeric and time series models, it is possible that the Fuzzy Time Series Cheng method is suitable to be implemented. But currently there is no research on the use of this method in predicting the number of positive cases of Covid-19 that occurred in Indonesia.

With this description of the problem, authors are conducting a research entitled “Cheng's Fuzzy Time Series Method Implementation in Predicting the Number Of Covid-19 Positive Cases in Indonesia.”

2. Research Method

2.1 Covid-19

Coronavirus disease 2019 (Covid-19) is a new disease that is caused by a virus from the Coronavirus group, that is SARS-CoV-2 and is often called the Corona Virus. This disease was first discovered in Wuhan City, China at the end of December 2019. The Corona Virus or Covid-19 was then transmitted between humans and is spreadring to dozens of countries rapidly, including Indonesia in just a few months [4].

In Indonesia, the number of positive cases of Covid-19 has infected more than 300,000 people in October 2020. The usual symptoms of Covid-19 are fatigue, fever, and dry cough. Then there are colds, sore throats, aches and pains, diarrhea, and nasal congestion. Some are healthy without symptoms [5].

2.2 Fuzzy Time Series

Fuzzy Time Series (FTS) was first developed by Song and Chissom in 1993. FTS is using the Fuzzy principle and it is one of the forecasting methods. Usually the fuzzy set is equated as a class whose numbers have fuzzy boundaries. If U is a universal set, then its equation function is:

$$A_i = \mu_{Ai}(u_1)/u_1 + \cdots + \mu_{Ai}(u_p)/u_p A_i = \mu_{Ai}(u_1)/u_1 + \cdots + \mu_{Ai}(u_p)/u_p$$

With $\mu_{Ai}(u_j)$ is the derivative of u_i ke A_i along with $\mu_{Ai}(u_j)\epsilon[0,1]$ dan $1 \leq j \leq p$ (*p* is the number of classes). The derivative value of $\mu_{Ai}(u_j)$ determined according to the following rules:

Rule 1 : If the actual data of X_t is included in u_j, then the derivative value of u_j is 1 , and u_{j+1} is 0.5 , and if it is not u_j, and u_{j+1}, it is considered as 0.

Rule 2 : If the actual data of X_t X_t is included inu_i, $1 \leq j \leq p$ then the derivative value u_j is 1, whereas u_{j-1} and u_{j+1} are 0.5, and if it is not u_j, u_{j-1} and u_{j+1} it is considered as0.

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Rule 3 : If the actual data of $X_t X_t$ is included in u_j , then the derivative value u_j is 1, whereas u_{j-1} is 0.5 , and if it is not u_j and u_{j-1} it is considered as 0 [6].

2.3 Fuzzy Time Series Cheng

The FTS Cheng method has a different method from Chen's in making intervals, using a Fuzzy Logical Relationship (FLR) which connects several data and then gives weights if the FLRs are equal. FTS Cheng's steps are as the following:

1. Determining the universal set and then divide it into several intervals whose range or distance are the same.M

$$U = [D_{min}; D_{max}] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

2. Interval width formation
   a. Calculating the range using the following formula:

   $$R = D_{max} - D_{min} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

   R is *range*, D_{max} is the largest data, D_{min} is the least.

   b. For the next step, the universal set is broken down and further divided into several intervals that have the same width. In determining this interval distance, the Struges formula is applicable.

   $$K = 1 + 3.322\ log\ (n) \ldots\ldots\ldots\ldots\ldots \text{(4)}$$

   n is the sum of all historical data used. From these results, several linguistic values will be formed which are used to describe fuzzy sets, that is intervals from the universal set. (U).

   $$U = \{u_1, u_1, \ldots, u_K\} \ldots\ldots\ldots\ldots\ldots\ldots \text{(5)}$$

   c. Determining the width of the interval

   $$l = \frac{range\ (R)}{numbers\ of\ class\ intervals(K)} \ldots\ldots\ldots \text{(6)}$$

   d. Calculating the midpoint

   $$m_i = \frac{(lower\ limit + upper\ limit)}{2} \ldots\ldots \text{(7)}$$

   With i is a *Fuzzy* set.
   From the calculations, the partition of the universal set according to the length of the interval is obtained.

   $$u_i = (D_{min}; D_{min} + l)$$
   $$u_2 = (D_{min} + l; D_{min} + 2l)$$
   $$u_3 = (D_{min} + 2l; D_{min} + 3l)$$
   $$\vdots$$
   $$u_k = (D_{min} + (k-1)l; D_{min} + kl) \ldots \text{(8)}$$

