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FORECASTING THE NUMBER OF COVID-19 SUFFERERS IN NORTH SUMATRA USING THE AUTOMATIC CLUSTERING FUZZY TIME SERIES MARKOV CHAIN METHOD

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ABSTRACT

Corona virus is a virus that is currently endemic throughout the world, including in Indonesia, one of which is in North Sumatra Province, because this virus has claimed many victims. North Sumatra Province in positive cases of Covid-19 is ranked 13th out of 34 provinces in Indonesia. The government's anticipation in handling Covid-19 cases is by forecasting the number of positive Covid-19 cases. One of the methods used to forecast Covid-19 sufferers is the Automatic Clustering Fuzzy Time Series Markov Chain method. The Fuzzy Time Series Markov Chain method is used to resolve the deviation value from a forecasted value, while Automatic Clustering is used to determine the length of the interval by grouping numerical data. Then the error calculation will be carried out using the Mean Absolute Percentage Error (MAPE) to determine the level of accuracy of the forecasting model that has been made. The parameter used in this study is the number of Covid-19 sufferers. The results of this study from data on the number of Covid-19 sufferers have a MAPE value of 4.53%. The MAPE value which is less than 10% means that the forecasting of this study has very good criteria. So the Automatic Clustering Fuzzy Time Series Markov Chain method is very good to be applied in forecasting the number of Covid-19 sufferers in North Sumatra Province.
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1. INTRODUCTION

Corona virus is a virus that infects the respiratory tract. This viral infection is called COVID-19. Corona viruses cause common colds to more severe ones such as Middle East respiratory syndrome (Mers-Cov) and severe acute respiratory syndrome (SARS-Cov). This virus spreads quite quickly and has spread to several countries, including Indonesia, one of which is in North Sumatra Province (Anggraini Saragih et al, 2020). North Sumatra Province in positive cases of Covid-19 is ranked 13th out of 34 provinces in Indonesia.

North Sumatra Province is an area that continues to increase, precisely at the end of September the number of cases was 9,749, recovered 6,006, and died 410. With the number of cases increasing every day, it is impossible to estimate the number of treatments such as providing services, facilities, and medical personnel who cannot predictable. Seeing the development of the number of people who have been infected, research can be carried out to predict the number of COVID-19 sufferers.

One of the methods used to forecast Covid-19 sufferers is the Automatic Clustering Fuzzy Time Series Markov Chain method. The Fuzzy Time Series Markov Chain method is used to resolve the deviation value from a forecasted value, while Automatic Clustering is used to determine the length of the interval by grouping numerical data.

2. RESEARCH METHODE

2.1 COVID-19

The World Health Organization (WHO) explains that corona virus is a virus that infects the respiratory system. This infection is called COVID-19. Corona viruses are zoonotic which means they are transmitted between animals and humans.

Covid-19 spreads like other viruses in general, such as splashing the saliva of an infected person (coughing and sneezing), touching the hands or face of an infected person, touching the eyes, nose, or mouth after handling items that have been splashed by the saliva of a person with the corona virus. Covid-19, the incubation period is not known for sure. However, the average symptoms that appear after 2-14 days after the virus first entered the body.

a. Forecasting

Forecasting is an estimate of something that has not yet happened. Forecasting is also identified as the art and science of predicting future events. This can be done by involving taking data in the past and placing it into the future with a mathematical model (Subagyo, 1986).

b. Time Series Data

Time series data is the result of observations on a variable that occurs within a certain period of time based on a time index sequentially with fixed (constant) time intervals. Time series analysis is one of the statistical procedures applied to predict the probabilistic structure of conditions that will occur in the future in the context of making decisions for a particular plan (Hendikawati, 2014).

c. Fuzzy Logic

Fuzzy logic was first introduced by prof. Lofti A. Zadeh in 1965 (Kusumadewi and Purnomo, 2010). Some definitions of fuzzy logic are as follows:

a. According to Kusumadewi (2003), fuzzy logic is an appropriate way to map an input space into an output space, has a continuous value and fuzzy logic is expressed in degrees of membership and degrees of truth.

b. According to Susilo (2006), fuzzy logic is logic that uses the concept of obscurity. So fuzzy logic is logic with infinitely many truth values expressed in real numbers in the interval [0,1].