3. Calculating the Fuzzy set aims to see the number of frequencies that are not the same, with its largest frequency being divided by h equal intervals. Moreover, the second largest is divided into h-1 intervals that have similarities, and the third one is divided into h-2 which are the same, and so on until it can no longer be divided, and that is the last frequency.
4. Performing the *Fuzzification*
   Supposing that $A_1, A_2, \ldots, A_p$ is a *Fuzzy* set whose linguistics value is obtained from the linguictics variable(s), the set is calculated as *Fuzzy* $A_1, A_2, \ldots, A_p$ whereas the universal set U is as the following :

$$A_1 = \{1/u_1 + 0.5/u_2 + 0/u_3 + \cdots + 0/u_p\}$$
$$A_2 = \{0.5/u_1 + 1/u_2 + 0.5/u_3 + \cdots + 0/u_p\}$$
$$A_3 = \{0/u_1 + 0.5/u_2 + 1/u_3 + \cdots + 0/u_p\}$$
$$\vdots$$
$$A_p = \{0/u_1 + 0/u_2 + 0/u_3 + 0/u_4 + \cdots + 0.5/u_{p-1} + 1/u_p\} \ldots\ldots \text{(9)}$$

With $u_j(i = 1,2, \dots, p)$ is a universal set (U) and the symbol "/" is the derivation of $\mu_{Ai}(u_j)$ upon $A_i(i = 1,2, \dots, p)$ whose value is 0, 0.5 or 1.

5. Formig the *Fuzzy Logic Relationships* (*FLR*) and *Fuzzy Logic Relationships Group* (*FLRG*). Finding out the correlation between *FLR* with a historical data. After the data is *Fuzzified*, if it uses order one, then the two data are sequential as in $A_i(t-1)$ and $A_i(t)$ then FLR $A_i \to A_j$. Relationships are identified based on the results of the *fuzzyfication* of time series data. If the variable of *time series* $i = F(t-1)$ is a *fuzzyfication* asA_k and $F(t)$ is the result of *fuzzification* asA_m, then A_k and A_m can be denoted as$A_k \to A_m$, with A_k is a current state historical data and A_m is a next state historical data. If the *FLR* is forming as $A_1 \to A_3, A_1 \to A_4, A_1 \to A_5$, accordingly, the *FLRG* from the previously mentioned FLR is $A_1 \to A_3, A_4, A_5$.
6. Assigning the scale to the same group of Fuzzy Logic relations.
Determining the scale of the FLR relationship into FLRG is by grouping those that have similarity and then give the scale. FLRs with the same current state (Ai) are grouped and given the scale, then transfer it to the scaled matrix. The formula is as follows:
$$W = |w_{11}\ w_{12}\ \cdots \quad w_{1p}\ w_{21}\ w_{22}\ \cdots \quad w_{1p}\ \vdots\ w_{p1}\ \vdots\ w_{p2}\ w_{ij} \quad \vdots \quad \cdots \quad w_{pp} \quad | \dots\dots\dots\dots \text{(10)}$$
Where (?) is the weighting matrix and is the weight of the matrix in row-i and in-j column with $i = 1,2, \cdots, p\ ; j = 1,2, \cdots, p$. Sending the FLRG weights to a standardized weighting matrix is next, which has the following equation:
$$W *= |w_{11} *\ w_{12} *\ \cdots \quad w_{1p} *\ w_{21} *\ w_{22} *\ \cdots \quad w_{1p} * \vdots\ w_{p1} * \vdots\ w_{p2} *\ w_{ij} * \quad \vdots \quad \cdots \quad w_{pp} * \quad | \dots\dots\dots \text{(11)}$$
Where the weighting matrix is standardized with the following formula:
$$w_{ij} *= \frac{w_{ij}}{\sum_{j=1}^{p} w_{ij}} \dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(12)}$$
7. Looking out for defuzzification in case one want to produce a predictive value , the standardized matrix $W *$ is multiplied with m_i (m_i is the middle value of the *Fuzzy* set). The calculation in the prediction is as follows:
$$F_i = w_{i1} * (m_1) + w_{i2} * (m_2) + \cdots + w_{ip} * (m_p) \dots\dots\dots\dots \text{(13)}$$
With F_i is the result ofprediction, with the equation of 22. If the *fuzzification* from the -i period is A_i, and A_i is naught from *FLR* as well as *FLRG*, it then could be written down as $A_j \to \emptyset$, where the maximum value is at u_i, then the value of the prediction$(F_i)$is the middle value u_i, or can be defined by m_i [7].

2.4 MAPE Predicting Accuracy

MAPE is a relative measure that is widely used to see the percentage of deviations or errors from prediction or forecasting results, the MAPE equation can be seen as follows:
$$MAPE = \frac{1}{n} \sum_{i=1}^{n} \quad |PE_i| \dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(14)}$$
With PE_i is the error percentage with the following formula:
$$PE_i = \frac{Y_t - F_t}{Y_t} x100\% \dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(15)}$$
With Y_t is actual data or original data on research F_t and is the predicted data or the *forecasting* data result [8].

3. Findings

3.Descriptive Analysis of the Data

The data that the researchers use is data on daily positive cases of Covid-19 in Indonesia, from September 1, 2020 to October 30, 2020, which was obtained from the official website of the Indonesian government Covid19.go.id. The amount of data used is 60 data from data on daily positive cases of Covid-19.
Figure 1 shows a graph of the number of positive Covid-19 cases that occurred in Indonesia from September 1, 2020 to October 30, 2020. Based on the data within the two months, it can be seen that the least positive case of Covid was September 1, 2020, amounting to 2775. And the most is in October 8, 2020, which is 4850. The trend of the graph tends to be fluctuated.

Figure 1. Illustration of the number of positive cases of Covid-19 in Indonesia

3.2 Cheng's Fuzzy Time Series Method

3.2.1 Formation of the Universal Set

The formation of the universal set using historical data, by defining $D_{min}; D_{max}$, which are the lowest and highest data. It can be concluded:

$$U = [D_{min}; D_{max}]$$
$$U = [2775 ; 4850]$$

3.2.2 Formation of Interval Length

a. Calculating the Range

$$R = [D_{max} - D_{min}]$$
$$R = 4850 - 2775$$
$$R = 2075$$

b. Calculating the Amount of the Interval Cases

In calculating the number of interval classes, the Struges formula is used, where n is the number of historical data:

$$K = 1 + 3{,}322\ log\ log\ n$$
$$K = 1 + 3{,}322\ log\ log\ 60$$
$$K = 6{,}907018454$$
$$K = 7$$

c. Calculating the Inerval Width

The width of the interval resulting from the division between the Range and the number of interval classes is as follows:

$$l = \frac{R}{K}$$
$$l = \frac{2075}{7}$$
$$l = 296{,}4285714$$

3.2.3 Fuzzy Set Formation

Fuzzy sets are made by looking at frequencies that are not the same or different. The results of the density frequency calculation can be shown in table 1.

Interval	Lower Limit	Upper Limit	Total Data	Total Sub Interval	Sub Interval Width
U_1	2775	3071,428571	4	2	148,2143
U_2	3071,428571	3367,857143	7	3	98,80952
U_3	3367,857143	3664,285714	11	4	74,10714
U_4	3664,285714	3960,714286	7	3	98,80952

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U_5	3960,714286	4257,142857	15	6	49,40476
U_6	4257,142857	4553,571429	13	5	59,28571
U_7	4553,571429	4850	3	1	296,4286
Total			60	24	
Frequency			15, 13, 11, 7, 4, 3		

Table 1. Density Frequency

Next is to assume that $A_1, A_2, \dots, A_k$ as a fuzzy set of linguistic values of linguistic variables. The total number of sub intervals is 24, then creating a fuzzy interval with frequency density can be seen in table 2.

Sub interval	Lower Limit	Upper Limit	Median	Sub Interval Width
A_1	2775	2923,214286	2849,107143	148,2142857
A_2	2923,214286	3071,428571	2997,321429	148,2142857
⋮	⋮	⋮	⋮	⋮
A_{23}	4494,285714	4553,571429	4523,928571	59,28571429
A_{24}	4553,571429	4850	4701,785714	296,4285714

Table 2. Fuzzy Interval with Density Frequency

Determining the new limit of each interval according to the width of the sub interval in each sub interval and the number of sub intervals according to the number of sub intervals. Then, determining the middle value by adding the lower and upper limits and then dividing them by 2.

3.2.4 Performing the Fuzzification

Fuzzyfication results can be seen in table 3.

Date	Positive Case	*Fuzzification*	Date	Positive Case	*Fuzzification*
01-Sep-20	2775	A_1	01-Oct-20	4174	A_{17}
02-Sep-20	3075	A_3	02-Oct-20	4317	A_{20}
⋮	⋮	⋮	⋮	⋮	⋮
15-Sep-20	3507	A_7	15-Oct-20	4411	A_{21}
16-Sep-20	3963	A_{13}	16-Oct-20	4301	A_{19}
⋮	⋮	⋮	⋮	⋮	⋮
29-Sep-20	4002	A_{13}	29-Oct-20	3565	A_8

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30-Sep-20	4284	A_{19}	30-Oct-20	2897	A_1

Table 3. Fuzzification of Historical Data

The formation of *fuzzyfication* on historical data is carried out by looking at the latest fuzzy interval. *Fuzzyfication* is done by defining the data into appropriate intervals, that is the historical data that falls into a range at certain intervals.