Fuzzy Time Series

Fuzzy Time Series (FTS) was first introduced by Song and Chissom in 1993. If U is the set of universes, where $U = \{u_1, u_2, u_3, \ldots, u_n\}$, then a fuzzy set A from U can be defined as follows:

$$A = \frac{f_{Ai}(u_1)}{u_1} + \frac{f_{Ai}(u_2)}{u_2} + \cdots + \frac{f_{Ai}(u_n)}{u_n},$$

Where f_A is a membership function A, $f_A : U \to [0,1]$, $f_A(u_i)$ indicates membership class u_i in fuzzy set A, $f_A(u_i) \in [0,1]$, and $1 \leq I \leq n$ (Saxena et al, 2012).

Determine forecasting in the form of fuzzy sets (t) and defuzzify the forecasting results, with the following principles.

Principle 1. If the current fuzzy set and the FLR in the FLRG is $A_i \to$, in other words there is only one FLR, then the forecasting result is m_j or the midpoint of the interval u_j

Principle 2. If the current fuzzy set and the FLR in the FLRG is empty, for example ($A_i \to \neq$), then the forecasting result is or the midpoint of the interval u_i.

Principle 3. If the current fuzzy set A_i and the FLR in the FLRG are $A_i \to A_{1,2}, \ldots, A_k$, then the forecast value is $\frac{m_1+m_2+\cdots+m_k}{k}$ where $m_1+m_2+\ldots+m_k$ is the middle point, respectively. of the interval $u_1, u_2, \ldots, u_k$ in other words the forecast value is the average of the midpoint of the interval.

2.5 Automatic Clustering

Automatic clustering is an algorithm used to group numeric data into intervals. According to Chen, Wan, and Pan (Chen et al, 2009) there are five steps in the automatic clustering algorithm, which are as follows:

1. Sorts data sequentially from smallest to largest which has n different data and no data is the same.
2. Forming clusters based on several principles.
3. Improve the contents of the cluster.
4. Converting clusters to intervals.
5. For each interval obtained in step 4, divide each interval into $p \geq 1$.

2.6 Markov chains

Markov chain is a form of stochastic process that fulfills the Markov property, namely the probability of occurrence or random variable X at time $t+1$ will only be affected by events X at time t and will not be affected by events before time t.

Ross (2007) in Haryono et al says if $X_n = i$, then this process occurs at i at time n. assuming that whenever this process occurs in state i, there is a probability point that P_{ij} will move to state j. thus it can be written as follows:

$$P\{X_{n+1} = j | X_{n-1} = i_{n-1}, \dots, X_1 = i_1, X_0 = i_0\} = P_{ij}$$

For all states $i_0 = i_1, \dots, i_{n-1}, i, j, n \geq 0$. Such a process is called a Markov chain. The equation is interpreted in the Markov chain as a conditional distribution of the future state X_{n+1} which is obtained from the previous state $X_0, X_1, \dots, X_{n-1}$ and the current state X_n, and does not depend on the previous state but depends on the current state. The value of P_{ij} represents the probability of the transition process from i to j. because the probability value is always positive and the transition process moves, then:

$$P_{ij} \geq 0, i, j \geq 0; = \sum_{j=1}^{\infty} P_{ij} = 1, i = 0,1, \dots$$

The notation in the equation states that in general, the transition probability is a function that contains not only the initial state and the final state, but also the transition time. If the independent one-step transition probability for the time variable n is P_{ij}, then the Markov chain is said to have a stationary transition probability. If the numbers P_{ij} are arranged in a matrix, for example P is a transition probability matrix P_{ij}, then it can be denoted:

$$\text{P} = \begin{bmatrix} P_{00} & P_{01} & P_{02} \\ P_{10} & P_{11} & P_{12} \\ \vdots & \vdots & \vdots \\ P_{i0} & P_{i1} & P_{i2} \\ \vdots & \vdots & \vdots \end{bmatrix}$$

The notation p = k P_{ij} k is expressed as a Markov matrix or transition probability matrix. The first i+1 row of the P matrix is the probability distribution value of $X_n + 1$ under the condition $X_n = i$ (Widyasari, 2012).