3.2.5 Classifying *Fuzzy Logic Relationship* (*FLR*)

FLR is formed based upon the current historical data$F(t-1)$ or the current state with future historical data$F(t)$ or the next state. The results of the formation of the FLR are formed from the results of the previous *fuzzification.* The following results from the first order FLR can be seen in table 4.

Date	FLR	Date	FLR
01-Sep-20	-	01-Oct-20	$A_{19} \rightarrow A_{17}$
02-Sep-20	$A_1 \rightarrow A_3$	02-Oct-20	$A_{17} \rightarrow A_{20}$
⋮	⋮	⋮	⋮
15-Sep-20	$A_3 \rightarrow A_7$	15-Oct-20	$A_{16} \rightarrow A_{31}$
16-Sep-20	$A_7 \rightarrow A_{13}$	16-Oct-20	$A_{21} \rightarrow A_{19}$
⋮	⋮	⋮	⋮
29-Sep-20	$A_7 \rightarrow A_{13}$	29-Oct-20	$A_{14} \rightarrow A_8$
30-Sep-20	$A_{13} \rightarrow A_{19}$	30-Oct-20	$A_8 \rightarrow A_1$

Table 4. Hasil *FLR*

3.2.6 Classifying Fuzzy Logic Relationship Group (*FLRG*)

The FLRG builds on the previous FLR. Fuzzy set predicts more than one set, so right hand side can be combined into one group. Fuzzy Logic Relationship Group (FLRG) can be seen in table 5.

FLRG	Current state	Next state
G1	$A_1 \rightarrow$	A_3, A_2
G2	$A_2 \rightarrow$	A_5
⋮	⋮	⋮
G22	$A_{22} \rightarrow$	A_{24}, A_4
G23	$A_{23} \rightarrow$	A_{24}, A_{22}, A_{15}

. **Table 5.** *FLRG* Result

3.2.7 Scaling

The scaling is done by observing on how many relations are the same in the FLRG. The following scaling result is illustrated in Table 6.

FLRG	Current state	Next state
G1	$A_1 \rightarrow$	A_3, A_2
G2	$A_2 \rightarrow$	A_5
⋮	⋮	⋮
G22	$A_{22} \rightarrow$	A_{24}, A_4
G23	$A_{23} \rightarrow$	A_{24}, A_{22}, A_{15}

Table 6. Scaling Result

3.2.8 *Fuzzy Time Series Cheng* Prediction Result

Determining the prediction results is based on the FLRG that has been formed. The following prediction results based on FLRG is illustrated in Table 7.

FLRG	Current state	Next state	Total	Prediction	Integerated Prediction
G1	$A_1 \rightarrow$	A_3, A_2	2	3059,077381	3059
G2	$A_2 \rightarrow$	A_5	1	3318,452381	3318
⋮	⋮	⋮	⋮	⋮	4316
G22	$A_{22} \rightarrow$	A_{24}, A_4	2	3960,714286	3961
G23	$A_{23} \rightarrow$	$A_{24}, A_{22},$	3	4416,884921	4417

Table 7. Prediction Results Built Upon the FLRG

To obtain the prediction results, *defuzzification* is carried out by multiplying the mean value of the sub interval. Since there is some scaling in the Cheng method, it is included in the *defuzzification*. After that, the prediction results based on FLRG are entered into historical data after being grouped by FLRG. The following results from the predictions can be seen in Table 8.

Date	Positive Case	FLR	FLRG	Prediction
01-Sep-20	2775	-	-	-
02-Sep-20	3075	$A_1 \rightarrow A_3$	G1	3059
⋮	⋮	⋮	⋮	⋮
30-Sep-20	4284	$A_{13} \rightarrow A_{19}$	G13	3942
01-Oct-20	4174	$A_{19} \rightarrow A_{17}$	G18	4297
⋮	⋮	⋮	⋮	⋮
29-Oct-20	3565	$A_{14} \rightarrow A_8$	G14	4039
30-Oct-20	2897	$A_8 \rightarrow A_1$	G8	3442

Table 8. Prediction Result

3.3 MAPE Calculation

The accuracy of the prediction results with MAPE. The following MAPE results can be seen in Table 9.

Date	Positive Case		Prediction	MAPE
01-Sep-20	2775		-	-
02-Sep-20	3075		3059	0,520325203
⋮	⋮		⋮	⋮
30-Sep-20	4284		3942	7,983193277
01-Oct-20	4174		4297	2,946813608
⋮	⋮		⋮	⋮
29-Oct-20	3565		4039	13,29593268

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30-Oct-20	2897		3442	18,81256472
	Total			411,6663101
	Average MAPE			6,977395086

Table 9. MAPE Result

The average MAPE is 6.977395086%. This means that the Cheng Fuzzy Time Series method produces a MAPE error of 6.977395086% or rounded to 7% so it is considered splendid.

3.4 Number of Covid-19 Positive Case Prediction

Predicting by using the FTS Cheng method is calculated by observing at the latest data. In history, the latest data is seen on October 30, 2020, thus predictions on the next date is carried out per October 31, 2020. Looking next at the *fuzzyfication* of the previous data, prediction is calculated per October 31, 2020 using the *fuzzyfication* of October 30, 2020, that is the A_1. Accordingly, the calculation is as follows:

31 October 2020 has the A_1 *fuzzyfication.* Therefore, FLR $A_1 \rightarrow A_1$ from *fuzzification* on 30 October 2020 to 31 October 2020 and entered into FLRG G1, because its current state is A_1 and inside G1 has next state A_3, A_2 then adding up next state from 31 October 2020 data to A_3, A_2, A_1 and the total is 3, then the prediction calculation is as follows:

$$F_i = w_{i1} * (m_1) + w_{i2} * (m_2) + \cdots + w_{ip} * (m_p)$$
$$F(G1) = w_3 * (m_3) + w_2 * (m_2) + w_1 * (m_1)$$
$$= \left[\frac{1}{3}\right] * [3120,833333] + \left[\frac{1}{3}\right] * [2997,321429] + \left[\frac{1}{3}\right] * [2849,107143]$$
$$= 1040,27777 + 999,107133 + 949,702372$$
$$= 2989,087302$$
$$= 2989$$

It can be concluded that the predicted number of positive cases of Covid-19 in Indonesia in October 31, 2020 using the Cheng Fuzzy Time Series method was 2989. Then the graph of historical data and predictive data can be seen in Figure 2.

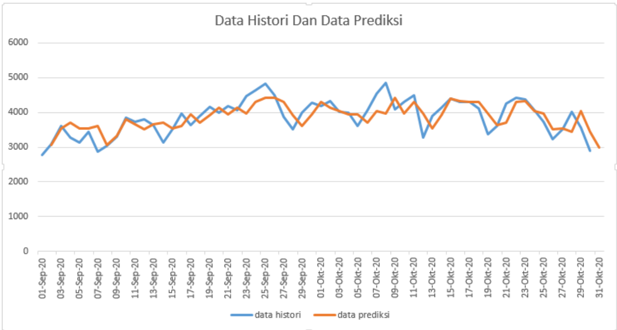

Figure 2. Graph of Historical and Prediction Data

Throughout the research, the actual data on the number of positive Covid-19 cases on October 31, 2020 is already existed, as many as 3143. Therefore, the MAPE errors based on the prediction results on October 31, 2020 is obtained as many as 2989 result with the following calculations:

$$MAPE = \frac{\sum_i^n \quad |(X_t - F_t)/X_t|x100\%}{n}$$
$$= \frac{(3143 - 2989)/3143\ |x100\%}{1}$$
$$= 4,899777283\%$$

All in all, the prediction results using the FTS Cheng method on October 31, 2020 had a MAPE error of 4.899777283% or 5%, meaning that it had very good accuracy.

4. Conclusion

1. The FTS Cheng method predicts the number of positive cases of Covid-19 in Indonesia using 60 data from September 1, 2020 to October 30, 2020 gives an average MAPE error of7% stating that the FTS Cheng method has a very good performance since the MAPE error is lower than 10%.
2. The results of the prediction of the number of positive cases of Covid-19 that occured in Indonesia on October 31,2020 with the FTS Cheng Series method of 2989 producing as much as 5% MAPE error by 95%.
3. The FTS Cheng method can be implemented to predict the the number of positive cases of Covid-19 that occured in Indonesia seeing that the MAPE error is lower than 10%.

4.2 Suggestion

For further research, it is recommended to conduct research with other forecasting methods to predict the number of positive cases of Covid-19 in Indonesia. Then it is recommended to make a program to simplify the calculations.

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