2.7 Research Procedures

1. Apply automatic clustering on historical data to an interval and calculate the mean value of each interval.
2. Assuming that there are n intervals $u_1, u_2, u_3, .., u_n$, then define each fuzzy set, where $1 \leq i \leq n$, as follows:

$$A_1 = \left\{ {}^{1}/_{u_1}, {}^{0,5}/_{u_2}, {}^{0}/_{u_3}, {}^{0}/_{u_4}, \dots, {}^{0}/_{u_{n-1}}, {}^{0}/_{u_n} \right\}$$
$$A_2 = \left\{ {}^{0,5}/_{u_1}, {}^{1}/_{u_2}, {}^{0,5}/_{u_3}, {}^{0}/_{u_4}, \dots, {}^{0}/_{u_{n-1}}, {}^{0}/_{u_n} \right\}$$
$$A_3 = \left\{ {}^{0}/_{u_1}, {}^{0,5}/_{u_2}, {}^{1}/_{u_3}, {}^{0,5}/_{u_4}, \dots, {}^{0}/_{u_{n-1}}, {}^{0}/_{u_n} \right\}$$
$$\vdots$$
$$A_n = \left\{ {}^{0}/_{u_1}, {}^{0}/_{u_2}, {}^{0}/_{u_3}, {}^{0}/_{u_4}, \dots, {}^{0,5}/_{u_{n-1}}, {}^{1}/_{u_n} \right\}$$

3. Fuzzyfication of each historical data from the data into a fuzzy set. If there is u_i, where $1 \leq i \leq n$, then the data is fuzzified to A_i.
4. Create a fuzzy logic relation from historical data in step 3.
5. Calculating the forecast value, for time series data, group fuzzy logic relations are used, which can be induced by probability information for the next state.

6. Adjusting the trend of the forecast value.
7. Forecasting results (Haryono et al, 2013).

3. RESULT AND ANALYSIS

The data used by the researchers is daily data on the number of Covid-19 sufferers from the North Sumatra Provincial Health Office from July to September 2020, therefore there are 196 observational data used by researchers in this study.

Table 6.1 Data on Covid-19 Patients in North Sumatra Province

T	Day-Month	Data
1	19-Mar	35
2	20-Mar	35
3	21-Mar	2
4	22-Mar	2
5	23-Mar	2
⋮	⋮	⋮
194	28-Sep	10123
195	29-Sep	10211
196	30-Sep	10313

a. Sort the data sequentially from smallest to largest which has *n* different data and no data is the same as follows: 2, 8, 9, 14, 20, 26, 30, 34, 35, 36, 56, 57, 76, 84, 87, 87, 89, 90, 96, 100, 102, 103, 104, ..., 9941, 10038, 10123, 10211, 10313.

Then calculate the value of "avareage diff"

$$Avarage\_diff = \frac{\sum_{i=1}^{n-1}(d_{i+1}-d_i)}{n-1}$$

$$= \frac{\{(8-2)+(9-8)+(14-9)+\cdots+(10211-10123)+(10313-10211)\}}{196-1}$$

$$= \frac{(6+1+5+\cdots+88+102)}{195}$$

$$= \frac{10311}{195} = 52{,}87692$$

b. Forming clusters based on the value of "average diff"

Data that has been arranged in an attractive order will be divided into several clusters according to existing principles, here are the steps in forming a cluster:

Table 6.2 Formation of Clusters Based on Avarage_diff

Cluster 1	{2 ; 8 ; 9}
Cluster 2	{14}
Cluster 3	{20 ; 26 ; 30 ; 34 ; 35 ; 36}
⋮	⋮
Cluster 116	{10123}
Cluster 117	{10211}
Cluster 118	{10313}

c. Refining Cluster Contents

After getting the grouping results from step 2, then for the next stage, that is adjusting the contents of the cluster

Tabel 6.3 Cluster Grouping

Cluster 1	{2 ; 9}
Cluster 2	{14}
Cluster 3	{20 ; 36}
Cluster 4	{56 ; 57}
Cluster 5	{76 ; 90}

⋮	⋮
Cluster 117	{10211}
Cluster 118	{10260,124 ; 10313}

d. Converting clusters to intervals

In this fourth step, the cluster that we have formed will be converted into an interval form. Here are the steps to convert the cluster into an interval form:

Tabel 6.4 Formation Interval

u_1= [2 ; 9)
u_2= [9 ; 14)
u_3= [14 ; 20)
u_4= [20 ; 36)
u_5= [36 ; 56)
⋮
u_{191}= [9993,876 ; 10038)
u_{192}= [10038 ; 10070,124)
u_{193}= [10070,124 ; 10175,876)
u_{194}= [10175,876 ; 10211)
u_{195}= [10211 ; 10260.124)
u_{196}= [10260,124 ; 10313)

Divides each interval into p sub-intervals. The greater the p value, the more accurate the forecasting results. In this study, the value of p = 1 was taken, so that the new interval as well as the mid point was obtained as follows:

Tabel 6.5 Intervals with *p=1*

u_1= [2 ; 9)	m_1 = 5,5
u_2= [9 ; 14)	m_2 = 11,5
u_3= [14 ; 20)	m_3 = 17
u_4= [20 ; 36)	m_4 = 28
u_5= [36 ; 56)	m_5 = 46
⋮	⋮
u_{194}= [10175,876 ; 10211)	m_{194} = 10193,438
u_{195}= [10211 ; 10260.124)	m_{195} = 10235,562
u_{196}= [10260,124 ; 10313)	m_{196} = 10286,562

The next step is to create a fuzzy set by determining each fuzzy set A_i as many as intervals that have been divided previously. For simplicity, the membership value of the fuzzy set A_i is between 0, 0.5, 1 where 1≤ i n, as follows:

$$A_1 = \left\{ {}^{1}/_{u_1}, {}^{0,5}/_{u_2}, {}^{0}/_{u_3}, {}^{0}/_{u_4}, \dots, {}^{0}/_{u_{195}}, {}^{0}/_{u_{196}} \right\}$$

$$A_2 = \left\{ {}^{0,5}/_{u_1}, {}^{1}/_{u_2}, {}^{0,5}/_{u_3}, {}^{0}/_{u_4}, \dots, {}^{0}/_{u_{195}}, {}^{0}/_{u_{196}} \right\}$$

$$A_3 = \left\{ {}^{0}/_{u_1}, {}^{0,5}/_{u_2}, {}^{1}/_{u_3}, {}^{0,5}/_{u_4}, \dots, {}^{0}/_{u_{195}}, {}^{0}/_{u_{196}} \right\}$$

$$\vdots$$

$$A_{195} = \left\{ {}^{0}/_{u_1}, {}^{0}/_{u_2}, {}^{0}/_{u_3}, {}^{0}/_{u_4}, \dots, {}^{1}/_{u_{195}}, {}^{0,5}/_{u_{196}} \right\}$$

The next step, based on the fuzzy set, the historical data of Covid-19 sufferers in North Sumatra Province can be fuzzified as shown in Table 4.8. As an illustration example, for example, historical data on March 19 is 35,because 35 is included int heu_4 interval,then it is fuzzified toA_4.

Table 6.6 Fuzzification of Historical Data of Covid-19 Patients

T	Date/Month	Data	Fuzzifikasi

1	19-Mar	35	A_4
2	20-Mar	35	A_4
3	21-Mar	2	A_1
⋮	⋮	⋮	⋮
194	28-Sep	10123	A_{193}
195	29-Sep	10211	A_{194}
196	30-Sep	10313	A_{196}

From Table 6.5 , it can be seen that on March 19 and March 20 both had fuzzification results, namely A_4 and A_4.Then these results can be denoted by $A_4 \rightarrow A_4$. Like wise for the fuzzification results, here are the results of the FLR.

Table 6.7 Fuzzy Logical Relationship (FLR)

Data Order	**FLR**
1-2	$A_4 \rightarrow A_4$
2-3	$A_4 \rightarrow A_1$
3-4	$A_1 \rightarrow A_1$
⋮	⋮
193-194	$A_{192} \rightarrow A_{193}$
194-195	$A_{193} \rightarrow A_{195}$
195-196	$A_{195} \rightarrow A_{196}$

After obtaining the FLR, the FLRG can then be determined which is the grouping of each state transfer, namely the current state and the next state. In each FLRG there is a relationship between two states called the current state and the next state.

Table 6.8 *Fuzzy Logical Relationship Group* (FLRG)

Current State		*Next State*
A_4	→	$A_1, A_4(\mathbf{4}), A_5$
A_1	→	$A_1(\mathbf{3}), A_2$
A_2	→	$A_2(\mathbf{2})A_3$
A_3	→	$A_3\ , A_4$
⋮	→	⋮
A_{192}	→	A_{193}
A_{193}	→	A_{195}
A_{195}	→	A_{196}

After the fuzzy groups that have been grouped are used to form a forecasting transition process that describes the relationship between each state and other states.

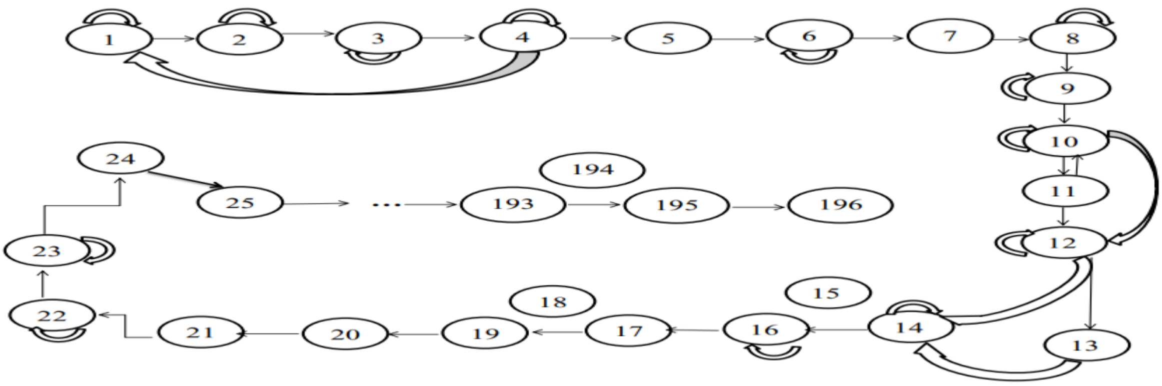

Figure 6.1 Markov Chain Forecasting Transitions Based on FLRG

Based on Figure 6.1 the one-way arrow indicates the state is transitioning from the origin of the arrowhead to the tip of the arrow, for example, state 2 transitions to state 3 does not apply vice versa. While the two-way arrow indicates that the states communicate with each other, for example in state 10 and state 11, and the arrow that transitions to itself, for example in state 1.

Calculate the initial forecast value.

Determination of the initial forecasting results on the FST-MC using previous historical data, then the FLRG that has been determined in the previous stage is used to form a Markov transition probability matrix

$F_2 = m_1P_1 + Y_{(t-1)}P_4 + m_5P_5$

$= (5{,}5)\frac{1}{6} + 35\left(\frac{4}{6}\right) + (46)\left(\frac{1}{6}\right)$

= 31,91666667

Table 6.9 Forecasting Results Before Adjusted

T	Tgl/Bulan	Data	Peramalan Awal
1	19-Mar	35	-
2	20-Mar	35	31.91666667
3	21-Mar	2	31.91666667
4	22-Mar	2	4.375
5	23-Mar	2	4.375
⋮	⋮	⋮	⋮
194	28-Sep	10123	10123
195	29-Sep	10211	10235.562
196	30-Sep	10313	10286.562

After getting the initial forecasting results, the settlement value can then be found to reduce deviations in the forecast. Trend adjustments are made for each relationship between the current state and the next state of the FLR. As an example of the adjustment calculation for March 25, in Table 6.9 the next state is $A_2$and the current stateis A_1 then the calculation for the adjustment value is as follows

$D_{t7} = \left(\frac{l}{2}\right)$

$= \left(\frac{52{,}96}{2}\right)$

= 26,48

The final forecast of forecasting the number of Covid-19 sufferers in North Sumatra Province, which is carried out by adding up the results of the initial forecast

$F'_2 = F_2 + D$

= 31,91666667 + 0

= 31,91666667

Error Calculation

After forecasting, the error value of each forecast can be calculated. The error value of this research data forecasting results using MAPE as follows:

Tabel 6.10 adjustment table and forecasting results

T	Date/Month	Data	Early Forecasting	Adjustment Value	Final Forecast	$\left\lvert\frac{Y_t - F'}{Y_t}\right\rvert$
1	19-Mar	35	-	-	-	-
2	20-Mar	35	1408.5	0	31.91666667	0.088095238
3	21-Mar	2	1463.5	-79.44	-47.52333333	24.76166667
4	22-Mar	2	1482.75	0	4.375	-1.1875
5	23-Mar	2	1492.75	0	4.375	-1.1875

⋮	⋮	⋮	⋮	⋮	⋮	⋮
194	28-Sep	10123	10123	26.48	10149.48	-0.00261583
195	29-Sep	10211	10235.562	52.96	10288.522	-0.00759201
196	30-Sep	10313	10286.562	26.48	10313.042	-0.0000040725

$$\text{MAPE} = \frac{(0{,}088095238+24{,}76166667+1{,}1875+\cdots+0{,}00759201+0{,}0000040725}{n} \times 100\%$$

$$= \frac{8{,}893660132}{196}$$

$$= 0{,}0453 \times 100\%$$

$$= 4{,}53\%$$

Based on the results of research ranging from data collection to the process of forecasting calculations using the Automatic Clustering Fuzzy Time Series Markov Chain method. The final result obtained in the form of the level of accuracy of the method obtained MAPE (Mean Absolute Percentage Error) value of 4.53%, which means that the forecasting of this study has very good criteria. The results of the forecast can be seen in Figure 4.2 and compared with the actual data.

Visualization of the comparison graph between the actual data and the forecast value using the Automatic Clustering Fuzzy Time Series Markov Chain method can be seen in Figure 6.2 below:

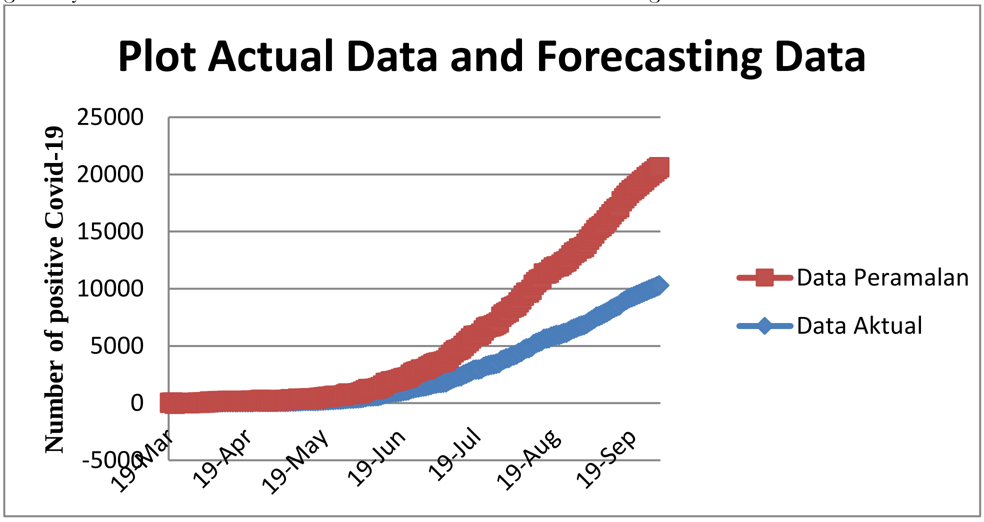

Figure 6.2 Comparison Graph of Actual Data with Forecasting Data

Based on Figure 6.2 the results of forecasting Covid-19 sufferers in North Sumatra from March 19 to September 30, 2020 using the Automatic Clustering Fuzzy Time Series Markov Chain method which is shown by a red graph, it explains that the pattern of the actual data generated is almost the same as the pattern of the values obtained. actually. Although the resulting value is not the same as the actual data value, the pattern of forecasting values from the Automatic Clustering Fuzzy Time Series Markov Chain method follows the pattern of the actual data.

4. CONCLUSION

From the results of research and discussion on forecasting the number of Covid-19 sufferers using the Automatic Clustering Fuzzy Times Series Markov Chain method with data on Covid-19 patients obtained from the North Sumatra Provincial Health Office on March 19 to September 30, 2020, the following conclusions can be drawn.

Based on testing and research that has been carried out using the Automatic Clustering Fuzzy Time Series Markov Chain method to predict the number of Covid-19 sufferers in North Sumatra Province which produces an error rate of 4.53%, so that the number of predictions for the next 92 days of Covid-19 sufferers is obtained. . But this Covid-19 case can also change at any time depending on the efforts of the North Sumatra Provincial government and also public awareness to always maintain cleanliness and also carry out health protocols that have been put in place to reduce the virus chain.

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